RCD 5.0 — Technical Appendices

Absolute Rule, Pipelines, and Engineering-Grade Reproducibility

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Abstract

These appendices establish the reproducibility framework for RCD 5.0. They formalize the Absolute Rule, NASA/ESA-style multi-pipeline validation, data integrity requirements, and the minimal computable example for independent verification. All definitions follow axioms A1–A5 from the Core Theory.

A. Absolute Rule (Axiom A5 Formalization)

The Absolute Rule mandates that every computation in RCD must include:

1. **Full input disclosure:** Baryonic mass model, grid resolution, units, constants, precision mode, dataset version.
2. **Arithmetic log (step-by-step):** Each arithmetic operation must be recorded with:
   - operation type,
   - operands (in consistent units),
   - rounding rule (IEEE 754 double or specified multiprecision),
   - resulting value.
3. **Unit discipline:** Every quantity must carry explicit physical units.
4. **Integrity via SHA-256:** A single digest must be computed over the concatenation:
$$H = \mathrm{SHA256}(\mathrm{inputs} \,\|\, \mathrm{code} \,\|\, \text{arithmetic-log} \,\|\, \mathrm{outputs}).$$
5. **Replication requirement:** Results are only valid if reproduced by an *independent pipeline*.

The Absolute Rule is not optional and invalidates any claim lacking complete logs.

B. Multi-Pipeline Verification (NASA/ESA Standard Integration)

To ensure engineering-grade reproducibility, RCD adopts the tri-pipeline method:

Pipeline A — Author's Implementation

May be written in Python/Julia/C++ or similar. Must produce:

$$D_T(r),\ T_{\mathrm{Causal}}(r),\ V_{\mathrm{Causal}}(r),\ \chi^2_{\mathrm{red}}.$$

Pipeline B — Minimal Independent Reimplementation

A minimal script (preferably < 100 lines) using the same formulas but different code structure. Must reproduce all numerical values within tolerance.

Pipeline C — Manual/Hybrid Check

A reduced-resolution run (coarse grid) computed manually or with a symbolic system to confirm consistency of:

$$T_{\text{Causal}},\ D_T,\ V_{\text{Causal}}.$$

Validation Criterion. Agreement among A, B, C within declared tolerance (machine-precision compatible) **is mandatory**.

C. Reproducible Computational Pipeline (Formal Steps)

1. Load baryonic mass model $M_b(r)$ and observational data (V_{obs}, σ).
2. Compute Newtonian:
$$V_N(r) = \sqrt{\frac{G\,M_b(r)}{r}}.$$
3. Compute causal density $\rho_{\text{local}}(r)$ (method must be documented).
4. Evaluate:
$$T_{\text{Causal}}(r) = \frac{\rho_{\text{local}}(r)}{\rho_{\text{cut}}} C^*.$$
5. Compute suppression:
$$D_T(r) = \frac{1}{1 + T_{\text{Causal}}(r)^2}.$$
6. Generate corrected velocity:
$$V_{\text{Causal}}(r) = V_N(r) D_T(r).$$
7. Compute residuals and:
$$\chi^2_{\text{red}} = \frac{1}{N-k} \sum_r \frac{\big(V_{\text{Causal}}(r) - V_{\text{obs}}(r)\big)^2}{\sigma(r)^2}.$$
8. Record full arithmetic log.
9. Compute SHA-256 digest.
10. Replicate with Pipelines B and C.

D. Minimal Verifiable Example (Complete Skeleton)

For any galaxy (SPARC or otherwise), the following must be provided:

- baryonic mass points $(r_i, M_b(r_i))$,
- Newtonian velocity array $\{V_N(r_i)\}$,
- causal density array $\{\rho_{\text{local}}(r_i)\}$,

- $T_{\text{Causal}}(r_i)$ and $D_T(r_i)$ arrays,
- $V_{\text{Causal}}(r_i)$,
- residuals,
- χ^2_{red},
- arithmetic log (text file),
- SHA-256 of the complete bundle.

This bundle must allow a reviewer to reproduce the entire computation.

E. Data Provenance and Traceability

Every dataset must include:

1. Source (e.g., SPARC, Kepler EB Catalog).
2. Version, release date, and citation.
3. Any transformation or smoothing applied.
4. Hash of the raw dataset.
5. Scripts for conversion to RCD format.

F. Summary

These appendices define:

- the Absolute Rule (full verifiability),
- multi-pipeline reproducibility (NASA/ESA standard),
- computational pipeline for D_T, T_{Causal}, V_{Causal},
- minimal example for external validation.

This completes the rigor layer of RCD 5.0.

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).