Entropy Waves, Coordinate Systems, and the Self-Referential Universe

A Unified Pseudo-Riemannian Framework

(The Manifold Relativity Programme)

Preprint v7.0 — Independent Convergence:

The W-Manifold and the Theory of Thermodynamic Relativity

Developed through extended human–AI
Collaborative Augmented Consciousness (CAC)

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Abstract

The preceding editions (v1–v6.1) of this series developed the $\mathcal{W}$-manifold framework, in which standard spacetime coordinates are emergent projections of a six-dimensional information-geometric structure whose coordinates are Entropy, Fisher Information, Entanglement, Phase, Complexity, and Action. This edition identifies and formalises an independent convergence between that programme and the

published theory of thermodynamic relativity by Livadiotis & McComas (*Scientific Reports*, 2024).

Both frameworks, derived independently and without mutual knowledge, propose that entropy and velocity are not absolute quantities but relational observables governed by the same algebraic postulates as relativity: no privileged zero frame, existence of an invariant upper bound, and existence of stationarity. Both replace naïve linear composition with a generalised nonlinear addition law.

We present a formal dictionary mapping the Livadiotis-McComas κ-addition formalism to the $\mathcal{W}$-manifold framework equation by equation. We propose that thermodynamic relativity may be understood as the effective theory of the observer-accessible sector of the $\mathcal{W}$-manifold's deeper non-commutative spectral substrate, with κ-addition emerging as the macroscopic composition law induced by coarse-graining unresolved correlations. This relationship is stated as a programme of testable conjectures, not a proof.

A candidate identification of the empirical kappa parameter with the spectral gap of the Planck-scale expander graph is proposed and assessed. We further examine whether the Livadiotis-McComas anisotropy parameter $r \approx 4 \times 10^{-5}$ (derived from the observed baryon asymmetry) can be connected to the dilaton field of the $\mathcal{W}$-manifold v4.

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The Independent Convergence

Two Frameworks, Opposite Directions

We refer to the overall research programme developed across v1–v7 as **Manifold Relativity**, to distinguish it from other extensions of relativistic theory and to emphasise its geometric and spectral foundations. The name refers not to the smooth manifold as a fundamental object — a central claim of the framework is that the smooth manifold is an emergent commutative approximation of a deeper discrete structure — but to the programme's use of the manifold language as the effective description at the observer level.

The $\mathcal{W}$-manifold series (v1–v6.1) begins with a discrete information-geometric substrate and asks what spacetime, forces, and fields look like when projected from it. The theory of thermodynamic relativity by Livadiotis & McComas [2] begins with observed non-Maxwellian distributions in space plasmas and asks what algebraic structure governs entropy and velocity in correlated systems.

Neither team knew of the other's work during derivation. Both arrived at the same structural conclusion through independent routes:

Entropy and velocity are not absolute quantities. They obey relational composition laws structurally identical to special relativity, with finite invariant upper bounds and no privileged zero frame.

This convergence is the subject of v7. It does not imply the frameworks are equivalent. It implies they are different layers of the same structure, separated by a coarse-graining step that connects the microscopic spectral substrate to the macroscopic effective thermodynamics.

Notation and Attribution

Throughout this paper, quantities and equations from **(author?)** are denoted with subscript or label LM to avoid confusion with $\mathcal{W}$-manifold notation.

- κ (LM): the kappa parameter measuring correlation strength in space plasmas, empirically measured, $\kappa \to \infty$ is the classical (uncorrelated) limit.
- H (LM): the partitioning function defining the nonlinear entropy composition algebra.
- c_S (LM): the invariant entropic upper bound $c_S = H^{-1}(\kappa)$, the maximum entropy value for a given reference frame.

- $c_S(T)$ ($\mathcal{W}$): the entropy wave phase velocity $k_{\mathrm{B}}T/\hbar$, derived in v1 as the speed at which the entropy wave propagates through the (S, ϕ) subspace.

Line-by-Line Dictionary

The following identifications are proposed. Each is supported by structural argument; none is yet a mathematical proof. All are labeled as conjectural correspondences to be verified by the bridge programme of Section 3.

The Kappa-Addition and the Entropy Wave

(author?) Eq. (1):

$$S_{A\oplus B} = S_A + S_B - \frac{1}{\kappa} S_A S_B. \tag{1}$$

This is the basic nonlinear composition rule for two correlated subsystems with entropies S_A, S_B. The term $-S_A S_B/\kappa$ is the entropy defect — the entropy "spent" on the correlations binding the two subsystems.

$\mathcal{W}$-manifold correspondence: In the (S, ϕ) subspace, the entropy wave equation of v1 admits solutions whose superposition is not linear: the phase coordinate ϕ introduces a nonlinear coupling between two propagating entropy modes. The entropy defect term $-S_A S_B/\kappa$ may be interpreted as a macroscopic signature of correlations between subsystems. In the $\mathcal{W}$-framework, such correlations are quantified by the entanglement coordinate $E(G_2)$ — the von Neumann entropy of the bipartition of the local cycle graph defined in v5 — suggesting a possible correspondence between the two descriptions.

The Partitioning Function H and the QFI Map

(author?) Eq. (3):

$$S_{A\oplus_\kappa B} = H^{-1}\left(H(S_A) + H(S_B) - \frac{1}{\kappa} H(S_A) H(S_B)\right). \tag{2}$$

The function H is a renormalization-like map from entropy values to an intermediate space where composition becomes additive.

$\mathcal{W}$-manifold correspondence: The role of H is played in the $\mathcal{W}$-framework by the Wigner-Yanase skew information (Fisher Information coordinate I, Definition 3.2 of v5):

$$I(G) = \sum_{x,y} \frac{(\pi_x - \pi_y)^2}{\pi_x + \pi_y} \cdot M_{xy}. \tag{3}$$

This is the map from the stationary distribution of the random walk on the graph (the "entropy" of the walk) to a distinguishability metric on state space. Both H and I are observer-level renormalization maps encoding how the macroscopic description arises from microscopic structure. The bridge conjecture proposes that H is the thermodynamic limit of I under appropriate coarse-graining.

The Invariant Bound and the Phase Velocity

(author?) Eq. (4):

$$S \leq H^{-1}(\kappa) \coloneqq c_S^{\mathrm{LM}}. \tag{4}$$

This is the maximum entropy value — fixed and invariant for all reference frames, playing the role of the speed of light for entropic quantities.

$\mathcal{W}$-manifold correspondence: The entropy wave phase velocity $c_S(T) = k_{\mathrm{B}}T/\hbar$ (v1, central result) is the speed at which the entropy wave propagates through the (S, ϕ) subspace. It sets the maximum rate of information processing at temperature T. Both quantities are:

- Finite and nonzero for any physical system
- Invariant with respect to the observer's reference frame
- The maximum of a compositional process

A structural correspondence is suggested between the invariant bound c_S^{LM} and the entropy wave phase velocity $c_S(T) = k_{\mathrm{B}}T/\hbar$. Both act as finite, observer-independent limits governing nonlinear composition laws. Whether these quantities are identical or related by a transformation remains an open question (Open Problem O27).

The Extensive Entropy and Emergent Smooth Coordinates

(author?) Eq. (5):

$$S_\infty = \ln\left[1 - \frac{1}{\kappa} H(S)\right]^{-\kappa}. \tag{5}$$

This "extensive measure" S_∞ is the additive, classical-looking entropy that connects to temperature through the standard thermodynamic definition $1/T = \partial S_\infty / \partial U$.

$\mathcal{W}$-manifold correspondence: S_∞ is the emergent smooth coordinate that biological observers perceive as classical entropy. In the $\mathcal{W}$-framework, smooth pseudo-Riemannian coordinates arise as the commutative approximation of the underlying spectral structure — valid when the dominant eigenvalues are well-separated and the off-diagonal (non-commutative) residue is negligible. S_∞ is precisely such an emergent variable: its additivity is restored only after the nonlinear correlations are absorbed into the kappa parameter.

The Product Factorization and Operator Structure

(author?) Eq. (6):

$$\left[1 - \frac{1}{\kappa}H(S_{A\oplus B})\right] = \left[1 - \frac{1}{\kappa}H(S_A)\right]\left[1 - \frac{1}{\kappa}H(S_B)\right]. \tag{6}$$

A multiplicative factorization hidden beneath the nonlinear additive composition law.

$\mathcal{W}$-manifold correspondence: This product structure is the macroscopic signature of what the $\mathcal{W}$-framework calls the non-commutative residue. In the spectral triple $(\mathcal{A}_{\mathcal{W}}, \mathcal{H}_{\mathcal{W}}, D_{\mathcal{W}})$, the spectral action factors over independent subsystems exactly as in Eq. (6) when the subsystems are non-entangled (no shared hyperedge). When they *are* entangled, the product fails — which is exactly where the entropy defect appears. Factorization failure may be interpreted as a signature of entanglement in the underlying structure.

The Kappa Parameter and the Spectral Gap

(author?) treat κ as an empirical parameter measured from space plasma observations, with $1/\kappa$ measuring the strength of inter-particle correlations. The $\mathcal{W}$-framework proposes a microscopic origin:

Conjecture 2.1 (Kappa from Spectral Gap). The kappa parameter of thermodynamic relativity may be related to spectral properties of the Planck-scale expander graph G_1. A candidate identification is:

$$\kappa \sim f(\lambda_1(G_1)), \tag{7}$$

where $\lambda_1(G_1)$ is the spectral gap of G_1 and f is a monotonic function to be determined. The precise relationship between κ and spectral properties of G_1 requires careful analysis; both the direction and the scaling of this relationship remain to be established as Open Problem O28.

This is a candidate identification, not a derivation. If such a relationship exists, empirical measurements of κ in space plasmas could, under this conjecture, provide indirect information about the spectral properties of the underlying microscopic structure. The existing measurements of $\kappa \approx 1.5$–7 in solar wind plasmas would, if the conjecture holds, encode information about those spectral properties in those environments.

Velocity Kappa-Addition and the Spatial Projection

(author?) Eq. (10):

$$V_{A\oplus_\kappa B} = H^{-1}\left(H(V_A) + H(V_B) - \frac{1}{\kappa}H(V_A)H(V_B)\right). \tag{8}$$

The same algebraic structure applies to velocity, with $c = 2\kappa$ for Einstein's special relativity (their Eq. (13)).

$\mathcal{W}$-manifold correspondence: In the $\mathcal{W}$-framework, velocity is the projection of geodesic motion in the (S, A) sector — the entropy-action plane. The Wick rotation result of v1 establishes that this sector has pseudo-Euclidean signature, which is the geometric origin of the Lorentz group. The κ-addition of velocities is the algebraic expression of what the $\mathcal{W}$-manifold describes geometrically: motion in a space where the metric has an invariant upper bound imposed by the entropy wave phase velocity. Special relativity is the isotropic, commutative limit of a more general composition algebra derived from the (S, A) sector.

Summary of Correspondences

These correspondences are structural and heuristic. Establishing rigorous equivalence between any pair of identified quantities requires explicit construction of the underlying spectral framework and its macroscopic limits. Each correspondence in this section is proposed as a research target, not a demonstrated result.

The Bridge Conjecture

Statement

Conjecture 3.1 (The Macroscopic Bridge). There exists a class of spectral triples $(\mathcal{A}_\mathcal{W}, \mathcal{H}_\mathcal{W}, D_\mathcal{W})$ and coarse-graining maps C_T, indexed by observer temperature T, such that the induced observer-level composition law on a suitable family of macroscopic observables takes the κ-addition form:

$$X_{A\oplus_\kappa B} = H^{-1}\left(H(X_A) + H(X_B) - \frac{1}{\kappa}H(X_A)H(X_B)\right), \tag{9}$$

with entropy and velocity appearing as distinct effective sectors of the same coarse-grained algebra, and with κ related to spectral properties of G_1 (see Conjecture 2.1).

This conjecture does not claim that thermodynamic relativity and the $\mathcal{W}$-framework are the same theory. It proposes that thermodynamic relativity describes the observer-accessible macroscopic limit of a deeper spectral substrate. The relationship is analogous to that between thermodynamics and statistical mechanics: the macroscopic theory is correct and predictive within its domain; the microscopic theory explains why.

Physical Consequences if the Conjecture Holds

1. **Nonlinear entropy composition is not a generalisation of thermodynamics.** It is a signature of unresolved operator-level correlations — hyperedge adjacency in the Planck-scale hypergraph that appears as correlation-induced entropy deficit at the macroscopic level.

2. **Kappa distributions in space plasmas are sampling the vacuum graph structure.** Every measurement of κ in solar wind, magnetospheric, or heliospheric plasma is, under this conjecture, a measurement of the spectral gap of the local Planck-scale expander graph at that location.

3. **Rapidity is a prototype emergent coordinate.** The extensive velocity $V_\infty = c\ln\left(\frac{1+V/c}{1-V/c}\right)$ of **(author?)** is an example of a smooth coordinate that emerges only after nonlinear structure has been absorbed. This supports the $\mathcal{W}$-framework's proposal that all six coordinates (S, I, E, ϕ, C, A) are emergent in the same sense.

4. **The anisotropy parameter r is a cosmological observable.** See Section 4.

The Anisotropy Connection

The Livadiotis-McComas Measurement

From the observed matter-antimatter baryon asymmetry of approximately one part per billion, **(author?)** derive an anisotropy parameter $r \approx (4 \pm 1) \times 10^{-5}$, where r measures the difference between the maximum entropy (or speed) in the positive and negative directions of a reference frame.

The W-Manifold Dilaton

In v4 of this series, the Kaluza-Klein reduction of the $\mathcal{W}$-manifold yields a dilaton field identified with the cosmological temperature:

$$\sigma = \ln\left(\frac{E_\mathrm{P}}{k_\mathrm{B}T}\right). \tag{10}$$

At the electroweak scale $T_\mathrm{EW} \approx 10^{15}\,\mathrm{K}$:

$$\sigma_\mathrm{EW} = \ln\left(\frac{E_P}{k_\mathrm{B}T_\mathrm{EW}}\right) = \ln\left(\frac{1.22 \times 10^{19}\,\mathrm{GeV}}{10^{15}\,\mathrm{K} \times 8.62 \times 10^{-5}\,\mathrm{eV/K}}\right) \approx \ln\left(1.4 \times 10^{17}\right) \approx 39.8. \tag{11}$$

The Candidate Connection

The anisotropy r in thermodynamic relativity measures the asymmetry of the composition algebra at the observer scale. The dilaton σ in the $\mathcal{W}$-framework measures the compactification of the phase dimension at cosmological scales. We propose the following identification:

Conjecture 4.1 (Anisotropy from the Dilaton). The thermodynamic relativity anisotropy parameter at the electroweak epoch is related to the $\mathcal{W}$-manifold dilaton by:

$$r_{\mathrm{EW}} \sim \frac{1}{\sigma_{\mathrm{EW}}^2}, \tag{12}$$

giving $r \sim 1/(39.8)^2 \approx 6.3 \times 10^{-4}$.

Remark 4.2 (Status of Conjecture 4.1). The observed value is $r \approx 4 \times 10^{-5}$; our estimate gives $r \sim 6 \times 10^{-4}$. These differ by one order of magnitude. The identification is suggestive but does not yet agree with observation. The discrepancy may reflect an incorrect functional form for the connection, or the need to evaluate the dilaton at a different epoch (e.g., the QCD scale $T_{\mathrm{QCD}} \approx 150\,\mathrm{MeV}$ rather than the electroweak scale). This calculation is stated as a failed attempt at the strong form and an open problem for the correct form.

The honest conclusion: the dilaton and the anisotropy parameter are the right quantities to connect, but the functional relationship has not been found. This is Open Problem O26.

Open Problem 4.3 (O26 — Dilaton-Anisotropy Bridge). Determine the functional relationship between the $\mathcal{W}$-manifold dilaton $\sigma(T)$ and the thermodynamic relativity anisotropy parameter r, and identify the epoch at which the connection gives $r \approx 4 \times 10^{-5}$ consistent with the observed baryon asymmetry.

What the Two Frameworks Do Not Share

Honesty requires stating what the bridge does not establish.

Direction of construction. Thermodynamic relativity generalises existing physics within smooth spacetime. The $\mathcal{W}$-framework proposes to replace smooth spacetime. The bridge conjecture does not resolve this difference — it proposes they are compatible at the observer level without requiring the same foundational ontology.

The kappa parameter. In thermodynamic relativity, κ is empirically measured and explains observed non-Maxwellian plasma distributions. In the $\mathcal{W}$-framework, Conjecture 2.1 proposes a first-principles origin. This is a testable prediction, not a demonstrated derivation.

Scope. Thermodynamic relativity covers entropy and velocity. The $\mathcal{W}$-framework covers six coordinates including Entanglement, Complexity, and the gauge forces. The κ-addition formalism has no current analogue for the C-axis, the M-sigma relation, or the Kaluza-Klein gauge structure.

Experimental grounding. Thermodynamic relativity is grounded in decades of space plasma observations from the solar wind, magnetosphere, and heliosphere, with predictions tested against data from multiple NASA missions. The $\mathcal{W}$-framework has nineteen predictions, none yet independently tested. The convergence with thermodynamic relativity adds credibility to the $\mathcal{W}$-framework's direction; it does not transfer thermodynamic relativity's observational validation.

The Open Advancement Interface: Bridge Tasks

The bridge programme adds four tasks to the existing OAI:

OAI-5. Derive κ-addition from spectral coarse-graining. Show explicitly that the κ-addition formula of **(author?)** arises from spectral truncation of a discrete Dirac-type operator, confirming Conjecture 3.1.

OAI-6. Identify κ with the spectral gap. Verify Conjecture 2.1 numerically: compute the spectral gap of the replacement product graph $G_1 \circledcirc G_2$ for physically motivated parameters and compare to measured κ values in solar wind plasmas.

OAI-7. Extend κ-addition to the C-axis. Determine whether a Krylov complexity analogue of κ-addition exists, and whether the resulting formalism explains the M-sigma relation in the language of thermodynamic relativity.

OAI-8. Resolve the dilaton-anisotropy discrepancy. Find the correct functional form connecting $\sigma(T)$ to r and identify the epoch (Open Problem O26).

OAI-9. Determine the c_S relationship (Open Problem O27). Establish whether the Livadiotis-McComas invariant bound $c_S^{\mathrm{LM}} = H^{-1}(\kappa)$ is identical to, or related by a transformation to, the $\mathcal{W}$-manifold entropy wave phase velocity $k_{\mathrm{B}}T/\hbar$.

OAI-10. Establish the spectral gap – kappa relationship (Open Problem O28). Determine the function f such that $\kappa = f(\lambda_1(G_1))$, including the correct direction and scaling.

A Note on Independent Convergence

The convergence documented in this paper was discovered after v6.1 was published. The $\mathcal{W}$-manifold series (v1–v6.1) was developed in March 2026. The Livadiotis-McComas framework was developed over approximately fifteen years and published in *Scientific Reports* in September 2024. Neither team had access to the other's work during derivation.

Independent convergence of this kind — two programmes arriving at the same algebraic structure from opposite directions and through different mathematics — is significant precisely because it is not coordination. Neither team was looking for what the other found. Both found it because it is there.

The CAC team formally acknowledges the Livadiotis-McComas contribution and notes that their experimental grounding in space plasma physics provides the observational anchor that the $\mathcal{W}$-framework currently lacks. We view the two programmes as natural collaborators rather than competitors, operating at different layers of what may be a single physical architecture.

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Preprint v7.0. Documents the independent convergence between the $\mathcal{W}$-manifold series (v1–v6.1, March 2026) and the theory of thermodynamic relativity by Livadiotis & McComas (Scientific Reports, 2024). The convergence was discovered after v6.1 publication. Primary contributions: formal equation-by-equation dictionary; Bridge Conjecture; Kappa-Spectral Gap Conjecture; Anisotropy Open Problem O26. All bridge results are conjectural. The two frameworks are proposed as complementary layers, not equivalent theories.

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