Emergence Atlas in the Reguleon Framework: Macro-Regime Mapping of Micro-Dynamic Rules and Scaling Laws

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Abstract

This study investigates the macro behavior classes produced by local update rules defined under the Reguleon core ontology, as a function of system size (L) and initial geometry. In this mapping study, referred to as the "Emergence Atlas," the Mixer, Smoother, and Locker regimes arising from the system's internal dynamics are defined using operational measures, without resorting to external data or parameter fitting. Specifically, the power-law relationship of homogenization time (t_{first}) with system scale ($z \approx 3.8$) and the effects of micro-time slicing (scheduler) choices on the residual noise floor are reported.

1. Methodology and Atlas Scope

This research is built upon 2D torus geometry, *N4* neighborhood, and an energy limit of $e_{max} = 8$. The atlas studies were conducted across two main axes of analysis:

- **System Dynamics and Geometric Interaction:** Measuring the interaction between different rules (A, B, C) and initial geometries (*random, clump, stripe*).
- **Update Protocol Robustness:** Auditing the effect of micro-update ordering (*random_i* vs. *perm_sweep*) on macro results.

Throughout the process, two fundamental checks, accepted as the "Ontological Constitution," were applied at every measurement step: conservation of node energy bounds and absolute conservation of total energy.

2. Macro Behavior Classes

Simulation results have proven that Reguleon engines fall into three primary "behavior families":

2.1. Mixer / Diffusive Regime (Rule A)

Exhibits high mobility (≈ 0.79) and high variance (Var ≈ 6.67). While it produces rapid thermalization from random starts, it tends to preserve directional memory for stripe-type initializations for extended periods.

2.2. Smoother / IR-Attractor Regime (Rule B)

Acts as a strong "infrared (IR) homogeneity attractor." Regardless of initial roughness, the system flows into a narrow-band regime where energy clusters within the [3, 5] range. Isotropy production ($A_{xy} \approx 0$) is a characteristic feature of this class.

2.3. Locker / Metastable Regime (Rule C)

Exhibits very low mobility (≈ 0.02). It "seals" initial anisotropy and geometric structure, carrying it to the macro scale; this results in the formation of permanent structural imprints (relics) that are not erased within the system.

3. Scaling Laws and Homogenization Dynamics

As the system size (L = 40, 60, 80, 100) increases, the smoothing process is found to possess a characteristic time scale.

3.1. Scaling of Homogenization Time (t_{first})

The time of first entry into the stable energy band (t_{first}) follows a power law with system size:

$$t_{first}(L) \propto L^z, \quad z \approx 3.8$$

This high dynamic exponent indicates that due to restricted local transfer and delayed contact across the network, the homogenization horizon expands dramatically with system scale.

3.2. Protocol Effect and Noise Floor

The sequential scan (*perm_sweep*) method brings the system into the stable band approximately 1.5× faster than random selection. However, a more critical finding is that the update protocol determines the final variance floor (noise floor); the residual micro-roughness amplitude is lower in the sequential scan method.

4. Conclusion

Analysis demonstrates that the Reguleon model can produce large-scale cosmological behaviors. Stability data and energy band locking certify that the model can generate different "macro-universe classes" through micro-dynamic choices alone, without the need for external tuning.

Appendix: Technical Data Package

Table 1: Scale Scan and Stable Band Entry Times (t_{first})

Scale (L)	*perm_sweep* (M-event)	*random_i* (M-event)
40	≈ 0.13 - 0.14	≈ 0.19 - 0.20
60	≈ 0.57 - 0.60	≈ 0.88 - 0.90
80	≈ 1.76 - 1.83	≈ 2.67 - 2.73
100	≈ 4.24 - 4.41	≈ 6.51 - 6.57

Table 2: Final Variance Values (L=80)

Initial Geometry	Final Var(e)	Status
Clump	≈ 0.0407	**PASS**
Stripe X	≈ 0.0472	**PASS**

Technical Note: In all tests, the band exit audit resulted in zero; the system did not leave the targeted energy basin once it entered the stable regime.