

# 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  $\rho_{\text{local}}$  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  $F_{\text{norm}}$  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  $\Omega$  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  $\Omega$  and  $\Omega'$  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  $s_{\text{cut}}$  regulates UV behavior.
- No divergent term is generated by  $A$  or  $\Omega$ .
- 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  $\rho_{\text{cut}}$  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

- [1] A. Einstein, “Die Feldgleichungen der Gravitation”, *Sitzungsberichte der Preussischen Akademie der Wissenschaften zu Berlin* (1915).
- [2] F. W. Hehl, P. von der Heyde, G. D. Kerlick, and J. M. Nester, “General relativity with spin and torsion: Foundations and prospects”, *Rev. Mod. Phys.* **48**, 393–416 (1976).
- [3] F. Lelli, S. S. McGaugh, and J. M. Schombert, “SPARC: mass models for 175 disk galaxies with Spitzer photometry and accurate rotation curves”, *Astron. J.* **152**, 157 (2016).