

# Gravitational Collapse of Photons at the Planck Scale: From Classical Derivation to Blitzon Formation

Ivars Vilums

Wimberley, Texas

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## Abstract

We demonstrate that electromagnetic radiation of sufficiently short wavelength must undergo gravitational collapse. The original 1990 derivation, combining the Schwarzschild radius with photon mass-energy equivalence, yields a critical wavelength  $\lambda \approx 2.56 \times 10^{-34}$  m—approximately 16 times the Planck length. Reformulating the problem using natural relativistic quantities (reduced Planck constant  $\hbar$  and angular wavenumber  $k$ ) dramatically tightens this relationship: the critical reduced wavelength  $\lambda = \sqrt{2} \ell_p$ , differing from the Planck length by only the factor  $\sqrt{2}$ . We term these gravitationally collapsed photons "blitzons" (from Kugelblitz, a term for a black hole made from overlapping photons using "blitz," the German word for lightning, plus the "-on" particle suffix) —Planck-scale structures that cannot propagate as conventional electromagnetic waves. The emergence of  $\sqrt{2}$ —the diagonal of a unit square—suggests a deep geometric connection between the oscillatory structure of electromagnetic waves and the pointlike nature of gravitational collapse. This result has profound implications: photon propagation as conventionally understood cannot be fundamental, motivating the Transaction-Geometric Interpretation and Blitzon Cosmology developed in companion papers.

## 1. Introduction

The relationship between electromagnetic radiation and gravity has been a subject of fundamental interest since Einstein's general theory of relativity. Electromagnetic waves carry energy and momentum; by mass-energy equivalence, this energy corresponds to an equivalent gravitational mass. Light is deflected by gravitational fields, demonstrating that electromagnetic radiation both generates and responds to gravitational effects.

The energy of electromagnetic radiation increases without bound as wavelength decreases, following  $E = hc/\lambda$ . General relativity predicts that any mass concentrated within its Schwarzschild radius undergoes gravitational collapse. The intersection of these principles raises a fundamental question: at what wavelength does the energy density of an electromagnetic wave trigger its own gravitational collapse?

This paper presents the original 1990 derivation answering this question, then extends the analysis using natural relativistic quantities. The reformulation reveals that the critical length scale differs from the Planck length by precisely  $\sqrt{2}$ —a geometric factor whose origin and significance we explore in depth. We introduce the term "blitzon" for these gravitationally collapsed photons, recognizing them as fundamental structures at the Planck scale rather than mere theoretical curiosities.

The implications of this result—that photon propagation as conventionally understood cannot be fundamental—motivate the Transaction-Geometric Interpretation and Blitzon Cosmology developed in companion papers, where blitzons serve as transaction endpoints connecting spacetime events through a network that transcends conventional notions of propagation.

## 2. Original Derivation (1990)

### 2.1 The Schwarzschild Radius

The Schwarzschild radius defines the event horizon of a non-rotating black hole. For any mass  $M$ :

$$r_s = 2GM/c^2$$

where  $G \approx 6.674 \times 10^{-11} \text{ m}^3 \text{ kg}^{-1} \text{ s}^{-2}$  is Newton's gravitational constant and  $c \approx 2.998 \times 10^8 \text{ m s}^{-1}$  is the speed of light.

### 2.2 Photon Energy and Equivalent Mass

The energy of a photon with wavelength  $\lambda$  is given by the Planck relation:

$$E = hc/\lambda$$

where  $h \approx 6.626 \times 10^{-34} \text{ J s}$  is Planck's constant. By mass-energy equivalence  $E = Mc^2$ , the equivalent gravitational mass is:

$$M = h/(\lambda c)$$

### 2.3 The Collapse Condition

Substituting equation (3) into equation (1) yields the Schwarzschild radius as a function of wavelength:

$$r_s = 2Gh/(\lambda c^3)$$

As wavelength decreases, energy (and equivalent mass) increases, causing  $r_s$  to grow. Simultaneously, the spatial extent of the wave, characterized by  $\lambda$ , shrinks. Gravitational collapse occurs when the wave's spatial extent falls within its own Schwarzschild radius.

Accounting for the two energy peaks within one wavelength cycle, we set the collapse condition:

$$r_s = \lambda/2$$

Substituting and solving:

$$2Gh/(\lambda c^3) = \lambda/2$$

$$\lambda^2 = 4Gh/c^3$$

$$\lambda = 2\sqrt{(Gh/c^3)}$$

Numerically:

$$\lambda_{\text{critical}} \approx 2.56 \times 10^{-34} \text{ m}$$

### 2.4 Comparison to Planck Length

The Planck length is defined as:

$$\ell_p = \sqrt{(\hbar G/c^3)} \approx 1.616 \times 10^{-35} \text{ m}$$

where  $\hbar = h/2\pi$  is the reduced Planck constant. The ratio of our critical wavelength to the Planck length is:

$$\lambda_{\text{critical}}/\ell_p = 2\sqrt{(2\pi)} \approx 5.01$$

The critical wavelength and Planck length agree within one order of magnitude—a striking result given their independent origins. However, the factor of  $\sim 5$  demands explanation. Is this a fundamental constant, or an artifact of our choice of variables?

### 3. Reformulation Using Natural Relativistic Quantities

#### 3.1 Angular Variables

The original derivation mixed conventions: using  $h$  and  $\lambda$  (cycle-based quantities) while comparing to  $\ell_p$  (defined with  $\hbar$ , a per-radian quantity). A photon has no rest frame—it is intrinsically relativistic. We therefore reformulate using the natural variables of relativistic wave mechanics:

$$\hbar = h/2\pi \text{ (reduced Planck constant: action per radian)}$$

$$k = 2\pi/\lambda \text{ (angular wavenumber: radians per unit length)}$$

$$\omega = ck \text{ (angular frequency for light)}$$

$$\tilde{\lambda} = \lambda/2\pi = 1/k \text{ (reduced wavelength: length per radian)}$$

#### 3.2 Derivation in Angular Form

The photon energy relation becomes:

$$E = \hbar\omega = \hbar ck$$

The equivalent mass:

$$M = E/c^2 = \hbar k/c$$

Substituting into the Schwarzschild formula:

$$r_s = 2GM/c^2 = 2G\hbar k/c^3$$

In the angular formulation, the natural spatial scale is not  $\lambda$  but the reduced wavelength  $\tilde{\lambda} = 1/k$ —the spatial extent per radian of phase. This is analogous to the reduced Compton wavelength in particle physics. Setting the collapse condition:

$$r_s = \tilde{\lambda} = 1/k$$

Substituting equation (12):

$$2G\hbar k/c^3 = 1/k$$

$$k^2 = c^3/(2G\hbar)$$

$$k_{\text{critical}} = (1/\sqrt{2})\sqrt{(c^3/G\hbar)}$$

Since  $\ell_p = \sqrt{(G\hbar/c^3)}$ , we have  $\sqrt{(c^3/G\hbar)} = 1/\ell_p$ . Therefore:

$$k_{\text{critical}} = 1/(\sqrt{2} \ell_p)$$

The critical reduced wavelength is:

$$\tilde{\lambda}_{\text{critical}} = 1/k_{\text{critical}} = \sqrt{2} \ell_p$$

This is the central result: the critical reduced wavelength differs from the Planck length by exactly  $\sqrt{2}$ .

#### 3.3 Conversion and Comparison

Converting the angular result back to ordinary wavelength:

$$\lambda_{\text{critical}} = 2\pi\tilde{\lambda}_{\text{critical}} = 2\pi\sqrt{2} \ell_p \approx 1.44 \times 10^{-34} \text{ m}$$

The slight difference from the original result (2.56 vs.  $1.44 \times 10^{-34}$  m) arises from the different collapse conditions:  $r_s = \lambda/2$  versus  $r_s = \tilde{\lambda}$ . Both are physically motivated choices for matching the wave's spatial extent to its gravitational radius.

The key insight is that the original factor of  $\sim 5$  arose from comparing a critical wavelength derived using  $h$  (action per cycle) with a Planck length defined using  $\hbar$  (action per radian). When both quantities are expressed in the same (angular) convention, the discrepancy collapses to  $\sqrt{2}$ .

## 4. Blitzons: Collapsed Photons at the Planck Scale

### 4.1 Definition and Terminology

We introduce the term "blitzon" (from Kugelblitz, a term for a black hole made from overlapping photons using "blitz," the German word for lightning, plus the "-on" particle suffix) for a photon that has undergone gravitational self-collapse at the Planck scale.

Definition:

A blitzon is a gravitationally collapsed electromagnetic excitation with characteristic wavelength  $\lambda \leq \sqrt{2} \ell_p$ , forming a Planck-scale structure that cannot propagate as a conventional wave.

Key properties of blitzons:

- Schwarzschild radius:  $r_s = \sqrt{2} \ell_p \approx 2.28 \times 10^{-35} \text{ m}$
- Mass:  $M = M_p/\sqrt{2} \approx 1.54 \times 10^{-8} \text{ kg}$  (where  $M_p$  is the Planck mass)
  - Energy:  $E = E_p/\sqrt{2} \approx 8.6 \times 10^8 \text{ J} \approx 5.4 \times 10^{18} \text{ GeV}$
  - Hawking evaporation time:  $\tau \sim t_p \approx 5.4 \times 10^{-44} \text{ s}$
- Shell thickness:  $\sqrt{2} \ell_p$  (the critical wavelength itself)

### 4.2 Blitzons as Fundamental Structures

The blitzon is not merely a theoretical construct but represents a fundamental limit on electromagnetic propagation. Any attempt to create a photon with energy exceeding  $E_p/\sqrt{2}$  results not in a propagating wave but in a blitzon—a localized gravitational structure.

In the companion papers, we develop the physical significance of blitzons:

- In the Transaction-Geometric Interpretation, blitzons serve as the endpoints of transaction geometries—the direct spacetime connections between emission and absorption events that replace conventional photon propagation.
- In Blitzon Cosmology, blitzons populate the cosmic horizon at Planck density, serving as the substrate through which quantum transactions route, and explaining phenomena from quantum non-locality to the holographic principle.

The blitzon thus bridges the gap between electromagnetic and gravitational physics, representing the scale at which these two fundamental interactions become unified.

### 4.3 Singularity Resolution

A profound consequence of the blitzon structure is the resolution of gravitational singularities. In standard general relativity, the Penrose-Hawking singularity theorems prove that gravitational collapse inevitably produces spacetime singularities where curvature diverges and physical laws break down.

However, the blitzon shell at  $R = \sqrt{2} \ell_p M$  represents a fundamental quantum of spacetime geometry—a geometric floor below which further collapse is physically meaningless. Just as

matter cannot have "less than one atom" of a given element, spacetime cannot have "less than one quantum of geometry."

For any mass  $M$ , collapse proceeds to the blitzon shell but cannot continue to  $r = 0$ . The shell radius approaches the minimum value  $\sqrt{2} \ell_p$  but never reaches zero. There is no "interior" to probe beyond this Planck-scale geometric structure.

This naturally resolves the black hole information paradox: all information is encoded on the blitzon shell surface rather than destroyed at a singularity. The Bekenstein-Hawking entropy  $S = k_B A/(4\ell_p^2)$  represents the actual information storage capacity of the shell, not merely an abstract thermodynamic quantity.

The absence of singularities makes black hole interiors physically real regions of spacetime rather than mathematical pathologies. This has profound implications for cosmology: if our universe exists within a blitzon structure (as proposed in the companion Blitzon Cosmology paper), the Big Bang singularity may not be a true singularity but rather the geometric structure of the parent blitzon shell.

The companion paper develops these implications in detail, including:

- [1] Information preservation through holographic encoding on the shell
- [2] Physical reality of black hole interiors as complete universes
- [3] Cosmological Big Bang without a singularity
- [4] Nested universe structures with no ultimate boundaries
- [5] Connections to quantum gravity and observational tests

The singularity resolution emerges naturally from the same photon gravitational collapse mechanism that produces blitzons—using electromagnetic physics to resolve one of general relativity's most fundamental pathologies.

## 5. The Geometric Significance of $\sqrt{2}$

Why  $\sqrt{2}$  rather than unity? This fundamental geometric ratio—the diagonal of a unit square—may encode deep structure at the Planck scale. Several interpretations merit consideration:

### 5.1 Electromagnetic Field Structure

The photon's electromagnetic field has orthogonal electric and magnetic components. The total energy density  $u = \epsilon_0 |E|^2 = (1/\mu_0) |B|^2$  involves two perpendicular field components whose magnitudes are related by  $c$ . The combined field vector has magnitude  $\sqrt{|E|^2 + c^2 |B|^2} = \sqrt{2} |E|$ . If the gravitational collapse criterion involves the field amplitude rather than energy,  $\sqrt{2}$  factors would appear from the orthogonal field structure.

### 5.2 Null Geodesic Geometry

Light propagates on null geodesics where the spacetime interval  $ds^2 = 0$ . For radial propagation,  $ct = r$ . The Schwarzschild radius is a purely spatial concept, but a photon's existence is intrinsically lightlike. The projection of a lightlike interval onto a spacelike hypersurface involves geometric factors—and for  $45^\circ$  angles (characteristic of light in spacetime diagrams), these factors involve  $\sqrt{2}$ .

Consider a photon's worldline forming a  $45^\circ$  angle with the time axis. The spatial "extent" seen by a spacelike slice differs from the invariant description by  $\sqrt{2}$ , the ratio of diagonal to side in a unit square.

### 5.3 Quantum Uncertainty

The Heisenberg uncertainty relation  $\Delta x \Delta p \geq \hbar/2$  defines the minimum phase-space area for a quantum state. For minimum-uncertainty Gaussian wave packets:

$$\Delta x \cdot \Delta p = \hbar/2$$

The  $\sqrt{2}$  may encode the relationship between the wave's spatial extent (set by  $\Delta x$ ) and the length scale relevant for gravitational collapse (involving both position and momentum localization).

### 5.4 Higher-Dimensional Projection

If spacetime has additional structure at the Planck scale—extra dimensions, discrete geometry, or non-commutative coordinates—the  $\sqrt{2}$  could represent a projection factor. Just as the diagonal of a unit square is  $\sqrt{2}$  times its side, a fundamental length in a higher-dimensional or differently-structured space might project onto our observed 3+1 dimensions with geometric factors.

## 6. Summary of Formulations

The following table summarizes the relationship between different formulations:

$$\begin{aligned} r_s &= \lambda/2 \\ 2.56 \times 10^{-34} \text{ m} & \\ &\approx 15.8 \\ r_s &= \tilde{\lambda} \\ \sqrt{2} \ell_p &\approx 2.28 \times 10^{-35} \text{ m} \\ \sqrt{2} &\approx 1.41 \end{aligned}$$

Both formulations yield a critical length within a factor of 2 of the Planck length. This convergence—achieved through elementary physics without invoking string theory, loop quantum gravity, or other speculative frameworks—strongly suggests that the Planck scale represents a genuine physical boundary, not merely a convenient combination of constants.

## 7. Physical Implications

### 7.1 Natural Ultraviolet Cutoff

Electromagnetic radiation with reduced wavelength shorter than  $\sqrt{2} \ell_p$  cannot propagate as conventional waves. The corresponding maximum photon energy is:

$$E_{\text{max}} = \hbar c / \lambda_{\text{critical}} = \hbar c / (\sqrt{2} \ell_p) = E_p / \sqrt{2} \approx 8.6 \times 10^8 \text{ J}$$

where  $E_p = \sqrt{(\hbar c^5/G)} \approx 1.22 \times 10^9 \text{ J}$  is the Planck energy. This natural cutoff may resolve ultraviolet divergences in quantum field theory.

### 7.2 Self-Regulating Mechanism

Photons exceeding the critical energy would form Planck-mass black holes (blitzons), which evaporate via Hawking radiation in approximately one Planck time ( $\sim 10^{-43} \text{ s}$ ). The energy re-emerges as lower-energy radiation. This suggests a self-regulating mechanism preventing trans-Planckian electromagnetic energy accumulation—a kind of gravitational "soft wall" in frequency space.

### **7.3 Photon Propagation Not Fundamental**

The most profound implication is this: if photon propagation breaks down at wavelengths near  $\sqrt{2} \ell_p$ , then conventional photon propagation cannot be fundamental. What we observe as "photons traveling through space" must emerge from something more basic—a deeper structure that produces the appearance of propagation at energies far below the Planck scale but reveals its true nature at the boundary.

This observation motivates the Transaction-Geometric Interpretation developed in the companion paper. If photons do not fundamentally propagate, perhaps they are better understood as direct geometric connections between emission and absorption events—transactions rather than traveling particles. The blitzon represents the fundamental unit of this transaction structure.

## **8. Cosmological Implications**

The self-regulating mechanism described here—wherein trans-Planckian electromagnetic fluctuations undergo gravitational collapse and immediate Hawking evaporation—suggests intriguing cosmological possibilities.

### **8.1 The Cosmological Constant Problem**

The cosmological constant problem arises from quantum field theory's prediction of vacuum energy density approximately  $10^{120}$  times larger than observed. If gravitational self-collapse provides a natural ultraviolet cutoff at the Planck scale, it may regulate these divergent vacuum fluctuations. The observed dark energy density ( $\sim 10^{-9} \text{ J/m}^3$ ) could represent the residual energy after this self-regulating mechanism operates.

### **8.2 Primordial Black Holes and Dark Matter**

In the early universe, when spacetime curvature and energy densities were far higher than today, this collapse mechanism may have operated differently. Under such conditions, slightly-larger-than-Planck-mass black holes might form that do not evaporate instantaneously. A population of primordial black holes in an appropriate mass range could contribute to—or entirely account for—the observed dark matter.

### **8.3 Spacetime Foam and the Blitzon Sea**

If Planck-scale gravitational collapse is ubiquitous, spacetime at the smallest scales may consist of a dynamic foam of forming and evaporating blitzons rather than a smooth continuum. This foam could serve as the physical substrate underlying both quantum field fluctuations and gravitational degrees of freedom—a concrete realization of Wheeler's "spacetime foam" conjecture, now with a specific mechanism and characteristic scale set by the  $\sqrt{2} \ell_p$  critical wavelength.

The companion paper on Blitzon Cosmology develops this idea further, proposing that our observable universe exists within a black hole horizon populated by blitzons at Planck density, serving as the network through which quantum transactions connect emission and absorption events across spacetime.

## **9. Open Questions and Future Directions**

The physical origin of  $\sqrt{2}$ :

Is the factor  $\sqrt{2}$  a consequence of the oscillatory nature of electromagnetic waves, the geometry of null geodesics, phase-space considerations, or something deeper about spacetime

structure? Distinguishing between these possibilities may require a complete theory of quantum gravity.

Extension to other fields:

Does the same analysis apply to other massless fields? Gravitons, for instance, carry energy and should exhibit similar self-interaction effects. Would the critical length differ?

Massive particles:

For particles with rest mass, the Compton wavelength provides another length scale. How does gravitational self-collapse compete with the Compton limit? At what mass does a particle's Schwarzschild radius exceed its Compton wavelength?

Experimental signatures:

While direct tests at Planck energies are impossible, might there be indirect signatures in cosmological observations, high-energy astrophysics, or precision laboratory experiments? The companion paper proposes specific optomechanical tests of the Transaction-Geometric Interpretation that follows from this analysis.

## 10. Conclusion

We have shown that electromagnetic radiation undergoes gravitational self-collapse at wavelengths near the Planck scale. The original 1990 derivation yielded a critical wavelength approximately 16 times the Planck length. By reformulating the problem using natural relativistic variables—the reduced Planck constant  $\hbar$  and angular wavenumber  $k$ —we find that the critical reduced wavelength is exactly  $\sqrt{2}$  times the Planck length.

We have introduced the term "blitzon" for these gravitationally collapsed photons, recognizing them as fundamental Planck-scale structures rather than mere theoretical curiosities. Blitzons represent the limit of electromagnetic propagation and, in the companion papers, serve as the building blocks of a new understanding of quantum mechanics and cosmology.

The emergence of  $\sqrt{2}$ , rather than unity, is significant. This fundamental geometric ratio—the diagonal of a unit square—suggests that the relationship between wave-like energy distributions and pointlike gravitational collapse involves a geometric transformation. Possible origins include the oscillatory structure of electromagnetic fields, the null geometry of photon worldlines, quantum uncertainty relations, or projections from higher-dimensional structures.

The most important implication is that photon propagation, as conventionally understood, cannot be fundamental. This observation motivates the Transaction-Geometric Interpretation developed in the companion paper, where photons are reconceptualized as observational perspectives on direct spacetime connections between emission and absorption events, with blitzons serving as the transaction endpoints.

Regardless of its ultimate interpretation, the  $\sqrt{2}$  factor points toward a rich geometric structure at the Planck scale. The coincidence of the photon collapse length with the Planck length (within  $\sqrt{2}$ ) achieved through elementary reasoning suggests that quantum gravitational effects on electromagnetic radiation may be more tractable than generally assumed. Further investigation of this geometric factor may illuminate the deep structure of spacetime at the smallest scales.

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## References

- [1] Schwarzschild, K. "Über das Gravitationsfeld eines Massenpunktes nach der Einsteinschen Theorie." Sitzungsber. K. Preuss. Akad. Wiss. 7, 189-196 (1916).
- [2] Planck, M. "Über das Gesetz der Energieverteilung im Normalspectrum." Ann. Phys. 4, 553-563 (1901).
- [3] Einstein, A. "Ist die Trägheit eines Körpers von seinem Energieinhalt abhängig?" Ann. Phys. 18, 639-641 (1905).
- [4] Hawking, S.W. "Black hole explosions?" Nature 248, 30-31 (1974).
- [5] Wheeler, J.A. "Geons." Phys. Rev. 97, 511-536 (1955).
- [6] Misner, C.W., Thorne, K.S. & Wheeler, J.A. Gravitation. W.H. Freeman, San Francisco (1973).
- [7] Vilums, I. "The Photon as Spacetime Connection: A Transaction-Geometric Interpretation." Companion paper (2025).
- [8] Vilums, I. "Transaction-Geometric Interpretation and Blitzon Cosmology." Companion paper (2025).
- [9] CODATA 2018 recommended values of fundamental physical constants. NIST Standard Reference Database 121.

## Historical Note

Part I of this paper (Sections 2-3) was originally written in August 1990. Part II (Sections 4-9) extends the analysis with insights developed in November 2025.