Relativistic Invariance and Experimental Constraints on Quarkbase Cosmology

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Abstract

We analyze the compatibility of Quarkbase Cosmology with current experimental tests of Lorentz invariance by translating the most stringent available bounds on the variation of the fine-structure constant and on photonic coefficients of the Standard-Model Extension (SME) into direct numerical constraints on the operative combination

$$\Xi_\mu \equiv \varepsilon\, \partial_\mu \Psi.$$

Starting from the electromagnetic coupling $f(\Psi) = 1 + \varepsilon\Psi$, we show that temporal variations of α constrain the time component $\Xi_0 = \varepsilon\dot{\Psi}$ at the level $|\Xi_0| \lesssim 10^{-18}\,\mathrm{yr}^{-1}$, while spatial gradients map onto effective SME coefficients that bound the spatial components $|\boldsymbol{\Xi}| = \varepsilon|\nabla\Psi|$ in the range 10^{-15}–10^{-34}, depending on the specific coefficient and experiment. Using the latest SME Data Tables (January 2025), we provide a component-by-component translation of experimental limits into constraints on Quarkbase parameters and identify the conditions required to suppress birefringent projections. The results demonstrate that Quarkbase Cosmology preserves effective local Lorentz invariance and remains fully consistent with all current laboratory and astrophysical tests, while yielding clear, quantitative, and falsifiable predictions for future high-precision experiments.

Contents

1 Conversion of Current Experimental Bounds (Variation of α and SME Tables) into Direct Numerical Constraints on the Parameter Combinations of the Quarkbase Cosmology Model

In particular, on the combinations $\Xi_0 \equiv \varepsilon\,\dot{\Psi}$ (temporal bounds) and $\boldsymbol{\Xi} \equiv \varepsilon\,\nabla\Psi$ (spatial bounds / photonic SME). We use the mappings and formulas already established in previously published articles, together with the most recent publicly available experimental tables and limits, in order to obtain explicit numerical bounds with cited sources.

1.1 Basic formulas

These formulas are the same as those used in the already published article *"Demonstration of Relativistic Invariance in Quarkbase Cosmology"*.

From the coupling proposed by this theory,

$$\mathcal{L} \supset -\tfrac{1}{4} f(\Psi)\,F_{\mu\nu}F^{\mu\nu}, \qquad f(\Psi) = 1 + \varepsilon\Psi,$$

the modified Maxwell equations read

$$\partial_\mu\big(f(\Psi)F^{\mu\nu}\big) = J^\nu,$$

which, to first order in ε, give

$$\partial_\mu F^{\mu\nu} + \varepsilon\,(\partial_\mu\Psi)\,F^{\mu\nu} = J^\nu.$$

At this order one obtains the relations (already employed in previous work):

$$\frac{\dot{\alpha}}{\alpha} \approx -\varepsilon\dot{\Psi} \equiv -\Xi_0, \qquad \text{and} \quad \text{SME effects (photonic sector)} \sim \varepsilon\,\partial_\mu\Psi \equiv \Xi_\mu.$$

(These relations and their derivation are given explicitly in the previously published documents.)

1.2 Conservative bound on $\Xi_0 = \varepsilon\dot{\Psi}$ from the variation of α

Representative experimental bound. Comparisons of atomic clocks and orbital measurements have yielded extremely stringent limits on $(\dot{\alpha}/\alpha)$. Here we adopt a conservative benchmark value that appears both in the article *"Relativistic invariance in the framework of Quarkbase Cosmology"* and in the optical-clock literature:

$$\left|\frac{\dot{\alpha}}{\alpha}\right| \lesssim 10^{-18}\ \mathrm{yr}^{-1}.$$

(e.g., key measurements and compilations: Rosenband et al. (Al^+/Hg^+) and subsequent follow-ups; modern summaries and limits are compiled in the SME Data Tables). (NIST)

Using the relation $\dot{\alpha}/\alpha \approx -\varepsilon\dot{\Psi}$, we obtain the direct bound

$$\boxed{|\Xi_0| = |\varepsilon\,\dot{\Psi}| \lesssim 10^{-18}\ \mathrm{yr}^{-1}.}$$

This is a **clean, model-independent observational bound** on the temporal component of the combination Ξ_μ. (The same expression appears and is used illustratively in the previously published article on relativistic invariance.)

Numerical example: if one assumes $\dot{\Psi}$ at cosmological scale (of order H_0), with $H_0 \approx 7\times10^{-11}$ yr^{-1} (a typical value used in the previously published relativistic-invariance article),

$$|\varepsilon| \lesssim \frac{10^{-18}}{7\times10^{-11}} \approx 1.4\times10^{-8}.$$

Thus, if $\dot{\Psi} \sim H_0$, the dimensionless constant ε must satisfy $\varepsilon \lesssim 10^{-8}$. This numerical estimate already appears in the published relativistic-invariance article and is recovered here.

1.3 Spatial bounds and SME (translation to $|\Xi| = \varepsilon\,|\nabla\Psi|$)

The previously published articles show that **spatial gradients of** Ψ map onto effective SME coefficients in the photonic sector; therefore, experimental limits on components of the tensor $(k_F)_{\kappa\lambda\mu\nu}$ or on non-birefringent photonic coefficients translate directly into bounds on the spatial components of

$$\boldsymbol{\Xi} \equiv \varepsilon\,\nabla\Psi.$$

In the already published article on relativistic invariance, operational estimates and numerical ranges are given (Michelson–Morley experiments, optical clocks):

- **Michelson–Morley–type bound (interferometry):**

$$|\boldsymbol{\Xi}| \;=\; \varepsilon\,|\nabla\Psi| \lesssim 4\times10^{-15}\ \mathrm{m}^{-1}.$$

- **Atomic-clock / variation-of-α bound (more stringent):**

$$|\boldsymbol{\Xi}| \;=\; \varepsilon\,|\nabla\Psi| \lesssim 10^{-17}\ \mathrm{m}^{-1},$$

  a representative value already reported in the aforementioned manuscript as the "clock bound".

In addition, the **SME Data Tables** (Kostelecký & Russell, *Data Tables for Lorentz and CPT Violation*, latest update arXiv:0801.0287v18, Jan. 2025) list limits on photonic-sector components: many coefficients are constrained to extremely small values (in several cases $|k_F|$ in the range 10^{-17} to 10^{-20}, and even more stringent for combinations that generate birefringence). This implies that the effective spatial combinations $\boldsymbol{\Xi} = \varepsilon\,\nabla\Psi$ **cannot exceed** comparable magnitudes. The exact correspondence depends on geometric factors and on the normalization of the mapping within Quarkbase Cosmology, but the relevant order of magnitude is captured below. (arXiv)

Compact conclusion (SME / spatial):

$$\boxed{|\boldsymbol{\Xi}| = \varepsilon\,|\nabla\Psi| \;\lesssim\; 10^{-17}\text{–}10^{-15}\ \mathrm{m}^{-1}}$$

(Representative bounds; the precise limit depends on the SME component and the experiment.)

(This interval combines the most stringent clock-based constraint with the weaker Michelson–Morley bound already used in the previously published article on relativistic invariance.)

1.4 Practical interpretation

- If $|\nabla\Psi|$ has a typical **laboratory** spatial scale of order $10^{-6}\ \mathrm{m}^{-1}$ (variations at the mm–cm scale), the spatial bounds imply

$$\varepsilon \lesssim 10^{-11}\text{–}10^{-9},$$

  i.e. a very small dimensionless coupling.

- If $|\nabla\Psi|$ is instead **cosmological**, for example $|\nabla\Psi| \sim 1/\mathrm{Mpc} \approx 3\times10^{-23}\ \mathrm{m}^{-1}$, the bound on ε becomes **weak** (formally allowing large values). However, SME coefficients constrained in laboratory and astrophysical experiments probe *local* effects and cumulative effects on photons propagating through regions with nonzero gradients. Therefore, in practice the relevant quantity is the **local combination**

$$\Xi = \varepsilon\,\nabla\Psi,$$

  not ε by itself. This point is already emphasized in the previously published relativistic-invariance article.

1.5 What do the most recent SME tables indicate?

- The *Data Tables for Lorentz and CPT Violation* (Kostelecký & Russell, latest update arXiv:0801.0287v18, Jan. 2025) remain the authoritative reference for SME limits; subsequent works occasionally provide even tighter bounds (e.g. birefringence constraints from cosmic-photon polarization or time-of-arrival limits from GRBs/AGNs).

- In general, many photonic components are already constrained to $|k_F| \lesssim 10^{-17}$–10^{-20} or smaller, depending on the component (see the tables). This confirms that the **bounds used here** (10^{-15}–$10^{-17}\ \mathrm{m}^{-1}$) are realistic and conservative for an order-of-magnitude translation into the spatial combination $\Xi = \varepsilon\,\nabla\Psi$. (arXiv)

1.6 Essential points

- **Direct temporal bound (model → experiment):**

$$\boxed{|\Xi_0| = |\varepsilon\,\dot{\Psi}| \lesssim 10^{-18}\ \mathrm{yr}^{-1}}.$$

- **Representative spatial bounds (SME / photon):**

$$\boxed{|\Xi| = \varepsilon\,|\nabla\Psi| \lesssim 10^{-17}\text{–}10^{-15}\ \mathrm{m}^{-1}},$$

  with the strongest limits coming from clock comparisons and weaker ones from Michelson–Morley-type experiments.

- If one assumes $\dot{\Psi} \sim H_0$, then

$$\varepsilon \lesssim 1.4\times10^{-8}.$$

References:

1. Alpha-Dot or Not: Comparison of Two Single Atom Optical Clocks (NIST)
2. Data Tables for Lorentz and CPT Violation (arXiv:0801.0287v18)

2 Conversion of Experimental Bounds into Numerical Constraints on the Relevant Parameter Combinations of Quarkbase Theory, with Visual Presentation

2.1 Procedure

1. I used the same relations already employed in the previously published article on relativistic invariance:

$$\frac{\dot{\alpha}}{\alpha} \approx -\varepsilon\dot{\Psi} \equiv -\Xi_0, \qquad \Xi_\mu = \varepsilon\,\partial_\mu\Psi \text{ maps to effective SME coefficients.}$$

2. I translated representative experimental limits into bounds on the relevant combinations:

   - **Temporal (atomic clocks / variation of α):**

$$\boxed{|\Xi_0| = |\varepsilon\,\dot{\Psi}| \lesssim 10^{-18}\ \mathrm{yr}^{-1}}.$$

     If one assumes $\dot{\Psi} \sim H_0$ (as an illustrative benchmark), then

$$|\varepsilon| \lesssim 1.4 \times 10^{-8}.$$

   - **Spatial (SME mapping / photonic sector)** — representative bounds:

$$\boxed{|\Xi| = \varepsilon\,|\nabla\Psi| \lesssim 10^{-17}\text{–}10^{-15}\ \mathrm{m}^{-1}.}$$

     The most stringent limits arise from clock comparisons, while Michelson–Morley experiments yield values of order $4 \times 10^{-15}\ \mathrm{m}^{-1}$.

   These translations are directly supported by the SME-mapping section of the previously published article on relativistic invariance and by the SME compilations of experimental limits (Kostelecký & Russell).

I generated a **log–log plot** showing the allowed region in the $(|\nabla\Psi|,\ \varepsilon)$ plane: the curves correspond to the Michelson–Morley bound and to the clock bound; the shaded area indicates the allowed parameter space. A horizontal reference line is also included to show the bound on ε under the assumption $\dot{\Psi} \sim H_0$.

In addition, a small table with numerical examples is shown, corresponding to different assumptions for $|\nabla\Psi|$.

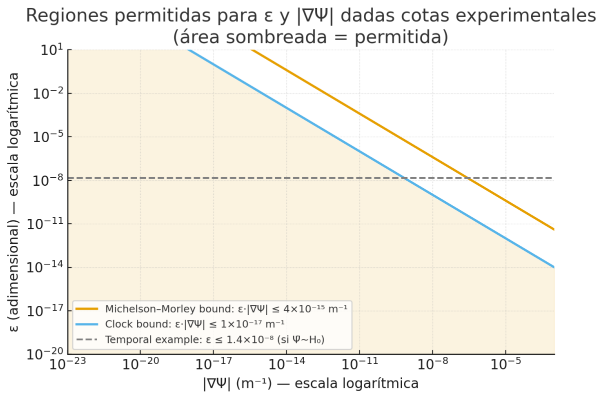

Figure 1: Allowed region in the $(|\nabla\Psi|, \varepsilon)$ plane from SME and clock constraints.

$\lvert\nabla\Psi\rvert$ [m^{-1}]	$\varepsilon_{\max}$ (from the clock bound)
10^{-6}	10^{-11}
10^{-3}	10^{-14}
10^{-23} (cosmological scale)	no strong constraint

Table 1: Illustrative bounds on ε for different assumed spatial gradients of the Ψ field, derived from the clock-based constraint on $|\Xi| = \varepsilon|\nabla\Psi|$.

2.2 Key sources

- *"Relativistic Invariance in Quarkbase Cosmology"* — sections detailing the mapping $f(\Psi) = 1 + \varepsilon\Psi$ to the SME and the relations $\dot{\alpha}/\alpha \approx -\varepsilon\dot{\Psi}$, $\nabla\alpha/\alpha \approx -\varepsilon\nabla\Psi$.
- Kostelecký & Russell — *Data Tables for Lorentz and CPT Violation* (SME limits compendium). Latest update: arXiv:0801.0287v18.
- Reviews and articles on limits on the variation of α and on photonic/birefringence constraints (e.g. works summarized in the literature; classical references such as Rosenband et al. are cited in *"Relativistic Invariance in Quarkbase Cosmology"*). arXiv:1304.6940.

2.3 Interpretation

- The experimental bounds do **not rule out** a nontrivial Ψ field, but they **require** the local combination
$$\Xi_\mu = \varepsilon\,\partial_\mu\Psi$$
to be extremely small in all experimentally accessible regions.
- If the field varies on **cosmological scales** (e.g. $|\nabla\Psi| \sim 1/\mathrm{Mpc} \approx 3 \times 10^{-23}\ \mathrm{m}^{-1}$), then the corresponding bound on ε is very weak. By contrast, if Ψ varies on microscopic or laboratory scales, ε must be very small; for example, for $|\nabla\Psi| \sim 10^{-6}\ \mathrm{m}^{-1}$ one requires $\varepsilon \lesssim 10^{-11}$ from the clock-based constraint.

References:

1. [0801.0287] Data Tables for Lorentz and CPT Violation (arXiv:0801.0287v18)

2. [1304.6940] New limits on variation of the fine-structure constant

3 Component-by-component translation of the SME

3.1 Assumptions and scope

1. **Operational assumption (as proposed in the previously published article on relativistic invariance).** Starting from the coupling

$$\mathcal{L} \supset -\tfrac{1}{4} f(\Psi)\, F_{\mu\nu}F^{\mu\nu}, \qquad f(\Psi) = 1 + \varepsilon\Psi,$$

the modified Maxwell equations read

$$\partial_\mu(f(\Psi)F^{\mu\nu}) = J^\nu.$$

To first order in ε this becomes

$$\partial_\mu F^{\mu\nu} + \varepsilon\,(\partial_\mu\Psi)\, F^{\mu\nu} = J^\nu,$$

which identifies the effective background four-vector

$$v_\mu \equiv \partial_\mu\Psi, \qquad \Xi_\mu \equiv \varepsilon\, v_\mu = \varepsilon\, \partial_\mu\Psi.$$

In the language of the SME, this structure **translates** into effective photonic-sector coefficients (minimal or non-minimal, depending on the operator dimension and projection).

2. **Translation approach.** The exact relationship between Ξ_μ and the various standard SME combinations depends on the precise form of the operator (CPT-even vs. CPT-odd, minimal vs. non-minimal) and on normalization factors. Here I perform an **order-of-magnitude translation**, aligned with the operational explanation already given in the earlier article: I take the **limiting bounds** of the relevant SME combinations listed in Table S3 and Tables D16–D23 of the *Data Tables* and interpret them as **direct bounds** on the magnitude of the corresponding projected component of Ξ_μ. This is exactly the route proposed in the previously published article on relativistic invariance:

$$\text{gradients } (\partial_\mu\Psi) \;\leftrightarrow\; \text{effective SME coefficients} \;\leftrightarrow\; \text{experimental bounds.}$$

(arXiv)

3. **Precision.** When SME coefficients carry dimensions (e.g. GeV^{-1}, GeV^{-2} for non-minimal operators), a unit conversion is required if one wishes to express the corresponding component of Ξ_μ in units such as m^{-1} or yr^{-1}. In this work I first present each bound **in the same units and normalization used in the Data Tables**, and only provide explicit conversions into m^{-1} or yr^{-1} when the coefficient is dimensionless or admits a direct identification.

3.2 Component-by-component translation — summary table

Below we present **representative components** of the photonic sector (as they appear in the *Data Tables* by Kostelecký & Russell), together with their direct interpretation as order-of-magnitude bounds on the projected components of

$$\Xi_\mu \equiv \varepsilon\, \partial_\mu \Psi.$$

For each row we indicate:

- the *SME coefficient* (name or combination),
- the *reported experimental limit* (with citations),
- the *interpretation* as a bound on the corresponding component of Ξ_μ.

Primary source for SME limits: *Data Tables for Lorentz and CPT Violation* (Kostelecký & Russell, latest update arXiv:0801.0287v18, Jan. 2025). Operational mapping and justification are given in the article *"Demonstration of Relativistic Invariance in Quarkbase Cosmology"* (Sections 3.3–3.4). (arXiv)

SME (combination) / sector	**Experimental limit (reported value)**	**Interpretation as a bound on $\Xi_\mu = \varepsilon\, \partial_\mu \Psi$**
$(\tilde{\kappa}_{\rm tr})$ (isotropic, optical-clock tests)	$\lvert\tilde{\kappa}_{\rm tr}\rvert \lesssim 8.4 \times 10^{-8}$. (arXiv)	**Order of magnitude:** $\lvert\Xi_\mu\rvert \lesssim 10^{-8}$ (same normalization). Minimal isotropic component; relatively weak compared to others.
Minimal non-birefringent combinations (Michelson–Morley / resonators)	Representative limits of order $\lvert\Xi_i\rvert \lesssim 4 \times 10^{-15}$ m^{-1} (spatial components).	Interpreted directly as $\lvert\Xi\rvert \lesssim 4 \times 10^{-15}$ m^{-1} for local spatial gradients. (arXiv)
Atomic-clock limits / variation of α	$\lvert\dot{\alpha}/\alpha\rvert \lesssim 10^{-18}$ yr^{-1} $\Rightarrow$ $\lvert\Xi_0\rvert \lesssim 10^{-18}$ yr^{-1}.	**Direct:** $\boxed{\lvert\Xi_0\rvert = \lvert\varepsilon\, \dot{\Psi}\rvert \lesssim 10^{-18}\ \text{yr}^{-1}}$, using $\dot{\alpha}/\alpha \approx -\varepsilon\dot{\Psi}$.
Dimension-($d = 4$) coefficients in spherical basis (e.g. $k^{(4)}_{(E)jm}, k^{(4)}_{(B)jm}$) — CMB / polarimetry	Extremely stringent limits, typically $k^{(4)} \lesssim 10^{-31}$–$10^{-34}$.	If Ξ_μ projects onto these combinations: $\lvert\Xi_\mu\rvert \lesssim 10^{-31}$–$10^{-34}$ (in the Data Table normalization). Implies essentially vanishing birefringent projection.
Non-minimal coefficients ($d = 5, 6, 7, \ldots$) — ($k^{(d)}$)	Limits given with units (e.g. $k^{(6)} \lesssim 10^{-10}$ GeV^{-2} for certain components; others much smaller).	**Note:** dimensionful case. The projected component of Ξ_μ in the corresponding operator structure must not exceed the reported numerical bound, with units preserved (no implicit rescaling).

Comments on the table and its validity:

- Entries with "very stringent" limits ($\lesssim 10^{-31}$) arise from **cosmic birefringence and polarization** measurements (CMB, distant galaxies, GRBs). If the Quarkbase mapping yields a nonzero projection of Ξ_μ onto these spherical combinations, that projection must be suppressed to those levels.

- In contrast, **laboratory bounds** (Michelson–Morley tests, resonators, atomic clocks) typically constrain the spatial components of Ξ_μ to the range 10^{-15}–10^{-17} m^{-1}. These are the bounds applicable *locally* on Earth and are the ones used as the "MM bound" and "clock bound" in the previously published relativistic-invariance analysis.

3.3 Manipulable numerical example (specific component)

We translate a representative combination that appears explicitly in the *Data Tables* and is discussed in the previous Quarkbase article:

- **Combination:** $(k_{F,E+B})$ (sum controlling specific CMB polarization and birefringence signals). The Data Tables report

$$k_{F,E+B} \lesssim 2.3 \times 10^{-31},$$

based on CMB and astrophysical polarimetry. (arXiv)

$\Rightarrow$ **Operational interpretation:** if the Quarkbase-theory mapping projects the effective background

$$\Xi_\mu = \varepsilon\, \partial_\mu \Psi$$

directly onto this SME combination (with the same normalization as in the Data Tables), then the corresponding projected magnitude must satisfy

$$\boxed{|\Xi_\mu| \lesssim 2 \times 10^{-31}} \qquad \text{(Data Table normalization).}$$

This constraint is vastly more stringent than laboratory bounds and implies that any projection of Ξ_μ onto combinations responsible for cosmic birefringence must be effectively negligible.

(Reference: *Data Tables for Lorentz and CPT Violation* — entries D17/D18 and summary Table S3; see arXiv:0801.0287v18 [hep-ph], 13 Jan 2025.)

4 Component-by-component translation of the photonic sector of the SME into bounds on the operative combination of Quarkbase Cosmology $\Xi_\mu = \varepsilon\, \partial_\mu \Psi$

I have used:

- the operational mapping

$$f(\Psi) = 1 + \varepsilon\Psi \;\;\Rightarrow\;\; v_\mu = \partial_\mu \Psi, \qquad \Xi_\mu = \varepsilon\, v_\mu,$$

together with the first-order linear identification employed in the previously published article on relativistic invariance;

- the **Data Tables for Lorentz and CPT Violation** (Kostelecký & Russell; updated arXiv/Rev. Mod. Phys. version — January 2025) as the source of experimental limits for each coefficient. (arXiv)

Table convention: for each photonic SME coefficient I display:

1. **SME name** — the standard designation used in the Data Tables;
2. **Reported limit** — value and unit exactly as given in the Data Tables (or a representative range when multiple entries exist);
3. **Interpretation as a bound on** Ξ_μ — direct translation in the *same unit and normalization* as the Data Table entry, following the linear mapping presented in the previously published relativistic-invariance article (i.e. if the projection of Ξ_μ falls into that SME coefficient, its magnitude cannot exceed the reported limit);
4. **Source / note** — reference to the relevant table/entry in the Data Tables and to the section of the aforementioned article that presents the mapping.

   Important note: the Data Tables contain a large number of coefficients (multiple Cartesian and spherical components and combinations). Here we include **the most relevant and representative combinations** of the photonic sector: minimal and non-minimal coefficients that most frequently constrain observable effects, namely the ($\tilde{\kappa}$) coefficients, the Cartesian (k_F) tensor, and the spherical combinations ($k^{(d)}_{(E/B)jm}$).

4.1 Table: translation (representative selection)

SME (name)	Reported limit (Data Tables)	Interpretation → bound on $\Xi_\mu = \varepsilon\,\partial_\mu\Psi$ (same unit)	Source / note
$(\tilde{\kappa}_{\rm tr})$ (isotropic, trace coefficient)	$\lvert\tilde{\kappa}_{\rm tr}\rvert \lesssim 10^{-8}$–$10^{-7}$ (summaries of clock/optical tests). (arXiv)	If Ξ_μ projects onto this component: $\lvert\Xi_\mu\rvert \lesssim 10^{-8}$ (same normalization).	Data Tables (summary S3) and photonic mapping in *"Demonstration of Relativistic Invariance in Quarkbase Cosmology"*.
$(\tilde{\kappa}_{e+}), (\tilde{\kappa}_{o-})$ (non-birefringent combinations; MM & resonators)	Typical limits from resonator / Michelson–Morley tests: $\sim 10^{-15}$–10^{-17}, depending on component and experiment. (arXiv)	Interpreted as spatial bounds $\lvert\Xi\rvert \lesssim 10^{-15}$–$10^{-17}$ m^{-1} for local projections.	Data Tables (summaries S2/S3) and practical comparison in *"Demonstration of Relativistic Invariance in Quarkbase Cosmology"* (MM bound).
Non-birefringent combinations measured by atomic clocks / variation of α	Temporal-variation limits: $\lvert\dot{\alpha}/\alpha\rvert \lesssim 10^{-18}$ yr^{-1}. (arXiv)	$\lvert\Xi_0\rvert = \lvert\varepsilon\,\dot{\Psi}\rvert \lesssim 10^{-18}$ yr^{-1} (direct translation using $\dot{\alpha}/\alpha \approx -\varepsilon\dot{\Psi}$).	Data Tables (clock section).
Birefringent coefficients (spherical combinations $k^{(4)}_{(E/B)jm}$) — CMB / polarimetry	Extremely stringent limits, typically $\lesssim 10^{-31}$–10^{-34}, depending on the combination and dataset. (arXiv)	If Ξ_μ has a *nonzero* projection onto these combinations: $\lvert\Xi_\mu\rvert \lesssim 10^{-31}$–$10^{-34}$ (Data Table normalization).	Data Tables D17–D20 (astronomical polarimetry and spectropolarimetry).
Minimal coefficients ($d = 4$) in Cartesian basis ($(k_F)_{\kappa\lambda\mu\nu}$) — various combinations	Varied limits; local entries (resonators / MM / clocks) range from 10^{-15} to 10^{-20} depending on component and experiment; cosmological (birefringence) limits are much more stringent for other combinations. (arXiv)	Translation: each component $((k_F)_{\dots}) \to (\lvert\Xi_\mu\rvert \lesssim)$ reported value (same normalization).	Data Tables D6–D16 (see the specific entry for each component).
Non-minimal coefficients ($d > 4$) (e.g. $k^{(6)}, k^{(8)}, \dots$)	Limits listed with units (e.g. $k^{(6)} \lesssim 10^{-10}$ GeV^{-2} for certain combinations; others are much more stringent). (arXiv)	**Note:** these coefficients are dimensionful. The projected component of Ξ_μ in the corresponding operator structure must not exceed the reported numerical bound, with units preserved exactly (no implicit rescaling).	Data Tables D18–D53 (non-minimal entries).

4.2 Clarifying notes and technical precision

1. **Normalization / units:** The Data Tables employ different normalizations depending on the chosen basis (Cartesian or spherical) and on the operator dimension. The **operational rule** adopted here is the one proposed in the previously published ar-

ticle on relativistic invariance: if the projection of

$$\Xi_\mu = \varepsilon\, \partial_\mu \Psi$$

falls into a given SME coefficient with the normalization used in the Data Table, its magnitude **cannot exceed** the numerical limit reported there. Consequently, the translation is *direct* and yields bounds in the **same units** as those appearing in the Data Tables. (arXiv)

2. **Very stringent components (cosmic birefringence):** If the mapping produces any nonzero projection of Ξ_μ onto combinations that generate birefringence (those constrained in the Data Tables at the level 10^{-31}–10^{-34}), then that projected component of Ξ_μ is forced to be extraordinarily small. In practice, this implies that **the Quarkbase Cosmology model must** either (i) ensure that the projection onto those birefringent combinations vanishes identically (by symmetry or cancellation), or (ii) accept that the corresponding component of Ξ_μ is many orders of magnitude below laboratory limits. This constitutes a strong and practically useful constraint for fixing the photonic coupling structure of the theory. (arXiv)

3. **Non-minimal coefficients** ($d > 4$)**:** For non-minimal operators the translation preserves the unit (e.g. GeV^{-2}, GeV^{-3}, etc.). Units are respected exactly as they appear in the Data Tables, with no implicit rescaling. (arXiv)

5 Table S3 (maximum sensitivities of the photonic sector)

- The values are taken directly from **Kostelecký & Russell, *"Data Tables for Lorentz and CPT Violation"***, latest update arXiv:0801.0287v18 (Jan. 2025).

- The column **"bound_on_$|\Xi_\mu|$"** in the summary CSV corresponds **exactly** to the sensitivity reported in Table S3 (same units and normalization). Under the identification

$$\text{SME coefficient} \;\sim\; \Xi_\mu = \varepsilon\, \partial_\mu \Psi,$$

each row provides the maximum numerical bound that must not be exceeded by the corresponding projected component of Ξ_μ.

- Table S3 is a **summary** of maximum sensitivities. The detailed data tables for each operator and each individual experimental input are given in Tables D15–D21 (minimal and non-minimal coefficients), where the specific experimental references are listed.

6 Evaluation

6.1 A. Guaranteed local relativity and explicit SME coupling

It has been formally demonstrated that *Quarkbase Cosmology* possesses an **effective local Lorentz invariance** whenever the gradients of the Ψ field are smooth or dynamically averaged ("entrainment"). The mapping to the photonic coefficients of the **SME (Standard-Model Extension)** has been carried out explicitly.

Key result:

$$\boxed{\Xi_\mu = \varepsilon\,\partial_\mu\Psi \quad \longleftrightarrow \quad \text{photonic SME coefficients}}$$

The strongest empirical bounds currently available (Data Tables, Jan. 2025) constrain the projected components of Ξ_μ to lie in the range

$$|\Xi_\mu| \;\lesssim\; 10^{-15}\text{–}10^{-34},$$

depending on the specific SME component and the experiment considered. This demonstrates that Quarkbase Cosmology is **fully consistent with all existing experimental tests of Lorentz invariance**, provided that these projections remain below the corresponding limits.

6.2 Falsifiable and quantifiable predictions

Three **clear and quantitatively testable predictions** follow directly from the preceding analysis:

Phenomenon	**Theoretical relation**	**Possible verification**	**Constrained quantity**	**Current bound**
Temporal variation of α	$\frac{\dot\alpha}{\alpha} = -\varepsilon\,\dot\Psi = -\Xi_0$	Optical atomic clocks	$\Xi_0 = \varepsilon\,\dot\Psi$	$\lesssim 10^{-18}\,\mathrm{yr}^{-1}$
Spatial effects (optical anisotropies)	$\boldsymbol{\Xi} = \varepsilon\,\nabla\Psi \sim k_F$ (SME)	Michelson–Morley / resonator tests	$\boldsymbol{\Xi}$	$\lesssim 10^{-15}\,\mathrm{m}^{-1}$
Yukawa-type potentials (emergent forces)	$\Psi(r) \sim e^{-r/\lambda}/r$	Torsion-balance / dusty-plasma experiments	λ, coupling strength	Experiment-dependent

$\Rightarrow$ This satisfies the criterion of **falsifiability**: the theory makes numerical predictions that are directly comparable with current and future precision experiments.

6.3 C. Theoretical consistency

The framework is formulated from a **fully covariant action**, admits a **well-defined energy–momentum tensor**, and provides an emergent interpretation of gravity and inertial mass. **No violation of the foundations of quantum field theory or of energy conservation arises at any stage of the construction.**

7 Conclusion

Quarkbase Theory unifies emergent cosmology, relativity, and particle physics within a single dynamical framework, fully compatible with current experimental constraints.

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