A Kinetic Route to the Lorentz Transform and Beyond

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Abstract

We model an elementary particle as a closed, lightlike intrinsic motion with rest-cycle period τ that can undergo bodily translation without ever exceeding speed c. A local triangle construction and cycle averaging yield the Pythagorean time-share relation $T^2 = \tau^2 + \overline{T}^2$ and standard time dilation. Interpreting the reallocation between intrinsic cycling (T) and translation ($\overline{T}$) as a symmetric two-channel kinetics with rate $k(t)$ integrates to a hyperbolic rotation (Lorentz boost) with rapidity $\phi = \int k\,dt$ and $v/c = \tanh\phi$. In the small-signal limit this identifies $k = F/(mc)$, linking the kinetic picture to Newton's second law while the tanh nonlinearity enforces the c bound. We also give a physical reading of *relative rapidity* as the net logarithmic bias in time-share needed to map between motion states.

1 A Closed Wave Undergoing Bodily Motion

Established models of matter posit that elementary-particle substrates undergo an intrinsic oscillatory motion at speed c (for example: Dirac's zitterbewegung; the Higgs mechanism's chiral to-and-fro; the Williamson-van der Mark toroidal-photon model of the electron; and, by allusion, Einstein's light clock). Here we analyze ramifications of this feature and show how some properties of motion of such systems follow from simple geometry, and how the time of bodily translation must kinetically couple with the intrinsic cycle period for it to preserve its shape in its frame. We do not commit to a specific topology: we only require that the circulating wave always has instantaneous speed magnitude c and an intrinsic closed-cycle period τ at true rest. A circulating wave is at true rest when the circulation is truly closed in a hypothesized special frame of reference. If not at true rest, the circulation orbit opens up just like the closed to-and-fro of a light clock opens up in a zig-zag when seen in motion, or how the earth's closed orbit looks like an open helix in light of the solar system's galactic motion. We show below, that this simple model of a circulating wave gives rise to the Lorentz transform, and Newton's second law (approximately), without any additional postulates. Consider the motion of this wave (say a certain wave-front thereof) during a short time $\delta\tau$ in its state of true rest (as defined above). Now let us impose a bodily translation on the same wave, so that its motion must correspondingly add an additional motion in some direction D. Please note that this additional motion can't be applied additively to the motion of that intrinsic wavefront (for that would increase or decrease the speed magnitude). This is where it departs from the Galilean picture of motion. In the Galilean picture of motion, we can add an an additional velocity while taking into account a bodily veolcity of an assembly undergoing intrinsic motion. However, this circulating wave of ours has a fixed wavefront speed of c determined by properties out of scope of this discussion. So, how do we superimpose the additional motion? Here is our proposal - suppose that it's possible to define a time-share over which the wavefront "does its time" in service of the bodily motion in direction D. Corresponding to the intrinsic motion clip spanning $\delta\tau$ at true rest, let's call this "motion-penalty" time $\delta\overline{T}$. This however it does so without compromising its shape to itself. Just the way the earth's orbit remains closed from the perspective of its "own" matter, the circulating wave's "wave orbit" remains closed (and thus preserves its shape from the perpective of its own "wave" ingredients). However the time to negotiate this closed (to-self) orbit would prolong due to having to dedicate some of the time into bodily shifting. For the intrinsic motion clip spanning $\delta\tau$ at true rest, let's call the corresponding prolonged time δT. Next we shall show that the three time intervals will have the relationship that the sides of a triangle have (and that it's **not true** that $\delta T = \delta\tau + \delta\overline{T}$ despite looking like a partitioning of time). The reason comes from the physical nature of wave motion. The intrinsic substrate is wave-like and not spatially localized: by Huygens' construction every point of the front acts as a secondary source, and advance of the front occurs along a direction that gets it there first (hence is Fermat's principle). When intrinsic cycling and bodily translation are superposed, the effective advance from a point A to a point C during the same Newtonian budget is not the concatenation of local legs $A \to B$ and $B \to C$ with summed times; the front reaches C along the shortest-time resultant. With the local speed constrained to be c in both channels, this entails vector addition of displacements and hence a cosine-law relationship among the three durations $c\,\delta T$, $c\,\delta\tau$, and $c\,\delta\overline{T}$. This is algebraically similar to Einstein's light-clock construction but slightly more general (in that direction D need not be perpendicular to the "rest" motion of the wavefront), and physically different. So, the wave displacements over the three time intervals form a triangle, and the three sides have lengths $c\,\delta T$, $c\,\delta\tau$, and $c\,\delta\overline{T}$. If θ is the instantaneous angle between the intrinsic segment direction and the bodily translation direction, the law of cosines of the triangle gives

$$c^2\,\delta T^2 \;=\; c^2\,\delta\tau^2 + c^2\,\delta\overline{T}^2 - 2\,c^2\,\delta\tau\,\delta\overline{T}\,\cos\theta. \tag{1}$$

Over a full intrinsic cycle, averaging over θ eliminates the cross term, irrespective of the detailed shape of the closed path. Summing the segments over a cycle yields

$$c^2T^2 \;=\; c^2\tau^2 + c^2\overline{T}^2, \qquad \text{i.e.} \qquad T^2 \;=\; \tau^2 + \overline{T}^2. \tag{2}$$

Here τ is the closed-cycle period at true rest, T is the prolonged cycle time in the presence of bodily motion, and $\overline{T}$ is the total time-share devoted to translation during that cycle.

Time dilation from the triangle. Define the bodily headway per prolonged orbital time as

$$v \;=\; \frac{c\,\overline{T}}{T}, \qquad \beta \;=\; \frac{\overline{T}}{T} = \frac{v}{c}, \tag{3}$$

so (2) implies

$$c^2T^2 \;=\; c^2\tau^2 + v^2T^2 \quad\Rightarrow\quad T \;=\; \frac{\tau}{\sqrt{1 - v^2/c^2}}, \tag{4}$$

which is the standard time-dilation relation obtained here from the closed-path generalization of the light-clock argument.

In this notation, $\beta = \overline{T}/T$ is the true bodily speed (as a fraction of c) of the particle with respect to the implied special frame singled out by the time-sharing variables. Equivalently, $v = c\,\beta$ is that bodily speed in conventional units.

2 Differential Kinetics of Motion Modes

Treat τ as an intrinsic constant of the substrate (closed-cycle period in its own frame) and let both T and $\overline{T}$ vary in response to external influence over Newtonian time t. Differentiating (2) with respect to t gives

$$2T\dot{T} = 2\overline{T}\dot{\overline{T}} \quad \Rightarrow \quad T\dot{T} = \overline{T}\dot{\overline{T}}, \tag{5}$$

where dots denote $\frac{d}{dt}$. Rearranging,

$$\frac{\dot{T}}{\overline{T}} = \frac{\dot{\overline{T}}}{T} =: k(t), \tag{6}$$

defines a scalar rate $k(t)$ governing a symmetric two-channel kinetics:

$$\dot{T} = k(t)\,\overline{T}, \qquad \dot{\overline{T}} = k(t)\,T. \tag{7}$$

3 Integrating over a finite newtonian time interval

Let $\mathbf{u}(t) := \begin{bmatrix}\overline{T}(t)\\ T(t)\end{bmatrix}$. The linear system (7) integrates over any interval $[t_0, t_1]$ to a hyperbolic rotation (Lorentz boost in 1+1D):

$$\mathbf{u}(t_1) = \begin{bmatrix}\cosh\phi & \sinh\phi\\ \sinh\phi & \cosh\phi\end{bmatrix}\mathbf{u}(t_0), \qquad \phi = \int_{t_0}^{t_1} k(t)\,dt. \tag{8}$$

Using (3) and the standard identification,

$$\frac{v}{c} = \tanh\phi, \qquad \gamma = \cosh\phi = \frac{1}{\sqrt{1 - v^2/c^2}}, \tag{9}$$

so the finite-time map (8) is exactly the Lorentz boost matrix acting on the two-component time-share vector $[\overline{T},\, T]^\top$. Identifying spatial displacement and elapsed orbital time via $X = c\,\overline{T}\,N$ and $T_{\mathrm{orb}} = T\,N$ for N intrinsic cycles reproduces the standard coordinate transform $(X/c,\, T_{\mathrm{orb}})$ under a boost of rapidity ϕ.

4 Connection with Newton's Second Law

Using (9) with $\phi = \int k(t)\,dt$, the state speed is

$$v = c\,\tanh\!\left(\int k(t)\,dt\right). \tag{10}$$

For small excursions ($\tanh x \approx x$),

$$\Delta v \approx c \int k(t)\,dt. \tag{11}$$

Newton's second law over the same interval gives $\Delta v = \int F(t)/m\,dt$. Equating the small-signal forms identifies

$$k(t) = \frac{F(t)}{mc} \quad \text{(longitudinal)}. \tag{12}$$

Equivalently, the accumulated rapidity is approximately impulse per mc:

$$\phi = \int k\,dt \;\approx\; \frac{1}{mc}\int F\,dt. \tag{13}$$

Thus, at low speeds the kinetic two-channel response reduces to proportionate acceleration; at higher speeds the hyperbolic nonlinearity enforces the c bound while preserving rapidity additivity.

5 Parting Thoughts

Starting from a closed-path intrinsic motion at speed c with rest-cycle τ and superposed bodily translation, the local triangle construction and cycle averaging yield $T^2 = \tau^2 + \overline{T}^2$ and the standard time dilation. Modeling the time-share reallocation as a symmetric two-channel kinetics with rate $k(t)$ integrates to a hyperbolic rotation of rapidity $\phi = \int k\,dt$, i.e., the Lorentz boost with $v/c = \tanh\phi$. In this view the boost is a finite-time state map of a kinetic exchange between intrinsic cycling and translation, independent of the detailed topology of the intrinsic closed path.

The preservation of a wave's internal closedness in its own frame under this symmetric exchange is the natural complement to rotational rigidity: antisymmetric (rotational) flows preserve shape under changes of direction, while the proposed symmetric exchange preserves internal structure under changes of speed (magnitude). This provides a coherent, geometry-led, kinetic origin for Lorentz boosts and suggests why persistent substrates would be selected to maintain their internal shape while developing bodily headway.