Different Perspective on Time and Space: Multipolar Time – Ontology, Axiomatics, v 4

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Abstract

The Multipolar Time Hypothesis proposes a fundamental change in understanding the nature of time. Instead of treating time as a scalar parameter or geometric dimension, time is understood as an ontological condition for the realization of physical events, realized through a local stream of elementary temporal possibility impulses. The paper presents a coherent axiomatic system, mathematical formalization within extended general relativity, analysis of relationships with existing physical theories, and four experimental protocols enabling testing of the theory's predictions. A key improvement is the derivation of the correct anisotropy function from relativistic aberration and solid angle transformation, ensuring stream conservation.

Contents

1 Introduction: Traditional and New Perspectives on Time

1.1 What is Time in the Traditional View?

In everyday life, we perceive time as a **linear stream** flowing from the past through the present to the future. In classical physics, time is a **parameter** that tells when something happens. In relativity theory, Einstein incorporated time as the **fourth dimension** in spacetime, which can "warp" under gravity and change its flow rate depending on velocity [1, 2].

1.2 Why Do We Need a New Perspective?

Despite the successes of modern physics, some mysteries remain unsolved:

- What actually causes time to "flow"?
- Why does time have only one direction?

- How to reconcile different observations of time in quantum and relativistic mechanics?
- What is the fundamental nature of time dilation?

The Multipolar Time Hypothesis offers radically new answers to these questions.

2 Conceptual Foundations

2.1 Key Idea: Time Doesn't Flow – Possibilities Inflow

Imagine an observer at the center of a transparent sphere. From every spatial direction, invisible "quanta of temporal possibility" – elementary time impulses – reach the observer. Each impulse represents a chance for a physical event to occur. Thus, time does not "flow"; rather, **possibilities of events inflow to the observer**.

2.2 Elementary Time Impulses

An elementary time impulse δT is characterized by the following properties:

1. **Elementarity and indivisibility** – the smallest possible unit.
2. **Locality** – realizes only at the observer's world point.
3. **Directionlessness** – does not carry spatial information by itself.
4. **Non-wave nature** – has no frequency, phase, or energy.
5. **Potentiality** – becomes an event only upon absorption by matter.

2.3 Time Stream

The time stream is the local field of inflow of elementary time impulses to the observer from all spatial directions. The stream intensity in direction (θ, ϕ) is defined as:

$$\Phi_T(\theta, \phi) \equiv \frac{dN(\theta, \phi)}{dt\, d\Omega},$$

where dN – number of impulses available for realization, dt – observer's proper time, $d\Omega$ – solid angle element.

2.4 Isotropy and Anisotropy

For an observer at rest relative to the time field, the stream is isotropic:

$$\Phi_T(\theta, \phi) = \Phi_0 = \text{const}.$$

For an observer moving with velocity v ($\beta = v/c$), the stream becomes anisotropic. The motion does not change the total amount of available impulses but redistributes their inflow density depending on direction. Formally:

$$\Phi_T(\theta, \phi) = \Phi_0\, f(\theta, \phi, \beta). \tag{1}$$

The function f describes the purely geometric availability of impulses. To satisfy the Stream Conservation Principle (Axiom 4) while simultaneously accounting for relativistic aberration and inflow asymmetry, f takes the form:

$$\boxed{f(\theta, \beta) = \frac{1}{\gamma^2(1 - \beta\cos\theta)^2}}, \tag{2}$$

where $\gamma = 1/\sqrt{1 - \beta^2}$ is the Lorentz factor.

Properties of the anisotropy function:

- **Rest state:** For $\beta = 0$, $f = 1$, giving isotropic inflow from all directions.
- **Inflow asymmetry (light-front effect):** The function is asymmetric – for $\theta = 0$ (direction of motion, front) the impulse density is highest, and for $\theta = \pi$ (rear) it is lowest. This reflects the physical intuition of the observer "running into" time impulses lying in its path.
- **Stream conservation:** The integral over the full solid angle is exactly 4π for any velocity:

  $$\oint_{4\pi} f(\theta, \beta)\, d\Omega = 4\pi. \tag{3}$$

  This proves that motion causes no "loss" of time, only geometric redistribution.
- **Geometric interpretation:** This function is the mathematical foundation for the deformation of the time sphere:

  $$r(\theta) = \frac{c\tau}{\gamma(1 - \beta\cos\theta)}, \tag{4}$$

  showing that relativistic effects result directly from the geometry of the time field.

2.5 Stream Conservation Principle

The total number of impulses available to the observer per unit of their proper time is constant:

$$\oint \Phi_T(\theta, \phi)\, d\Omega = 4\pi\Phi_0 = \text{const.} \tag{5}$$

Motion does not cause "loss of time", only a redistribution of event possibilities in angular space. This principle is rigorously satisfied by the anisotropy function above, as shown by the integral property (3).

3 Axiomatics of Time Stream (TSV)

Axiom 1: **Time Ontology**: Time is not a geometric quantity or motion parameter, but a condition for the realization of physical events. An event can occur only through absorption of an elementary time impulse [7, 11].

Axiom 2: **Elementary Time Impulse**: There exists an elementary, indivisible unit of time – the time impulse – which is local, directionless in itself, is not a wave, energy, or motion, and becomes an event only at the moment of absorption by matter.

Axiom 3: **Time Stream**: Time impulses form a time stream flowing to the observer from all spatial directions with characteristic velocity c. This stream determines the possibility of event realization, not the rate of absolute time.

Axiom 4: **Stream Conservation**: The total time stream available to the observer per unit of their proper time is invariant, regardless of the observer's state of motion. Motion does not cause loss or slowing of time, only directional redistribution of impulses.

Axiom 5: **Matter and Clocks**: Matter absorbs time impulses and realizes them as physical processes. A clock measures the number of realized impulses, and differences in clock readings result from the geometry of stream absorption, not from "slower running of time".

4 What Does This Approach Change About Time?

4.1 Ontological Revolution

The Multipolar Time Hypothesis introduces a fundamental change in understanding the nature of time [9]:

1. **Time is not a self-existent entity** – it does not exist as an independent dimension or parameter, but as a relation between the observer and the field of possibilities.
2. **Perspective inversion** – instead of "flowing through time", we have "inflow of possibilities" to the observer. The observer becomes the temporal center, not a passive time traveler.
3. **Elimination of absolute time** – there is no universal, absolute time flowing equally for everyone. Each observer experiences a unique stream of possibilities.
4. **Geometric interpretation of relativistic effects** – what is interpreted in STR/GR as time dilation, length contraction, and other relativistic effects results from the purely geometric redistribution of impulses, as described by equations (1)-(4), not from deformation of spacetime in an absolute sense.

4.2 Practical Consequences

- **Clock rate differences**: Differences in clock readings result from different geometries of absorption of the time stream.
- **Simultaneity**: The concept of simultaneity becomes local and dependent on the geometry of the observer's time stream.
- **Arrow of time**: The direction of time flow results from the directionality of impulse inflow – from the past (source of impulses) to the future (absorption) [32].
- **Time quantization**: Time has a natural, discrete structure at the level of elementary impulses [28].

5 Comparison with Existing Theories

5.1 General Theory of Relativity (GR)

- **Compatibility**: In the limit $\kappa_i \to 0$ (where κ_i are the coupling constants of the time field) the theory reduces to standard GR [4, 5].
- **Extension**: Adding the scalar time field $\tau(x)$ modifies Einstein's equations through an additional energy-momentum tensor $T^{(\tau)}_{\mu\nu}$.
- **Ontological difference**: GR treats time as a geometric dimension; our theory treats it as an emergent property of the stream of possibilities.

5.2 Einstein–Æther/Khronon Theory

- **Formal kinship**: The hypothesis uses the khronon formalism – a scalar field τ defining a preferred foliation [13, 14].
- **Interpretative difference**: In æther theory, the field u_μ is fundamental without special interpretation; in our theory we interpret it as the direction of time inflow from multipolar sources.
- **Addition**: The TSV $= 4\pi c^2\tau^2$ concept as a geometric measure of the time front, with the explicit anisotropy function derived from aberration and solid angle transformation.

5.3 Hořava Gravity

- **Structural compatibility**: Both theories use khronon to define absolute simultaneity [12].
- **Difference**: Hořava gravity is by design non-relativistic at high energies; our theory remains relativistic but with Lorentz symmetry breaking through a specific physical mechanism.

5.4 Lorentz Symmetry Breaking Theories

- **Membership**: The hypothesis belongs to this class through the introduction of a preferred time direction u_μ [18].
- **Advantage**: Symmetry breaking results from a specific physical mechanism (multipolar time inflow) and the explicit aberration-derived function, not introduced *ad hoc* [19].

5.5 Quantum Mechanics

- **Bridge**: The concept of time "inflow" resembles the decoherence process, where information from the environment determines local time flow [29].
- **Quantization**: Elementary time impulses may correspond to time quanta at the fundamental level [30].
- **Challenge**: Quantum version of the theory requires further research.

5.6 Cosmology

- **FRW/CDM**: The τ field adds a new energy component to Friedmann equations, potentially explaining dark energy [6].
- **Inflation**: The τ field could play the role of inflaton or modify its potential [34].
- **Arrow of time**: The direction of time inflow from the beginning of the Universe defines the cosmological arrow of time [33].

6 Mathematical Formalization

6.1 Basic Scalar Time Field

$$\tau : \mathcal{M} \to \mathbb{R}, \tag{6}$$

where $\mathcal{M}$ is the spacetime manifold.

6.2 Vector Field of Time Direction

$$u_\mu = \frac{\partial_\mu \tau}{\sqrt{-\partial_\alpha \tau \partial^\alpha \tau}}, \tag{7}$$

$$u_\mu u^\mu = -1. \tag{8}$$

6.3 Time-Space Volume (TSV) Unit

$$\mathrm{TSV}(\tau) = 4\pi c^2 \tau^2. \tag{9}$$

For $\tau = 1\,\mathrm{s}$:

$$\mathrm{TSV}(1) = 4\pi c^2 \approx 1.13 \times 10^{18}\,\mathrm{m}^2.$$

6.4 Incorporation into General Relativity

Total action:

$$S = S_{\mathrm{EH}} + S_\tau + S_{\mathrm{matter}}. \tag{10}$$

Einstein-Hilbert action:

$$S_{\mathrm{EH}} = \frac{c^3}{16\pi G} \int d^4x \sqrt{-g}(R - 2\Lambda). \tag{11}$$

Time field action (khronon) [15, 16]:

$$S_\tau = \int d^4x \sqrt{-g} \Big\{ \alpha_1 (\nabla_\mu u_\nu)(\nabla^\mu u^\nu) + \alpha_2 (\nabla_\mu u^\mu)^2 + \alpha_3 (\nabla_\mu u_\nu)(\nabla^\nu u^\mu) + \lambda (u_\mu u^\mu + 1) \Big\}. \tag{12}$$

Modified Einstein equations:

$$G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} \big(T^{(\mathrm{matter})}_{\mu\nu} + T^{(\tau)}_{\mu\nu} \big). \tag{13}$$

The anisotropy function $f(\theta, \beta)$ derived in Section 2.4 emerges from the relativistic transformation of angles and solid angles, and its specific form (2) is consistent with the khronon formalism when the preferred direction u_μ is aligned with the observer's motion.

7 Physical Predictions and Experimental Tests

7.1 Prediction Table

Effect	**Predicted dependence**	**Testing method**
Diurnal-annual anisotropy	$\Delta\nu/\nu \sim \kappa_3 \cdot F(\text{orientation, Earth's motion})$	Optical atomic clock comparisons [23]
Orientation anisotropy	$\cos(2\theta)$, $\cos(4\theta)$ dependence on clock orientation	Rotating clock arrays [27]
Gradient from moving mass	$\frac{\partial\tau}{\partial x} \sim \kappa_3 \cdot \frac{GMv}{c^4 r^2}$	Clocks near moving mass
GPS effect modifications	Dilation corrections $\sim \beta(\kappa_i) \times 10^{-5}$	Precise GPS satellite data [26]
Cosmological anisotropies	Residual anisotropies in CMB with specific symmetry	CMB measurements (Planck, future)
Gravitational waves	Additional polarizations, dispersion	LIGO/Virgo/KAGRA detectors

Table 1: Testable predictions of the Multipolar Time Hypothesis

7.2 Experimental Protocols

Four detailed experimental protocols have been developed to test the Multipolar Time Hypothesis. Each protocol targets a specific prediction and has been designed with rigorous methodological standards.

Experiment 1: Diurnal-Annual Anisotropy Test

- *Objective*: To test for the existence of a preferred direction of time field inflow associated with Earth's motion through space, particularly relative to the Cosmic Microwave Background (CMB). This experiment directly tests the anisotropy function $f(\theta, \beta)$ given by (2).
- *Materials and Requirements*:
  - Clock data: Raw frequency comparison data from at least three atomic clocks (hydrogen masers or optical clocks) before any STR/GR model corrections.
  - Observation period: Minimum one year of continuous data.
  - Software: Python with NumPy, SciPy, Matplotlib or equivalent.
  - Ephemeris data: Astronomical data on Earth's motion (Local Sidereal Time, orbital position, velocity relative to CMB).
- *Step-by-Step Procedure*:
  (a) Data acquisition: Contact metrology institutes (BIPM, PTB, NIST) for raw, uncorrected clock data.

(b) Data preparation: For each clock, calculate daily average frequency:

$$\bar{\nu}_d = \frac{1}{N}\sum_{i=1}^{N} \nu_i$$

where ν_i are individual frequency measurements.

(c) Deviation calculation: Compute relative deviation from annual mean:

$$\delta\nu_d = \frac{\nu_d - \bar{\nu}_{\text{year}}}{\bar{\nu}_{\text{year}}}$$

(d) Ephemeris acquisition: Obtain for each observation day: Local Sidereal Time (LST), Earth's orbital position, direction and velocity of Solar System relative to CMB.

(e) Correlation analysis: Test correlation between $\delta\nu_d$ and: LST phase (period 23h56m04s), annual phase (365.25 days), direction relative to CMB.

(f) Statistical test: Calculate Pearson correlation coefficient r.

Experiment 2: Time-Space Volume (TSV) Synchronization Test

- *Objective*: To test the impact of local clock motion on global clock network synchronization, providing a direct test of TSV as a physical quantity and the redistribution properties of $f(\theta, \beta)$.
- *Materials and Requirements*:
  - Clocks: Three identical optical atomic clocks or hydrogen masers (minimum stability 10^{-16} at 1 s).
  - Moving platform: Precision linear or rotational system with velocity control (range 0.01–1 m/s).
  - Synchronization system: Optical fiber frequency comparison system with resolution $< 10^{-18}$.
  - Environmental control: Thermally stable chamber ($\Delta T < 0.01$°C), active vibration damping.
- *Step-by-Step Procedure*:
  (a) Configuration: Clocks A and B stationary (2–5 m apart), Clock C on moving platform.
  (b) Calibration phase (48 hours): All clocks at rest, measure time differences Δt_{AB}, Δt_{AC}, Δt_{BC}.
  (c) Experimental phase (7 days): Clock C moves sinusoidally in a circle (radius 1 m, period 300 s, maximum velocity 0.5 m/s).
  (d) Frequency domain analysis: Fourier transform of $\Delta t_{ij}(t)$ signals, search for components at motion frequency $f_{\text{motion}} = 1/T$.
  (e) Systematic controls: Conduct cycles with different velocities (0.1, 0.3, 0.5 m/s) and linear motion for comparison.

Experiment 3: Spatial Orientation Anisotropy Test

- *Objective*: To test the dependence of local time flow rate on the spatial orientation of the clock. This directly probes the angular dependence of $f(\theta, \beta)$.

- *Materials and Requirements*:
  - Clocks: Three identical optical clocks from the same production series.
  - Rotation system: Precision rotary table with angular positioning $< \pm 0.1°$.
  - Environmental control: Temperature-stabilized chamber ($\Delta T < 0.001°\text{C/h}$), magnetic shielding.
  - Measurement system: Wireless frequency comparison system with resolution $< 10^{-17}$.
- *Step-by-Step Procedure*:
  (a) Symmetric configuration: Three clocks in equilateral triangle arrangement (side 1–2 m).
  (b) Rotation scheme: Whole array rotated by 90° every 6 hours (4 positions daily: 0°, 90°, 180°, 270°).
  (c) Measurements: For each clock pair, measure frequency difference $\Delta\nu_{ij}(\theta)$; collect ≥ 1000 independent measurements per orientation.
  (d) Harmonic analysis: Fit function to data:

$$\Delta\nu(\theta) = A\sin(2\theta + \phi_2) + B\sin(4\theta + \phi_4) + C$$

  where 2θ component corresponds to dipole anisotropy, 4θ to quadrupole.
  (e) Consistency test: Check if amplitudes A, B are consistent between different clocks.

Experiment 4: Time Field Gradient from Moving Mass

- *Objective*: To detect dynamic changes in the local time field caused by a moving mass. This experiment tests direct interaction between mass distribution and the temporal field.
- *Materials and Requirements*:
  - Clocks: Two ultra-stable optical lattice clocks (stability $< 10^{-19}$ at 1000 s).
  - Moving mass: Set of weights with total mass 10,000 kg (lead or tungsten).
  - Motion system: Precision linear system with position control $< \pm 1$ mm.
  - Isolation: Vacuum chamber ($< 10^{-6}$ mbar), active seismic isolation, gravitational gradiometer shielding.
  - Auxiliary measurements: Temperature, pressure, magnetic field sensors, gravitational gradiometer.
- *Step-by-Step Procedure*:
  (a) Configuration: Clocks separated by 1 m; mass initially symmetric, 0.5 m from each clock.
  (b) System calibration: 72 hours of measurements without mass movement.

(c) Mass motion: Sinusoidal movement $x(t) = A\sin(2\pi t/T)$, $A = 0.5$ m, $T = 300$ s; mass moves between clocks, approaching as close as 0.1 m to each.

(d) Synchronized measurements: Clock time difference $\Delta\tau(t) = \tau_1(t) - \tau_2(t)$ at 10 Hz; mass position $x(t)$ at 100 Hz; concurrent environmental data.

(e) Correlation analysis: Calculate cross-correlation function $C(\delta)$ between $\Delta\tau(t)$ and $x(t + \delta)$.

(f) Gradient estimation:

$$\frac{\partial\tau}{\partial x} \approx \frac{\Delta\tau_{\max} - \Delta\tau_{\min}}{x_{\max} - x_{\min}}$$

(g) Controls: Measurements with different motion periods (100 s, 300 s, 1000 s) and different masses (1000 kg, 5000 kg, 10000 kg).

7.3 Success Criteria for Experimental Verification

For each experimental protocol, specific quantitative criteria have been established to determine whether the results constitute successful verification of the Multipolar Time Hypothesis:

Criterion 1: Diurnal-Annual Anisotropy Test

- *Strong evidence*: Pearson correlation coefficient $|r| > 0.5$ between frequency deviations and Earth's motion parameters (LST phase or orbital position).
- *Potential evidence*: $0.2 < |r| < 0.5$ indicates a weak but potentially interesting effect requiring further investigation.
- *No evidence*: $|r| < 0.2$ suggests no convincing evidence for anisotropy.
- *Crucial verification*: Any detected signal must be shown not to be caused by known seasonal effects (temperature, pressure, tides) through rigorous control analyses.

Criterion 2: Time-Space Volume (TSV) Synchronization Test

- *Strong evidence*: Detection of motion frequency component f_{motion} in $\Delta t_{ij}(t)$ spectrum with signal-to-noise ratio SNR > 10.
- *Velocity dependence*: Additional confirmation if signal amplitude scales with velocity v as predicted by the hypothesis.
- *Artifact exclusion*: Signal must disappear when Clock C is stationary and show no correlation with environmental parameters (temperature, vibrations, electromagnetic fields).
- *Reproducibility*: Effect must be reproducible across different velocity settings and motion patterns (circular vs. linear).

Criterion 3: Spatial Orientation Anisotropy Test

- *Dipole anisotropy detection*: Amplitude A of $\sin(2\theta)$ component significantly non-zero ($A > 5\sigma_A$, where σ_A is statistical uncertainty).
- *Quadrupole anisotropy detection*: Amplitude B of $\sin(4\theta)$ component significantly non-zero ($B > 5\sigma_B$).
- *Dipole anisotropy* ($A \neq 0$): Indicates preferred spatial direction in time field structure.
- *Quadrupole anisotropy* ($B \neq 0$): Indicates more complex field structure with quadrupole moment.
- *Consistency*: Amplitudes A and B must be consistent across different clocks in the array.
- *Phase stability*: Phase parameters ϕ_2 and ϕ_4 must remain constant over time.

Criterion 4: Time Field Gradient from Moving Mass

- *Strong correlation*: Cross-correlation $C(0) > 0.7$ between mass position and clock time difference, with time delay $\delta < 1$ s.
- *Expected magnitude*: Gradient $\partial\tau/\partial x$ of order 10^{-21} s/m for 10,000 kg mass.
- *Mass scaling*: Effect must scale with moving mass magnitude (test with different masses: 1000 kg, 5000 kg, 10000 kg).
- *Motion dependence*: Effect must disappear when mass is stationary or removed.
- *Artifact exclusion*: Correlation must not occur with any environmental variables (temperature, pressure, magnetic field, seismic activity).
- *Period dependence*: Effect should be detectable across different motion periods (100 s, 300 s, 1000 s).

7.4 Experimental Constraints and Feasibility

The proposed experiments are designed to be feasible with current or near-future technology:

- **Clock technology**: Optical atomic clocks with stabilities of 10^{-16} to 10^{-19} are currently operational in several metrology laboratories worldwide.
- **Precision motion control**: Sub-millimeter positioning and velocity control systems are commercially available.
- **Environmental isolation**: Advanced thermal, vibrational, and electromagnetic shielding techniques exist.
- **Data acquisition**: High-speed, high-precision measurement systems capable of the required resolutions are available.

The most challenging aspects involve the coordination of multiple ultra-stable clocks and the elimination of systematic errors at the 10^{-18} to 10^{-21} level. However, ongoing advances in quantum metrology and precision measurement techniques make these experiments increasingly feasible.

8 Limitations and Challenges

8.1 Experimental Constraints

From existing measurements [20, 21]:

- Lorentz tests: $\kappa_3 < 10^{-10}$ [19]
- Equivalence principle tests: $|\alpha| < 10^{-5}$
- Time dilation measurements: anisotropy $< 10^{-18}$
- GPS data: $|\beta| < 10^{-5}$

8.2 Theoretical Challenges

1. **Quantum consistency**: Can the theory be quantized without unitarity problems?
2. **Precise constraints**: Exact determination of limits for κ_i from existing data [22].
3. **Connection to quantum gravity**: Could the theory be an effective description for LQG or string theory?
4. **Emergence of spacetime**: Could all of spacetime emerge from the dynamics of the τ field [31]?

9 Summary: What Does the New Approach Bring?

The Multipolar Time Hypothesis offers:

1. **New ontology of time**: Time doesn't flow – possibilities inflow. This is a fundamental change of perspective [10].
2. **Geometric description of time stream anisotropy**: The anisotropy function (2) and time sphere deformation (4) provide a purely geometric account of how motion redistributes event possibilities, without invoking time dilation as a physical process.
3. **Quantum nature of time**: Elementary time impulses suggest discrete time structure at the fundamental level.
4. **Relationality of time**: Time is a relation between observer and environment, not an absolute entity.
5. **Testability**: Concrete, quantitative predictions differing from standard models, with detailed experimental protocols.
6. **Integration with existing theories**: Formal compatibility with GR in the limit $\kappa_i \to 0$, connections with khronon theories and Lorentz symmetry breaking [17].

9.1 Research Perspectives

- **Experimental**: Tests using next-generation optical atomic clocks, particularly searching for the predicted angular dependence $\propto (1 - \beta \cos\theta)^{-2}$ given by (2).
- **Theoretical**: Analysis of quantum consistency, development of formalism for black holes, full derivation of the anisotropy function from first principles (see Appendix).
- **Cosmological**: Inflationary and dark energy models based on τ field dynamics.
- **Fundamental**: Connection with quantum information theory and holographic concepts.

9.2 Final Message

The Multipolar Time Hypothesis represents a bold but mathematically consistent attempt to redefine the nature of time. Even if ultimately not experimentally confirmed, it serves an important heuristic function – forcing reconsideration of basic assumptions about the nature of time and its relationship with space, matter, and the observer.

Definition in one sentence: The time stream is a local, isotropic at rest and anisotropic in motion field of elementary impulses of event possibilities, whose absorption by matter determines the realization of physical processes, while maintaining total time availability.

A Derivation of the Anisotropy Function from Relativistic Aberration and Solid Angle Transformation

Here we present a step-by-step derivation of the anisotropy function $f(\theta, \beta) = 1/[\gamma^2(1 - \beta \cos\theta)^2]$ from first principles.

A.1 Rest Frame Isotropy

In the observer's rest frame O', the time impulse field is isotropic:

$$\frac{dN}{d\tau\, d\Omega'} = \Phi_0 = \text{const.} \tag{A.1}$$

A.2 Angle Transformation (Relativistic Aberration)

For an impulse arriving at angle θ' in O', the angle θ in the laboratory frame O (where the observer moves with velocity $v = \beta c$ along x) is given by:

$$\cos\theta' = \frac{\cos\theta - \beta}{1 - \beta \cos\theta}. \tag{A.2}$$

A.3 Solid Angle Transformation

Differentiating (A.2):

$$\frac{d\cos\theta'}{d\cos\theta} = \frac{1-\beta^2}{(1-\beta\cos\theta)^2} = \frac{1}{\gamma^2(1-\beta\cos\theta)^2}.$$

Since $d\Omega' = \sin\theta'\, d\theta'\, d\phi'$ and $\phi = \phi'$, we obtain:

$$d\Omega' = \frac{d\Omega}{\gamma^2(1-\beta\cos\theta)^2}. \tag{A.3}$$

A.4 Combining Transformations

The number of impulses dN registered in proper time $d\tau$ within solid angle $d\Omega$ is obtained by combining (A.1) and (A.3). Using $dN = \Phi_0\, d\tau\, d\Omega'$:

$$dN = \Phi_0\, d\tau\, \frac{d\Omega}{\gamma^2(1-\beta\cos\theta)^2}. \tag{A.4}$$

Thus, the flux density in the laboratory frame is:

$$\Phi_T(\theta,\phi) = \frac{dN}{d\tau\, d\Omega} = \Phi_0\, \frac{1}{\gamma^2(1-\beta\cos\theta)^2},$$

yielding the anisotropy function:

$$\boxed{f(\theta,\beta) = \frac{1}{\gamma^2(1-\beta\cos\theta)^2}}. \tag{A.5}$$

A.5 Verification of Stream Conservation

Integrating over all solid angles:

$$\oint f(\theta,\beta)\, d\Omega = \int_0^{2\pi}\int_0^{\pi} \frac{\sin\theta}{\gamma^2(1-\beta\cos\theta)^2}\, d\theta\, d\phi = 4\pi, \tag{A.6}$$

independent of β. This rigorously satisfies Axiom 4 and confirms that motion causes no loss of time, only geometric redistribution.

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