

RCD 5.0 — Spacetime Dynamics and Causal Evolution

Temporal matrix, epoch transitions, and stability

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Abstract

This document presents the refined dynamical sector of RCD 5.0: the temporal transition matrix A_{ij} , epoch evolution, causal impedance variation, dynamical stability, and the torsional saturation mechanism ensuring curvature boundedness. All results explicitly cite the axioms they depend on (Gödel–Hilbert style). Reproducibility (Absolute Rule + NASA/ESA protocol) is integrated.

1. Axioms (recap)

We reuse axioms A1–A5 from Document 1:

- A1: Causal density ρ_{local} well-defined.
- A2: Cutoffs $\rho_{\text{cut}}, s_{\text{cut}} > 0$.
- A3: Dimensionless causal coupling C^* .
- A4: Bounded torsional response $\Omega(s)$.
- A5: Absolute Rule: full logs, unit discipline, SHA-256 integrity.

No new axioms are introduced here.

2. Temporal evolution: causal impedance between epochs

Let T_1, T_2, T_3, T_4 denote fundamental cosmic epochs. Define causal impedance $\Xi(T) = 1/\sqrt{\rho(T)}$.

Definition 3.1. The temporal transition matrix:

$$A_{ij} = (\Xi(T_i) - \Xi(T_j)) F_{\text{norm}},$$

with F_{norm} dimensionless.

Dimensions:

$$[\Xi] = [\rho]^{-1/2} = L^2, \quad [A_{ij}] = L^2.$$

Anti-symmetry

$$A_{ij} = -A_{ji}.$$

This ensures: (i) no diagonal drift, (ii) pure rotational-type temporal evolution in the causal-impedance space.

3. Theorem (Pure imaginary eigenvalues = dynamical stability)

Theorem 3.1. (*Depends on {A1, A2}*) If A_{ij} is anti-symmetric, its eigenvalues are purely imaginary or zero; hence the evolution driven by A is dynamically stable (no exponential growth).

Sketch of proof. Anti-symmetric matrices have purely imaginary spectrum under real vector spaces. As A_{ij} is real and anti-symmetric, all eigenvalues satisfy $\lambda_k = i\omega_k$ or 0. Hence solutions evolve by bounded oscillations or static modes. \square

4. Cosmic evolution equation

Let $\vec{X}(t)$ represent the causal-state vector in epoch space. Evolution:

$$\frac{d\vec{X}}{dt} = A\vec{X}(t).$$

Solution:

$$\vec{X}(t) = \exp(At) \vec{X}(0),$$

and since $\exp(At)$ is unitary-like for anti-symmetric A , the norm is invariant:

$$\|\vec{X}(t)\| = \|\vec{X}(0)\|.$$

5. Torsional saturation and bounded curvature

RCD prevents curvature blow-up via:

$$\Omega(s) = \tanh(s/s_{\text{cut}}).$$

Theorem 3.2 (Curvature boundedness). (*Depends on {A2, A4}*) Since $\Omega(s) \rightarrow 1$ as $s \rightarrow \infty$ and $|\Omega| < 1$, torsion-induced curvature invariants remain finite.

Sketch. Curvature corrections involve derivatives and powers of $\Omega(s)$. As Ω is bounded and its derivative $\Omega'(s) = (1 - \tanh^2(s/s_{\text{cut}}))/s_{\text{cut}}$ vanishes as $s \rightarrow \infty$, any expression polynomial in Ω and Ω' stays finite. \square

6. Dimensional and cutoff consistency (field-theory perspective)

- A_{ij} has intrinsic scale L^2 , compatible with epoch transitions.
- The torsional cutoff s_{cut} regulates UV behavior.
- No divergent term is generated by A or Ω .
- Classical renormalizability is ensured by boundedness and natural cutoffs.

7. Reproducibility protocol (NASA/ESA integrated)

Required outputs for any temporal-evolution experiment:

1. full matrix A_{ij} (numerical, machine format),
2. value set $\{\rho(T_i)\}$ with uncertainties and source dataset,

3. evolution solution $\exp(At)$ in floating-point or symbolic form,
4. arithmetic log (step-by-step operations),
5. SHA-256 digest of input | code | output.
6. independent verification by recomputing $\exp(At)$ with a distinct pipeline.

8. Connection to observations

The temporal structure does not directly modify local gravitational fields. Its main role is to guarantee:

- large-scale causal stability,
- non-divergent vacuum evolution,
- consistency of the cutoff ρ_{cut} through cosmic time.

9. Summary

This document establishes the dynamical backbone of RCD 5.0: anti-symmetric temporal evolution, bounded torsional response, and global stability. All derivations depend solely on the unified set of axioms A1–A5, ensuring internal consistency and reproducibility at engineering-grade precision.

References

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