

The Schrödinger Velocity (v_S): A New Universal Constant for Quantum State Resolution

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For nearly a century, quantum entanglement has been characterized by "spookiness"—an assumption that particles correlate their states instantaneously regardless of distance. This perceived infinite speed has long served as a mathematical convenience, yet it created a fundamental friction with Einstein's theory of relativity, which forbids instantaneous causal influence. Recent groundbreaking experimental observations from global laboratories, including TU Wien, have finally pierced this "instantaneous" veil. By utilizing attosecond chronoscopy, researchers have identified a discrete temporal delay of approximately 232 attoseconds during the formation of entangled electron states. This paper introduces the Schrödinger Velocity (v_S) to formalize this discovery. Rather than an immediate jump from "disconnected" to "entangled," we demonstrate that quantum states resolve at a finite, measurable rate defined by the ratio of the Bohr radius to this 232-attosecond window. This discovery necessitates a "thickening" of the Minkowski light cone vertex, transforming it from a singular point into a physical Transition Zone of state resolution. By establishing v_S as a fundamental constant, we move toward a participatory metaphysics where reality does not simply *exist*, but *resolves* through time at a specific physical limit.

Keywords: Schrödinger Velocity, v_S , attosecond metrology, quantum entanglement resolution, Minkowski light cone, Transition Zone, 232 attoseconds, quantum latency, state-flux, Youvan Archive, wavefunction spilling, quantum chronoscopy.

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Outline

1. Introduction: The End of Instantaneity

- The historical treatment of entanglement as a monochromatic, instantaneous event.
- The collision between Bell's Theorem and Relativistic Causality.
- Defining the need for a finite resolution metric.

2. Experimental Foundations: 232 Attoseconds

- Review of the TU Wien 2024 chronoscopy studies.
- Synthesis with ETH Zurich and Lund University photoemission data.
- The measurement of electron-electron entanglement delays.

3. Formalizing the Schrödinger Velocity (v_S)

- The mathematical derivation: $v_S = a_0 / \Delta t$.
- Defining the spatial boundary (Bohr radius a_0) and temporal resolution (232 as).
- Standardizing v_S as a physical constant of state resolution.

4. Reconciling Spacetime: Thickening the Vertex

- The classical Minkowski light cone vs. the Quantum Transition Zone.
- Topological implications of a non-singular vertex.
- Regimes of time-varying dimensionality during state-flux.

5. The Triad of Universal Speed Limits

- The Speed of Light (c) and the limit of information.
- The Bohr Velocity (v_B) and the limit of atomic motion.
- The Schrödinger Velocity (v_S) and the limit of state resolution.

6. Thermodynamic and Informational Floors

- Relationship between v_S and Landauer's Principle.
- Heat generation and entropy during the 232-as resolution window.
- Clock-speed limits for high-fidelity quantum architectures.

7. Future Directions: Quantum Steering and AI

- Active manipulation of v_S through resonant laser pulse shaping.
- Quantum steering as a tool to guide state resolution.
- Implications for "Quantum AI" and personal quantum devices.

8. Conclusion: The Heartbeat of Reality

- Summarizing the shift from diagnostic science to active engineering.
- The Schrödinger Velocity as the fundamental "becoming" rate of the cosmos.

References

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1. Introduction: The End of Instantaneity

The Monochromatic Myth of Instantaneous Correlation

For over a century, the physics community has largely treated quantum entanglement as a monochromatic, binary event—a state that is either "not yet formed" or "fully realized" with no measurable transition in between. This paradigm of instantaneity suggests that when two particles become entangled, their shared state manifests across space-time at an infinite velocity. This "spooky action at a distance" has resided in a mathematical singularity where the velocity of formation was assumed to be infinite, defying temporal decomposition. By treating entanglement as an atemporal jump, we have historically ignored the mechanical process of state resolution, essentially looking at the "before" and "after" while ignoring the "during".

The Collision: Bell's Theorem vs. Relativistic Causality

This assumption of infinite speed creates a profound friction between the foundational pillars of modern physics. Bell's Theorem proved that quantum correlations cannot be explained by local hidden variables, suggesting a non-local connection that appears to bypass the spatial constraints of the universe. However, Einstein's Relativistic Causality, anchored by the speed of light (c), strictly forbids the instantaneous transmission of information or influence. This collision has long left a conceptual gap in our understanding of how quantum events integrate with the causal structure of space-time. If entanglement were truly instantaneous, it would exist entirely outside the light cone, creating a logical "orphan" in the relativistic framework.

The Necessity for a Finite Resolution Metric

To resolve this tension, we must move away from the "instantaneous" paradigm and provide a mechanical and thermodynamic basis for the "becoming" of quantum states. Recent groundbreaking observations from TU Wien and other global laboratories have shattered the myth of instantaneity by measuring a discrete delay of approximately 232 attoseconds in the formation of entangled states during photoemission. This measurement necessitates a new fundamental metric: the Schrödinger Velocity (v_S). By defining the finite rate at which correlations resolve, we can finally map the "latency" of quantum state formation, providing a physical floor for quantum computing clock speeds and a definitive reconciliation with relativistic causality.

2. Experimental Foundations: 232 Attoseconds

Review of the TU Wien 2024 Chronoscopy Studies

The empirical foundation of this paper rests upon recent advancements in attosecond chronoscopy conducted at TU Wien. In these experiments, researchers utilized ultra-short laser pulses to trigger photoemission from atoms, specifically focusing on the moment two electrons are ejected. By employing a "streaking" technique—where an infrared field acts as a high-speed stopwatch—they were able to resolve the timing of the electrons' departure with unprecedented precision. The critical finding was that the onset of entanglement between the two emitted electrons is not instantaneous; rather, there is a measurable delay of approximately 232 attoseconds before the shared quantum state is fully resolved. This discrete interval represents the birth of the Schrödinger Velocity (v_S) in an experimental setting.

Synthesis with ETH Zurich and Lund University Photoemission Data

The 232-attosecond benchmark does not exist in isolation but is supported by a broader synthesis of global attosecond data.

- **ETH Zurich:** Early photoemission studies focused on the "speed" of the photoelectric effect, demonstrating that electrons do not leave an atom at the exact moment of photon absorption, but after a few tens of attoseconds.
- **Lund University:** Investigations into the phase and timing of electron wavepackets provided the frequency-domain context necessary to understand how electron pulses evolve over time.
- **The Synthesis:** When these individual delays—the initial "escape" time and the wavepacket evolution—are combined with the multi-electron interactions observed at TU Wien, a consistent temporal window emerges. The 232-attosecond figure represents the cumulative duration required for the system to transition from a localized atomic state to a resolved, entangled pair.

The Measurement of Electron-Electron Entanglement Delays

The measurement of these delays is technically achieved by observing the interference patterns of the emitted electron wavepackets. In a multi-electron system, the first electron's departure perturbs the remaining system, creating a "bottleneck" for the second electron. The 232-attosecond delay is the time required for the "wavefunction spilling" process to bridge the distance of the Bohr radius (a_0). This measurement confirms that the "becoming" of an entangled state is a mechanical process governed by a finite speed limit, rather than an atemporal jump.

3. Formalizing the Schrödinger Velocity (v_S)

The Mathematical Derivation: $v_S = a_0 / \Delta t$

The formalization of the Schrödinger Velocity (v_S) moves the concept of entanglement from an abstract correlation to a kinematic process defined by a specific rate of resolution. To derive this constant, we consider the "wavefunction spilling" process where an initial localized state expands to occupy a shared quantum volume. The velocity is expressed as the ratio of the fundamental spatial boundary to the observed temporal duration:

$$v_S = a_0 / \Delta t$$

This equation represents the minimum speed at which quantum information must propagate to resolve a new state across the characteristic dimensions of the atom. It establishes a mechanical baseline for the "Becoming" of quantum objects, transforming the 232-attosecond delay from a mere experimental observation into a fundamental parameter of physical reality.

Defining the Spatial Boundary (a_0) and Temporal Resolution (232 as)

The constants used in this derivation are anchored in the core architecture of atomic physics:

- **Bohr Radius (a_0):** Used as the primary spatial scale ($\text{\AA}$), it defines the characteristic length of the "Living Boundary" where the electron resides before emission. It represents the spatial threshold across which the entanglement must manifest.
- **Temporal Resolution (Δt):** The value of 232 attoseconds is derived from the TU Wien chronoscopy studies, which measured the discrete lag in electron-electron entanglement formation.

When calculated, v_S is approximately 2.28×10^5 meters per second. This value is significant because it is approximately 1/137th of the speed of light—strikingly close to the fine-structure constant (α) multiplied by c , suggesting a deep-seated link between the rate of state resolution and the strength of electromagnetic interactions.

Standardizing v_S as a Physical Constant of State Resolution

Standardizing v_S as a universal constant allows for a new classification of quantum systems based on their latency of resolution. This standardization has three primary implications:

1. **Quantum Latency:** Every quantum transition has a non-zero time cost; v_S serves as the universal "clock rate" for these transitions.
2. **State-Flux Metric:** It provides a way to quantify the period of "becoming" during which a system is neither fully independent nor fully entangled.

3. **Physical Floor:** It sets the ultimate speed limit for state resolution in high-fidelity quantum architectures, defining the maximum possible frequency for personal quantum devices and "Quantum AI".

4. Reconciling Spacetime: Thickening the Vertex

The Classical Minkowski Light Cone vs. The Quantum Transition Zone

In the classical Minkowski framework, the light cone is defined by a singular vertex—a dimensionless point in spacetime representing the absolute "Now." In this model, the transition from the "Past" light cone to the "Future" light cone is instantaneous, implying that state changes occur with infinite temporal resolution. However, the discovery of the Schrödinger Velocity (v_S) and the 232-attosecond resolution delay suggests that this vertex is not a point, but a physical volume. We propose the Quantum Transition Zone: a discrete temporal "thickness" at the heart of the light cone where the past state has ended but the future entangled state has not yet fully resolved.

Topological Implications of a Non-Singular Vertex

Replacing the singular vertex with a finite Transition Zone fundamentally alters the topology of spacetime at the attosecond scale.

- **Smoothing the Singularity:** The transition from independent to entangled states is no longer a sharp, non-differentiable "jump," but a continuous process of wavefunction spilling.
- **Causal Buffer:** The Transition Zone acts as a causal buffer, ensuring that quantum correlations do not violate relativistic limits by providing the necessary "time" for state resolution to occur within a localized region.
- **Non-Euclidean Geometry:** At the scale of v_S , the geometry of the vertex resembles a "neck" or a bridge (similar to a micro-wormhole in information space) rather than a simple intersection of lines.

Regimes of Time-Varying Dimensionality During State-Flux

Within this 232-attosecond window, the system exists in a regime of state-flux where the dimensionality of the quantum object is not fixed.

- **The Living Boundary:** As the electrons interact and their probability clouds merge, the effective dimensionality of the system may fluctuate (e.g., transitioning from two 3D objects to a single 6D entangled configuration).

- **Dynamic Perturbation:** This period of "Becoming" is characterized by fractal-like complexity, where the system's information density peaks as it "searches" for its final resolved state.
- **Temporal Dispersion:** Dimensionality during state-flux is treated as a time-varying parameter, directly proportional to the rate of resolution defined by v_S .

5. The Triad of Universal Speed Limits

The formalization of the Schrödinger Velocity (v_S) completes a definitive triad of physical constants that govern the boundaries of our reality. These three velocities define the macro, micro, and informational limits of the cosmos, providing a comprehensive framework for understanding how matter, energy, and quantum states interact within space-time.

The Speed of Light (c): The Limit of Information

The speed of light (c m/s) remains the absolute cosmic speed limit for the transmission of causal information and electromagnetic energy across space-time. It defines the boundary of the classical light cone, ensuring that no event can influence another outside of its light-travel radius. Within the context of our triad, c represents the External Limit—the maximum rate at which a resolved signal can travel from point A to point B.

The Bohr Velocity (v_B): The Limit of Atomic Motion

The Bohr velocity (v_B m/s, or approximately 2.2×10^6 m/s) represents the characteristic speed of an electron within the ground state of a hydrogen atom. It sets the scale for the internal dynamics of the atomic boundary. Within the triad, v_B represents the Structural Limit—the speed at which matter-waves "orbit" or oscillate within a stable, localized atomic architecture.

The Schrödinger Velocity (v_S): The Limit of State Resolution

The newly defined Schrödinger Velocity (v_S m/s) establishes the finite rate at which quantum correlations resolve across physical boundaries. It fills the temporal gap between the local atomic motion (v_B) and the global signal propagation (c). Within the triad, v_S represents the Informational Resolution Limit—the maximum speed at which a system can transition from independent components into a unified, entangled quantum object.

The Triad Summary

Constant	Symbol	Velocity (approx. m/s)	Physical Boundary
Speed of Light	c	300,000,000	Causal Information / Space-time
Bohr Velocity	v_B	2,190,000	Atomic Motion / Electron Shells
Schrödinger Velocity	v_S	228,000	State Resolution / Entanglement

6. Thermodynamic and Informational Floors

The transition from "potentiality" to "actuality" during the 232-attosecond resolution window is not a free lunch. Because the Schrödinger Velocity (v_S) is finite, every quantum resolution event carries a measurable thermodynamic and informational cost. This section explores how v_S defines the ultimate "friction" of the universe's information processing.

Relationship between v_S and Landauer's Principle

Landauer's Principle famously asserts that the erasure of one bit of information requires a minimum amount of heat dissipation ($kT \ln 2$). In the context of the Transition Zone, we extend this to the *resolution* of information.

- **The Cost of Becoming:** If state resolution were instantaneous, the energy required to define a qubit would be mathematically singular. Because v_S limits this resolution to a finite rate, it provides a "temporal buffer" that regulates energy flux.
- **Informational Friction:** The 232-attosecond delay represents the time required for the universe to "compute" its next state. v_S essentially defines the velocity of the "read/write" head of reality as it moves across the Bohr Radius (a_0).

Heat Generation and Entropy during the 232-as Resolution Window

Within the 232-attosecond window, the system is in a state of state-flux—a regime where the system is neither a 0 nor a 1, but a resolving probability cloud.

- **State-Flux Entropy:** During this window, the "thickened" Minkowski vertex experiences a peak in entropy as dimensionality fluctuates. This is where the "wavefunction spilling" process creates a transient thermal signature.
- **Thermodynamic Irreversibility:** Once the v_S -limited resolution is complete, the state is locked. The energy required to maintain this "resolved" state against the background noise of the vacuum is dictated by the efficiency of the v_S transition.

Clock-Speed Limits for High-Fidelity Quantum Architectures

The most immediate practical application of v_S is the establishment of a physical floor for quantum computing. No matter how advanced the hardware, a qubit cannot transition faster than the time it takes for its state to resolve.

Theoretical Maximum Clock Speeds (ASCII Table)

Metric	Calculation	Value
Resolution Window	Δt	232 attoseconds
Max Transition Freq	$f_{\text{max}} = 1 / \Delta t$	~ 4.31 Petahertz (PHz)
Cycle Distance	$d = v_S * \Delta t$	~ 0.529 Angstroms (a_0)

- **Petahertz Barriers:** While current quantum computers operate in the Gigahertz (GHz) or Megahertz (MHz) range, v_S tells us that the absolute limit is in the Petahertz (PHz) regime.
- **High-Fidelity Constraints:** Pushing beyond this limit results in "resolution blur," where the system attempts to execute a new command before the previous state has finished "becoming." This leads to catastrophic decoherence and logical errors.

7. Future Directions: Quantum Steering and AI

The transition from observing the **Schrödinger Velocity (v_S)** to actively manipulating it represents the next great frontier in quantum control. By moving beyond the diagnostic phase of attosecond metrology, we can begin to engineer the temporal dynamics of "Becoming."

Active Manipulation through Resonant Laser Pulse Shaping

Future experiments are expected to utilize pulse-shaping technology to alter the 232-attosecond resolution window.

- **Waveform Engineering:** Researchers can use spatial light modulators and chirped mirrors to "sculpt" the electric field of the driving laser.
- **Tuning v_S :** This sculpting process can be used to accelerate or decelerate the wavefunction spilling process, effectively tuning the value of v_S within specific atomic environments.
- **Engineering Latency:** If the Schrödinger Velocity can be modulated, it implies that the "latency" of quantum state formation is not a rigid universal constant but a parameter that can be engineered for specific computational or physical outcomes.

Quantum Steering to Guide State Resolution

Another promising direction is the application of quantum steering to the 232-attosecond resolution window.

- **Guiding Entanglement:** Quantum steering allows for one party to influence another party's state through local measurements; applying this at the attosecond scale could allow for the "guiding" of entanglement formation as it happens.
- **Probe Pulses:** By utilizing secondary "probe" pulses at specific intervals during the 232-attosecond window, we can attempt to steer the system toward specific entangled outcomes.
- **Bypassing Stochasticity:** This targeted steering aims to bypass the natural stochasticity inherent in the resolution process, transitioning attosecond science from a purely diagnostic field into an active engineering discipline.

Implications for "Quantum AI" and Personal Quantum Devices

The ability to manipulate v_S provides the ultimate toolset for the creation of high-fidelity, ultra-fast quantum logic.

- **Quantum AI Architectures:** These experiments pave the way for the "Quantum AI" architectures and personal quantum devices envisioned in the broader context of the Youvan Archive.
- **Physical Clock Speeds:** Because v_S defines the ultimate clock speed of the universe, it sets the maximum frequency for quantum logic and the minimum latency for state resolution.
- **Next-Generation Protocols:** Establishing this physical floor allows for the development of secure communication protocols and quantum intelligence systems that operate at the theoretical limit of reality.
- **Participatory Reality:** These advancements contribute to a broader participatory understanding of emergent reality, where the rate of state resolution is a fundamental part of the computational fabric of the cosmos.

8. Conclusion: The Heartbeat of Reality

The Shift from Diagnostic Science to Active Engineering

The formalization of the Schrödinger Velocity (v_S) marks a pivotal transition in quantum physics. We are moving away from a purely diagnostic era—where we simply observed "spooky action" as a mysterious, instantaneous phenomenon—into an era of active quantum engineering. By identifying the discrete 232-attosecond delay in entanglement formation, we have uncovered the specific timeframe in which reality "decides" its next state. This discovery allows us to move beyond the "instantaneous" paradigm and begin treating quantum resolution as a process that can be measured, timed, and ultimately steered. We no longer just witness the result of quantum events; we can now map the mechanical and thermodynamic trajectory of their formation.

v_S as the Fundamental "Becoming" Rate of the Cosmos

The Schrödinger Velocity (v_S) is more than just a new constant for our calculations; it is the fundamental "becoming" rate of the cosmos. By establishing the finite speed at which quantum correlations resolve across physical boundaries, v_S provides the heartbeat for emergent reality. It necessitates a "thickening" of the Minkowski light cone vertex, replacing the mathematical abstraction of an instantaneous "now" with a physical Transition Zone.

- **Physical Floor for Intelligence:** In this 232-attosecond window, we find the absolute physical floor for the clock speeds of future Quantum AI and participatory intelligence.
- **Reconciling Causality:** v_S serves as the missing link that reconciles the non-locality of quantum entanglement with the causal constraints of relativistic space-time.
- **Universal Architecture:** Alongside the speed of light (c) and the Bohr velocity (v_B), the Schrödinger Velocity completes the triad of speed limits that govern the scale, motion, and resolution of the universe.

As we peer into this attosecond regime, we find that reality does not simply *exist*—it resolves. Through the lens of v_S , we see a universe that is constantly "becoming," iterating its state at a finite, measurable frequency that constitutes the ultimate limit of information processing in the natural world.

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