UNIFICATION II v1.00:
Implications of the Lightlike Boundary and Phase Structure

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Abstract

This paper develops a structural extension of the Chi Framework by examining the coupled limiting behavior associated with the shared lightlike boundary of relativistic and quantum descriptions.

Starting from the invariant boundary relations

$$E = pc \qquad \Leftrightarrow \qquad \omega = ck,$$

we define the dimensionless boundary parameter

$$\chi = \frac{v}{c} = \frac{pc}{E} = \frac{kc}{\omega},$$

and the corresponding deviation parameter

$$\delta = 1 - \chi^2.$$

These relations organize familiar quantities of relativistic physics, including the Lorentz factor, proper time, and phase amplification near the lightlike boundary.

The present work further explores the coupled appearance of zero-like and infinity-like limiting behavior, suggesting that vanishing and divergent quantities may arise together from the same invariant constraint.

The results are interpretive rather than dynamical.

No new equations of motion or modifications to established relativistic or quantum theory are introduced.

The contribution of this paper is to clarify how a small set of structural relations may organize familiar physical phenomena and motivate further development of the framework.

1 Introduction

In *UNIFICATION*, we introduced the idea that relativistic and quantum descriptions meet at a shared lightlike boundary.

On the relativistic side, this boundary is characterized by the massless condition:

$$E = pc. \tag{1}$$

On the quantum side, using the standard relations [1, 2],

$$E = \hbar\omega, \qquad p = \hbar k, \tag{2}$$

the same boundary yields:

$$\omega = ck. \tag{3}$$

This common limit motivated the definition of the dimensionless boundary parameter:

$$\chi = \frac{v}{c} = \frac{pc}{E} = \frac{kc}{\omega}. \tag{4}$$

In *UNIFICATION I*, we explored the phase-based interpretation [3, 7] of this boundary structure and introduced the deviation parameter:

$$\delta = 1 - \chi^2. \tag{5}$$

This parameter organizes familiar relativistic quantities, including the Lorentz factor, proper time, and phase amplification near the lightlike boundary.

The present paper extends that framework by examining the coupled limiting behavior that emerges as the lightlike boundary is approached.

In particular, we investigate how zero-like and infinity-like quantities may arise together from the same invariant constraint.

This suggests that vanishing and divergent quantities may not be independent, but instead represent complementary aspects of a shared limiting structure.

We further consider whether this coupled limit behavior may admit a geometric or curvature-based interpretation.

The present work remains structural and interpretive rather than dynamical.

No modification of established relativistic or quantum theory is claimed.

Rather, the purpose of this paper is to clarify how a small set of structural relations may organize familiar physical behavior and motivate further development of the Chi Framework.

2 Minimal Structural Recap

For clarity, we briefly summarize the minimal structural relations developed in the earlier papers.

The shared lightlike boundary is defined by the relativistic massless condition:

$$E = pc. \tag{6}$$

Using the standard quantum relations:

$$E = \hbar\omega, \qquad p = \hbar k, \tag{7}$$

this becomes:

$$\omega = ck. \tag{8}$$

Thus, both relativistic and quantum descriptions meet at the same invariant boundary.

The central dimensionless boundary parameter is:

$$\chi = \frac{v}{c} = \frac{pc}{E} = \frac{kc}{\omega}. \tag{9}$$

This parameter measures proximity to the lightlike boundary.
The corresponding deviation from the boundary is defined as:

$$\delta = 1 - \chi^2. \tag{10}$$

Using the relativistic energy–momentum relation [3, 5, 6]:

$$E^2 = p^2c^2 + m^2c^4, \tag{11}$$

we obtain:

$$\delta = \frac{m^2c^4}{E^2}. \tag{12}$$

Thus, the deviation parameter may be interpreted as the normalized mass-shell surplus.
Several familiar relativistic quantities follow directly:

$$\gamma = \frac{1}{\sqrt{1-\chi^2}} = \frac{1}{\sqrt{\delta}}, \tag{13}$$

and:

$$d\tau = dt\sqrt{1-\chi^2} = dt\sqrt{\delta}. \tag{14}$$

The phase ratio introduced in *UNIFICATION I* is:

$$\chi_\phi = \frac{\omega_{\text{ext}}}{\omega_{\text{int}}} = \gamma. \tag{15}$$

Thus, the principal structural relations may be summarized as:

$$\chi \to 1, \qquad \delta \to 0, \qquad \gamma \to \infty, \qquad \chi_\phi \to \infty, \qquad d\tau \to 0. \tag{16}$$

These coupled limits motivate the analysis developed in the present paper.

3 Proper Time as Internal Evolution

A central interpretive consequence of the Chi Framework is that proper time may be understood as internal temporal or phase evolution.

In standard relativistic form [7, 3], proper time is given by:

$$d\tau = dt\sqrt{1 - \frac{v^2}{c^2}}. \tag{17}$$

Using the boundary parameter:

$$\chi = \frac{v}{c}, \tag{18}$$

this becomes:

$$d\tau = dt\sqrt{1-\chi^2}. \tag{19}$$

Since:

$$\delta = 1 - \chi^2, \tag{20}$$

we obtain:

$$\boxed{d\tau = dt\sqrt{\delta}}. \tag{21}$$

Thus, proper time is directly determined by deviation from the lightlike boundary.

Using the phase-ratio relation from *UNIFICATION I*,

$$\chi_\phi = \frac{\omega_{\text{ext}}}{\omega_{\text{int}}} = \gamma, \tag{22}$$

and since:

$$\gamma = \frac{1}{\sqrt{\delta}}, \tag{23}$$

we may write:

$$\boxed{d\tau = \frac{dt}{\chi_\phi}}. \tag{24}$$

This suggests that proper time may be interpreted as the rate of internal phase evolution relative to externally expressed propagation.

As:

$$\chi \to 1, \tag{25}$$

we obtain:

$$\delta \to 0, \qquad \chi_\phi \to \infty, \qquad d\tau \to 0. \tag{26}$$

Thus, as systems approach the lightlike boundary, external phase propagation dominates while internal temporal progression is suppressed.

In this sense, relativistic time dilation may be interpreted as a shift in the balance between internal evolution and external propagation, organized by the same invariant boundary structure.

4 Phase Amplification and Relativistic Response

The Chi Framework suggests that several familiar relativistic effects may be interpreted as consequences of phase amplification near the lightlike boundary.

The phase ratio introduced previously is:

$$\chi_\phi = \frac{\omega_{\text{ext}}}{\omega_{\text{int}}}. \tag{27}$$

Using the relativistic relation:

$$E = \gamma mc^2, \tag{28}$$

we identified:

$$\chi_\phi = \gamma. \tag{29}$$

Since:

$$\gamma = \frac{1}{\sqrt{1-\chi^2}} = \frac{1}{\sqrt{\delta}}, \tag{30}$$

the phase ratio may be written as:

$$\boxed{\chi_\phi = \frac{1}{\sqrt{\delta}}}. \tag{31}$$

Thus, as:

$$\delta \to 0, \tag{32}$$

the phase ratio diverges:

$$\chi_\phi \to \infty. \tag{33}$$

This suggests that as the lightlike boundary is approached, external phase propagation becomes increasingly amplified relative to internal phase evolution.

Several familiar relativistic effects scale with the same amplification factor.

Energy Response

The total relativistic energy is:

$$E = \gamma m c^2. \tag{34}$$

Thus:

$$E = \chi_\phi m c^2. \tag{35}$$

Energy therefore increases in proportion to phase amplification.

Time-Dilation Response

Proper time evolves according to:

$$d\tau = \frac{dt}{\chi_\phi}. \tag{36}$$

Thus, increasing phase amplification suppresses internal temporal progression.

Mass Interpretation

Using:

$$\delta = \frac{m^2 c^4}{E^2}, \tag{37}$$

we obtain:

$$m = \frac{E}{c^2}\sqrt{\delta}. \tag{38}$$

This may be interpreted as showing that effective mass is linked to deviation from perfect lightlike phase propagation.

Interpretation

These results suggest that relativistic response near the lightlike boundary may be viewed as a unified amplification process.

As the boundary is approached:

- energy diverges,
- proper time is suppressed,
- external phase dominates,
- and the deviation parameter tends to zero.

Thus, several familiar relativistic effects may be understood as different manifestations of the same underlying amplification structure.

5 Zero, Infinity, and the Boundary

The Chi Framework organizes several limiting behaviors through the shared lightlike boundary.

As the boundary is approached:

$$\chi \to 1, \tag{39}$$

the deviation parameter tends to zero:

$$\delta \to 0. \tag{40}$$

At the same time, the Lorentz factor diverges:

$$\gamma = \frac{1}{\sqrt{\delta}} \to \infty. \tag{41}$$

Likewise, the phase ratio diverges:

$$\chi_\phi = \frac{1}{\sqrt{\delta}} \to \infty. \tag{42}$$

And proper time tends to zero:

$$d\tau = dt\sqrt{\delta} \to 0. \tag{43}$$

Thus, the limiting behavior may be summarized as:

$$\chi \to 1, \qquad \delta \to 0, \qquad \gamma \to \infty, \qquad \chi_\phi \to \infty, \qquad d\tau \to 0. \tag{44}$$

These zero-like and infinity-like behaviors are not independent.

They arise together from the same invariant boundary condition defined by the speed of light.

In this sense, the lightlike boundary may be interpreted as a structure linking vanishing and divergent physical quantities.

This perspective does not assign literal numerical meaning to zero or infinity themselves.

Rather, it treats them as complementary limiting behaviors arising from the same invariant constraint.

This observation motivates the next step of the framework: the exploration of whether these coupled limits may reflect deeper structural or geometric relationships.

6 Toward a Boundary Interpretation of Curvature

The coupled limiting behavior described above suggests a possible geometric interpretation.

In standard relativistic geometry, spacetime curvature governs the behavior of proper time, trajectories, and the propagation of fields [4, 8, 11].

Within the Chi Framework, the same invariant boundary structure organizes vanishing and divergent quantities through the parameter χ.

This suggests the possibility that the approach to the lightlike boundary may admit a geometric interpretation analogous to curvature.

In particular, as:

$$\chi \to 1, \tag{45}$$

we simultaneously obtain:

$$d\tau \to 0, \qquad \gamma \to \infty, \qquad \chi_\phi \to \infty. \tag{46}$$

These behaviors resemble singular or extreme geometric conditions in standard relativistic descriptions.

One possible interpretation is that the invariant boundary may correspond not merely to a kinematic limit, but to a structural or geometric constraint on allowed physical evolution.

In this view:

- proper time suppression may reflect geometric compression of internal evolution;
- phase amplification may reflect increased external propagation dominance;
- diverging relativistic response may reflect approach to a limiting geometric structure.

This interpretation remains speculative.

No explicit curvature tensor or modified geometric dynamics are introduced here.

The purpose of the present discussion is only to note that the coupled boundary behavior identified in the framework may admit future geometric or curvature-based development.

If such a development proves possible, then the Chi Framework may eventually connect not only relativistic and quantum descriptions, but also aspects of geometric structure through the same invariant boundary principle.

7 A Common Organizing Principle

The preceding sections suggest that a small set of structural relations may organize several familiar physical phenomena.

At the center of the framework is the shared lightlike boundary:

$$E = pc \qquad \Leftrightarrow \qquad \omega = ck. \tag{47}$$

From this follows the dimensionless boundary parameter:

$$\chi = \frac{v}{c} = \frac{pc}{E} = \frac{kc}{\omega}. \tag{48}$$

This parameter measures proximity to the invariant boundary.

The deviation from the boundary is:

$$\delta = 1 - \chi^2. \tag{49}$$

From this follow several familiar quantities:

$$\gamma = \frac{1}{\sqrt{\delta}}, \tag{50}$$

$$d\tau = dt\sqrt{\delta}, \tag{51}$$

and:

$$\chi_\phi = \frac{1}{\sqrt{\delta}}. \tag{52}$$

Thus, the same structural parameter organizes:

- relativistic response,
- proper-time suppression,
- phase amplification,
- and the coupled appearance of zero-like and infinity-like limits.

This suggests that these effects may not be independent laws, but different manifestations of a shared invariant constraint.

The present work does not claim that this constitutes a complete unified theory.

Rather, it suggests that a common organizing principle may underlie familiar relations that are often introduced separately.

In this sense, the Chi Framework may be viewed as a compact structural language for expressing how physical systems approach and depart from a shared lightlike boundary.

8 Coupled Limit Structure at the Lightlike Boundary

A central observation of the Chi Framework is that several limiting behaviors appear together as the lightlike boundary is approached.

These limits are not independent, but are coupled through the same invariant constraint.

As:

$$\chi \to 1, \tag{53}$$

the deviation parameter tends to zero:

$$\delta \to 0. \tag{54}$$

Since:

$$\gamma = \frac{1}{\sqrt{\delta}}, \tag{55}$$

the Lorentz factor diverges:

$$\gamma \to \infty. \tag{56}$$

Likewise, the phase ratio diverges:

$$\chi_\phi = \frac{1}{\sqrt{\delta}} \to \infty. \tag{57}$$

Proper time simultaneously tends to zero:

$$d\tau = dt\sqrt{\delta} \to 0. \tag{58}$$

Thus the coupled limit structure may be summarized as:

$$\chi \to 1 \quad \Rightarrow \quad \delta \to 0, \quad \gamma \to \infty, \quad \chi_\phi \to \infty, \quad d\tau \to 0. \tag{59}$$

This means that vanishing and divergent quantities arise together from the same boundary condition.

In this sense, zero-like and infinity-like behaviors may be viewed as coupled aspects of a common invariant structure rather than as unrelated extremes.

This observation strengthens the interpretation that the lightlike boundary is not merely a special kinematic case, but a structural organizing principle within the framework.

9 Scope and Non-Claims

The present work is intentionally limited in scope.

Its purpose is to identify and clarify a compact structural framework based on a shared lightlike boundary and the coupled limiting behavior associated with that boundary.

The results presented here are interpretive rather than dynamical.

No new equations of motion are introduced.

No modification of established relativistic or quantum theory is claimed [9, 12, 10].

No empirical predictions beyond known physics are derived in the present work.

No complete unified field theory is proposed.

The contribution of this paper is structural.

It suggests that a small set of relations may organize familiar physical phenomena in an unusually compact way.

In particular, the framework highlights possible structural connections among:

- relativistic response,
- proper-time suppression,
- phase amplification,
- coupled zero-like and infinity-like limits,
- and possible geometric interpretations.

Whether these relations can be extended into a predictive or dynamical theory remains a question for future work.

10 Conclusion

We have extended the Chi Framework by examining the coupled limiting behavior associated with the shared lightlike boundary.

The central boundary relations are:

$$E = pc \qquad \Leftrightarrow \qquad \omega = ck. \tag{60}$$

These motivate the dimensionless boundary parameter:

$$\chi = \frac{v}{c} = \frac{pc}{E} = \frac{kc}{\omega}. \tag{61}$$

The corresponding deviation parameter is:

$$\delta = 1 - \chi^2. \tag{62}$$

From this follow several familiar quantities:

$$\gamma = \frac{1}{\sqrt{\delta}}, \tag{63}$$

$$d\tau = dt\sqrt{\delta}, \tag{64}$$

and:

$$\chi_\phi = \frac{1}{\sqrt{\delta}}. \tag{65}$$

These relations imply that as the lightlike boundary is approached:

$$\chi \to 1, \tag{66}$$

we obtain the coupled limiting behavior:

$$\delta \to 0, \qquad \gamma \to \infty, \qquad \chi_\phi \to \infty, \qquad d\tau \to 0. \tag{67}$$

Thus, zero-like and infinity-like behaviors may be interpreted as coupled aspects of the same invariant boundary structure.

The framework also suggests that relativistic effects such as energy growth, time dilation, and phase amplification may be viewed as different manifestations of the same structural response.

A possible geometric or curvature-based interpretation was noted, though no explicit geometric dynamics are introduced here.

The present work remains structural and interpretive rather than dynamical.

No modification of established relativistic or quantum theory is claimed.

The contribution of this paper is to clarify how a small set of structural relations may organize familiar physical behavior in a unified and compact way.

Whether these structural insights can be extended into a predictive or dynamical theory remains a question for future work.

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References

[1] Louis de Broglie. *Recherches sur la théorie des quanta*. PhD thesis, Université de Paris, 1924. English translation: Research on the Theory of Quanta, University of Paris.

[2] Paul A. M. Dirac. *The Principles of Quantum Mechanics*. Clarendon Press, 1966.

[3] Albert Einstein. Zur elektrodynamik bewegter körper. *Annalen der Physik*, 17:891–921, 1905. English translation: On the Electrodynamics of Moving Bodies.

[4] Albert Einstein. Die grundlage der allgemeinen relativitätstheorie. *Annalen der Physik*, 49:769–822, 1916. English translation: The Foundation of the General Theory of Relativity.

[5] Albert Einstein. *The Meaning of Relativity*. Princeton University Press, 1922.

[6] Rafael Ferraro. *Einstein's Space-Time: An Introduction to Special and General Relativity*. Springer, 2007.

[7] Hermann Minkowski. Raum und zeit. *Physikalische Zeitschrift*, 10:75–88, 1909. English Translation: Space and Time.

[8] Charles W. Misner, Kip S. Thorne, and John Archibald Wheeler. *Gravitation*. W. H. Freeman, 1973.

[9] Michael E. Peskin and Daniel V. Schroeder. *An Introduction to Quantum Field Theory*. Westview Press, 1995.

[10] Carlo Rovelli. *Quantum Gravity*. Cambridge University Press, 2004.

[11] Robert M. Wald. *General Relativity*. University of Chicago Press, 1984.

[12] Steven Weinberg. *The Quantum Theory of Fields, Volume 1: Foundations*. Cambridge University Press, 1995.