RCD 5.0 — Field Geometry and Causal Response

Axiomatic refinement and geometric consistency

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Abstract

This document formalizes the RCD 5.0 field geometry: metric response, causal gradients, weak-field limit, and the geometric correction encoded in D_T. Axioms from Document 1 are reused here; new theorems explicitly list which axioms they depend on. Dimensional consistency and cutoff-stability (field-theory style) are checked for all geometric terms.

1. Preliminaries and axioms used

We reuse axioms A1–A5 from the core theory. For convenience:

- A1: Causal density well-defined.
- A2: Existence of cutoff scales ρ_{cut}, $s_{\text{cut}} > 0$.
- A3: Dimensionless coupling C^*.
- A4: Torsional saturation (bounded operator).
- A5: Absolute Rule — full arithmetic log + SHA-256 digest.

2. Effective RCD metric

The RCD geometric response modifies the GR metric via the suppression factor D_T:

$$g_{\mu\nu}^{\text{RCD}}(x) \; = \; g_{\mu\nu}^{\text{GR}}(x) \, D_T(x),$$

with D_T from the core theory:

$$D_T(x) = \frac{1}{1 + T_{\text{Causal}}(x)^2}, \qquad T_{\text{Causal}} = \frac{\rho_{\text{local}}}{\rho_{\text{cut}}} C^*.$$

Dimensional check:

$$[g_{\mu\nu}^{\text{RCD}}] = [g_{\mu\nu}^{\text{GR}}], \quad [D_T] = 1,$$

ensuring consistency.

3. Causal gradient as the generator of geometric anomaly

We define the causal gradient:

$$\nabla_i \rho_{\text{local}}(x) \; = \; \partial_i \rho_{\text{local}}(x),$$

which directly influences the geometric correction.

Theorem 2.1 (Causal-Gradient Anomaly). *(Depends on* $\{A1, A2, A3\}$*)* Galactic-scale anomalies arise precisely in regions where $\nabla\rho_{\text{local}}(r) \neq 0$. In such regions, $D_T(r) \neq 1$ and the RCD metric deviates from GR.

Sketch. If $\nabla\rho_{\text{local}} = 0$, then ρ_{local} is constant, hence T_{Causal} is constant; by calibration $T_{\text{Causal}} \to 0$ in the vacuum limit (A2), so $D_T = 1$. Conversely, if $\nabla\rho_{\text{local}} \neq 0$, then $T_{\text{Causal}}(r)$ varies, inducing $D_T(r) \neq 1$, therefore modifying $g_{\mu\nu}$. $\square$

4. Weak-field limit and rotation curves

In non-relativistic regimes, the Newtonian potential obeys:

$$\Phi_{\text{Newton}}(r) = -\frac{GM_b(r)}{r}.$$

RCD modifies the effective potential as:

$$\Phi_{\text{RCD}}(r) = \Phi_{\text{Newton}}(r)\, D_T(r),$$

yielding the corrected circular velocity:

$$V_{\text{Causal}}(r) = \sqrt{r\,|\Phi'_{\text{RCD}}(r)|} = V_{\text{Newton}}(r)\, D_T(r).$$

Dimensional consistency

$$[\Phi_{\text{RCD}}] = [\Phi_{\text{Newton}}] = \mathrm{L}^2/\mathrm{T}^2, \qquad [D_T] = 1.$$

Thus the modification is consistent with field-theory dimensional standards.

5. No dark-matter term

RCD does not add mass:

$$M_{\text{eff}}(r) = M_{\text{baryonic}}(r),$$

all deviations come from geometry. This is guaranteed because D_T is dimensionless and multiplicative.

Theorem 2.2 (Mass Non-Inflation). *(Depends on* $\{A1, A3\}$*)* The RCD modification cannot inflate enclosed mass. It alters velocity via geometry alone.

Proof (concise).

Assume Newtonian:

$$V_N^2(r) = GM_b(r)/r.$$

RCD yields:

$$V_{\text{C}}^2 = V_N^2 D_T^2.$$

If one falsely interpreted V_{C} as Newtonian, one would infer:

$$M_{\text{eff}} = M_b D_T^2.$$

But RCD does not modify M_b; the "extra mass" is a misinterpretation. $\square$

6. Vacuum limit → GR (again, geometric demonstration)

If $\nabla\rho_{\text{local}} = 0$ and $\rho_{\text{local}} = \rho_{\text{cut}}$ then:

$$T_{\text{Causal}} = 0, \qquad D_T = 1.$$

Thus:

$$g_{\mu\nu}^{\text{RCD}} = g_{\mu\nu}^{\text{GR}}.$$

7. Field-theory stability: cutoff and torsion

The causal density cutoff ρ_{cut} and the torsional cutoff s_{cut} regulate curvature behavior.

Torsional operator:

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

bounded and renormalization-safe (no blow-up for $s \to \infty$).

8. NASA/ESA reproducibility hooks

Each RCD geometric experiment must provide:

1. $g_{\mu\nu}^{\text{RCD}}(r)$ grid (machine format),
2. $D_T(r)$ values,
3. baryonic model used,
4. precision mode (double, quad),
5. SHA-256 of:
   - input mass model,
   - RCD-equation implementation,
   - output arrays.

9. Summary

This document formally states the geometric sector of RCD: where the corrections arise, how they scale, how they reduce to GR, and how to verify them independently.

References

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[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).