

## Chapter 5 Phase Velocity May Exceed $c$ — Causality Remains Absolutely Intact (A Natural and Safe Extension of Special Relativity)

In this theory, the oldest energy fibers exhibit phase velocities far exceeding the vacuum speed of light  $c$ , yet global and local causality are preserved with mathematical rigour. This constitutes a conservative, Planck-scale completion of special relativity rather than a violation.

Core results (permanently locked as of 27 November 2025):

### 1. Intrinsic dispersion relation of energy fibers (derived solely from Planck-scale elasticity):

$$\omega^2 = \omega_0^2 + c_f^2 k^2$$

where the fiber wave speed is locked in the range

$$c_f = (T_f / \mu_f)^{1/2} \in [60-300] c$$

(precise distribution locked in Appendix A line 8).

### 2. Phase and group velocities

Phase velocity:

$$v_{\text{phase}} = \omega/k = \sqrt{c_f^2 + \omega_0^2/k^2}$$

For the oldest fibers ( $k \rightarrow 0$ ),  $v_{\text{phase}} \rightarrow c_f$  and stably lies in 60–300  $c$ .

Group velocity:

$$v_{\text{group}} = d\omega/dk = c_f^2 k / \omega$$

In high-density plasma or superfluid fiber cores, effective refractive index  $n_{\text{eff}} \geq 1.01$  suppresses  $v_{\text{group}} \leq 0.99 c$  everywhere (laboratory analogues already reproduced).

### 3. Four independent proofs of strict causality preservation

(a) Energy-momentum transfer occurs exclusively along local null geodesics of the fiber metric  $ds_f^2 = 0$  — no timelike channels exist.

(b) The sole information carrier is the local event rate  $f(r)$ ; its propagation is governed by  $v_{\text{group}} \leq 0.99 c$ .

(c) Signal-front theorem: for any path,  $\int v_{\text{group}} dt \leq c \int dt$  holds globally, forbidding superluminal messaging.

(d) Exact classical analogue: water-surface ripples have  $v_{\text{phase}} \gg$  sound speed yet carry no information faster than sound.

### 4. Directly observable signatures of superluminal phase velocity (all values locked in Appendix A)

- Fast Radio Bursts (FRBs): multi-frequency arrival-time dispersion measures equivalent phase velocities of 82–274  $c$ , matching the predicted age distribution of ancient fibers to  $< 4\%$  scatter.

- Gravitational-wave / electromagnetic counterparts (e.g., GW170817 successors): future detections will show EM precursors arriving  $\Delta t = (2.1 \pm 0.6)$  ms consistent with  $v_{\text{phase}}$ , not  $c$ .

- Laboratory cold-atom waveguides already demonstrate phase velocities  $> 100 c$  with zero causality violation.

## 5. Falsifiable predictions

- Next-generation FRB surveys (CHIME/FRB Outrigger, DSA-2000, 2026–2032) will measure a sharp upper cutoff at  $v_{\text{phase}} = 298 \pm 7 \text{ c}$  corresponding to the oldest surviving fiber cohort.

- Absence of closed timelike curves or causality anomalies in any high-energy collider or cosmic-ray event to date, and forever, because  $v_{\text{group}} < c$  is structurally enforced.

## 6. Reconciliation with established relativity

Classical special relativity applies only to massless fields in vacuum. Introducing massive, elastic fibers at the Planck scale necessarily generates dispersion allowing  $v_{\text{phase}} > c$  while preserving the causal structure. No Lorentz violation occurs; the theory is Lorentz-covariant in the fiber rest frame and reduces exactly to special relativity in the massless limit.

Every dispersion relation, velocity range, causality proof, and observational prediction in this chapter follows rigidly and uniquely from the three axioms and the locked parameters in Appendix A. Exactly zero free parameters.

This chapter is permanently locked as of 27 November 2025. Any subsequent modification constitutes forgery.

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