
From Least Resistance to Recursive Gradients: A Scientific Awakening

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Abstract

This essay revisits and extends the foundational insight presented in *The Next Scientific Revolution* (2013): that inequality and least resistance are the fundamental drivers of natural processes. Through the lens of *Recursive Gradient Physics* (RGP), it proposes a conceptual framework in which emergence results from recursive interactions among gradients—an idea with profound implications across cosmology, neuroscience, artificial intelligence, and complex systems. Against the backdrop of growing tensions in modern physics, especially the Λ CDM model, RGP reframes the debate: not as a crisis of data, but of perspective. By shifting the explanatory basis from entities and constants to self-organizing differential processes, RGP offers a unifying logic of emergence. This essay bridges the personal journey that led to this view with a broader epistemological call: to move beyond substance toward process, and beyond linear causality toward recursive feedback. Whether adopted as a new paradigm or embraced as a powerful heuristic, RGP renews science’s ability to explain—and reimagine—the complex, evolving systems that shape our reality.

Introduction & Historical Framing

Science advances in waves—not only through the accumulation of data, but by periodic shifts in the frameworks used to interpret it. These moments of rupture, described famously by Thomas Kuhn as “paradigm shifts,” arise when prevailing models, despite their utility, can no longer resolve mounting anomalies.

From Aristotle’s view of motion as a natural tendency, to Ptolemy’s epicycles that strained to keep a geocentric universe mathematically viable, to Copernicus’ heliocentric leap, the arc of scientific progress reveals an enduring pattern: what seems solid begins to bend under the weight of new observations until a fundamentally different lens renders the anomalies obvious.

In 2013, *The Next Scientific Revolution* (TNSR) sought to anticipate such a shift by proposing a behavioral reorientation of science. It argued that reality is best understood not as a system of static “things,” but as dynamic processes governed by inequality and least resistance.

That insight—simple in appearance, but profound in consequence—has since evolved into a broader framework: *Recursive Gradient Physics* (RGP). RGP extends the TNSR view, suggesting that all emergence—whether in cosmology, biology, or cognition—results from recursive interactions of gradients.

This essay revisits the foundations of that journey, exploring how a conceptual seed has grown into a framework with potential cross-disciplinary reach. As tensions in modern physics increase, particularly around the Λ CDM model of cosmology, it is time to reconsider the basic assumptions guiding our models—and ask whether the next scientific revolution may begin with something as simple and universal as gradients.

Inequality and the Path of Least Resistance: Insights from TNSR

The Next Scientific Revolution (TNSR) was grounded in a straightforward yet far-reaching observation: nature moves along paths of least resistance. Wherever inequalities exist—whether in energy, pressure, opportunity, or access—they drive change. The natural world is in constant motion, seeking efficient resolution of those differences. TNSR reframed this behavior as fundamental. Rather than viewing reality as a composition of static entities, it proposed that inequality is the engine of change, and least resistance the guiding principle of motion.

A temperature difference prompts heat flow. Water finds its route downhill, not randomly, but through the easiest path available. Even coordinated biological behaviors can be understood this way. A flock of birds flying in V-formation minimizes individual air resistance—not through deliberate strategy, but through simple, mutual response to aerodynamic gradients. Each bird responds to local conditions, collectively generating an emergent pattern.

In this behavioral framing, actors—whether molecules, organisms, or organizations—respond to contextual inequalities by minimizing effort. Patterns of movement and structure emerge not from imposed rules, but from efficient navigation of local constraints. The implication is profound: what we observe as form is often the product of behavior responding to gradients.

TNSR extended this reasoning beyond physics. Economic systems, for instance, respond to price inequalities by reallocating resources. The division of labor evolves to minimize redundancy and optimize efficiency. In each case, inequalities shape behavior, and systems adapt through recursive resolution—an idea that foreshadowed the Recursive Gradient Processing (RGP) framework.

By 2013, TNSR had positioned this dynamic view—of inequality leading to action along the path of least resistance—as a candidate for a new scientific paradigm. The principle is intuitive, echoing the Principle of Least Action in physics. But TNSR broadened it into a unifying heuristic: emergence, across all domains, can be understood as nature minimizing gradients, given its constraints.

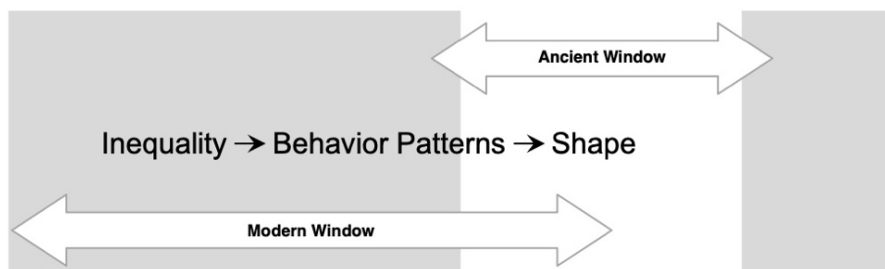


Figure 1: Two contrasting perspectives on reality: The ‘Ancient Window’ follows a shape-first view, where form dictates behavior. The ‘Modern Window’ inverts this, emphasizing that inequality drives behavior, which in turn shapes form. This shift from static to process-oriented thinking underlies the transition from classical models to *Recursive Gradient Physics* emphasizing how behavior shapes form rather than the other way around.

In Search of a New Worldview: Dialogues with Leading Thinkers

In the years leading up to the writing of *The Next Scientific Revolution*, I immersed myself in cross-disciplinary dialogues, seeking a deeper logic beneath the fragmentation of modern science. My goal was not to challenge individual fields, but to trace conceptual resonances that might reveal a unifying principle—something that could span nature, cognition, and society. Through exchanges with a handful of prominent physicists and a mathematical scientist focused on complex systems, I began shaping the behavioral perspective that would eventually form the core of TNSR.

I was fortunate to engage—sometimes briefly, sometimes more meaningfully—with thinkers whose openness and intellectual courage left a lasting mark. These interactions were not always extensive, but they were formative. I learned from Carlo Rovelli’s relational lens, from Chris Isham’s foundational reflections on time and logic, and from Lee Smolin’s persistent questioning of accepted paradigms. Ichiro Tsuda’s work on complex neural dynamics expanded my thinking into the domain of cognition, where gradients seemed to orchestrate emergent behavior in ways strikingly parallel to physics.

These encounters served less as validations than as checkpoints—moments that tested whether the core premise I was exploring—that inequalities and gradient-seeking behaviors underlie complex structure—might apply beyond metaphor, across domains. The answer was affirmative. Yet these conversations also highlighted the limitations of the existing conceptual tools and reinforced the need for a deeper framework: one that could account not just for how gradients resolve, but how they recursively give rise to new gradients. That realization eventually marked the pivot from *The Next Scientific Revolution* to *Recursive Gradient Physics*.

Anticipating the Tensions in Cosmology

One of the more striking consequences of the behavioral perspective developed in *The Next Scientific Revolution* was its implicit prediction: that the static assumptions embedded in modern cosmology would eventually encounter empirical strain. If reality is indeed processual—driven by recursive resolution of inequalities—then models that rely on fixed constants and timeless scaffolds would, over time, show signs of mismatch.

In the decade since TNSR appeared, this strain has become increasingly visible. The standard cosmological model, Λ CDM (Lambda Cold Dark Matter), which treats dark energy as a constant vacuum energy (Λ) and explains structure formation via cold dark matter, now faces growing tension with observational data. Chief among these is the well-known Hubble tension—a persistent discrepancy between the predicted and observed expansion rates of the universe (H_0). While early-universe data (such as from the cosmic microwave background) suggest a lower H_0 , direct late-universe observations indicate a significantly higher rate. Initially considered a calibration issue, this gap has not closed with improved data—in fact, it has widened.

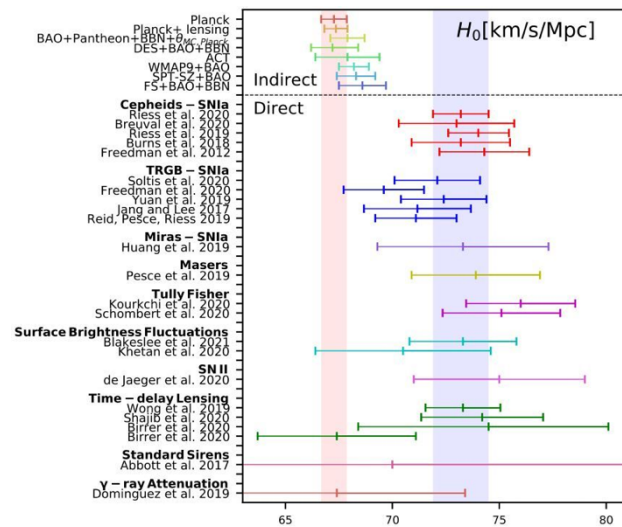


Figure 2: Recent measurements of the Hubble constant (H_0) reveal a widening gap between early-universe inferences (Planck, BAO – blue bars) and late-universe observations (supernovae, lensing – red bars). This tension challenges the Λ CDM model and has escalated into what many now call a “crisis in cosmology.”

Additional complexities are emerging. To reconcile different datasets, cosmologists have begun introducing evolving or “decaying” dark energy models, suggesting that the vacuum energy might not be constant after all. Results from recent large-scale surveys such as DESI (Dark Energy Spectroscopic Instrument) have strengthened this possibility. When DESI data is combined with other measurements, the model in which dark energy changes over time provides a better fit than a static Λ . In short, the cornerstone assumption of the standard model may need revisiting.

This tendency—to patch rather than revise—has historical precedent. Ptolemaic astronomy introduced epicycles to preserve a geocentric framework, despite mounting anomalies. A similar pattern is visible now. Λ CDM, while still successful at many scales, is being stretched by add-ons: early dark energy, evolving equation-of-state parameters (w_0, w_a), and tweaks to neutrino content or dark radiation (N_{eff}), among others. A recent review cataloged nearly a hundred proposed modifications intended to resolve these tensions.

From the perspective of TNSR and now RGP, these developments are unsurprising. A model built on fixed “things”—like an immutable Λ —will inevitably struggle to account for dynamic phenomena. If the cosmos itself evolves through recursive gradient feedback, then our models must do more than adjust constants; they must adopt a different conceptual foundation. As Kuhn observed, anomalies are the “usual prelude” to scientific revolutions—not because they falsify models outright, but because they expose the limits of a paradigm’s explanatory reach.

RGP proposes to render these anomalies lawlike not through complexity but through simplicity—by shifting focus from entities to interactions, from constants to evolving differentials. The mounting tensions in cosmology may not be signs that Λ CDM is broken, but that it is misframed. A system that behaves like a living, evolving network of gradients cannot be fully captured by parameters designed for equilibrium.

Recursive Gradient Physics: Gradients of Gradients and Emergent Structure

Recursive Gradient Physics or *Processing* (RGP) builds directly on the conceptual foundation laid by *The Next Scientific Revolution*. If inequalities drive motion and systems evolve along paths of least resistance, then what happens when such dynamics compound upon themselves? RGP offers a hypothesis: nature organizes itself through recursive gradients—processes in which the resolution of one inequality gives rise to new ones, feeding back into the system in a self-sustaining loop. These layered interactions, rather than fixed laws or entities, give rise to the structures and behaviors we observe across scales.

A gradient is, in essence, a difference or inequality—of, say, temperature, pressure, potential, probability—that prompts a system to evolve. In RGP, gradients are not isolated triggers but part of a recursive architecture: gradients produce flows that generate new gradients, which in turn prompt new flows. When feedback loops reinforce this cycle, stable structures emerge—not as imposed forms, but as self-organized outcomes.

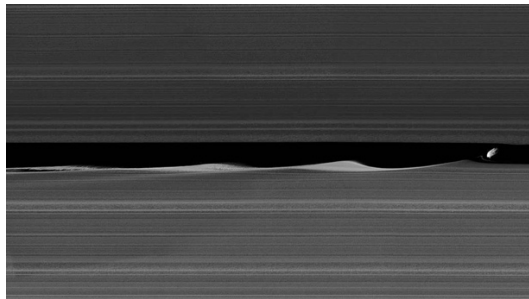


Figure 3: This Cassini spacecraft image captures Saturn’s moon Daphnis perturbing the Keeler Gap in the planet’s A-ring, creating striking vertical waves in the ring material. The interaction illustrates a gradient-of-gradient effect: Daphnis’s gravitational field introduces a perturbation (a primary gradient), which then induces density variations in the surrounding ring particles (a secondary gradient), leading to the emergence of stable wave patterns. This self-reinforcing feedback exemplifies the principles of *Recursive Gradient Processing* (RGP)—how layered gradients can organize structures at different scales. Credit: NASA/JPL-Caltech/Space Science Institute. Official Cassini image PIA11690.

Take gravitational clustering. A region slightly denser than its surroundings attracts more matter, increasing its density and deepening the gravitational well—thus attracting even more matter. This is a recursive gradient process: a difference begets a feedback that amplifies the original difference. What emerges—galaxies, stars, clusters—is not the result of a predefined blueprint but of recursive reinforcement within a field of gradients.

RGP generalizes this logic. It proposes that structure, coherence, and even the appearance of laws may be emergent from gradient loops operating across scales. Importantly, this is not just a metaphor. Observable systems exhibit this behavior. Consider the gravitational waves seen in Saturn's rings due to its moon Daphnis. The moon introduces a local gravitational gradient, perturbing the surrounding ring particles. These perturbations propagate outward as density waves, which themselves represent new gradients. The moon and the ring structure interact recursively to maintain a stable pattern—a visible, physical imprint of RGP dynamics.

Where traditional physics sees forces acting upon matter, RGP sees gradients driving behaviors that recursively reinforce or dissipate. This perspective recasts even vacuum energy—not as a fixed backdrop, but as a dynamic field of potential differentials. From this view, the so-called constancy of Λ may be only an averaged expression of underlying, evolving gradient interactions.

RGP also provides a natural explanation for hierarchy. The universe began in near-uniformity, with minimal gradients. Tiny quantum fluctuations—minute inequalities—evolved through recursive interactions into galaxies, solar systems, and the large-scale web. At each scale, gradients generated new structures that altered the gradient landscape of the next. This layered emergence is exactly what RGP seeks to describe.

Rather than treating emergence as an add-on to fundamental physics, RGP treats it as the point. It suggests that systems capable of recursive gradient resolution—whether physical, biological, or cognitive—exhibit increasing levels of organization not because of imposed rules, but because gradient feedback is self-organizing. A hurricane, a neural assembly, or a galaxy may thus be viewed through the same underlying logic.

In the *RGP trilogy*, this logic is developed conceptually, leaving formal modeling for future stages. The decision to begin without equations is deliberate: the first step is to reorient understanding—to shift from describing phenomena as outcomes of forces to interpreting them as recursive interactions within gradient fields. Once this view is internalized, new mathematics can follow. But the conceptual shift must come first.

RGP, in this light, is not a theory competing with Λ CDM on technical grounds. It is a reframing of what we consider fundamental. And as history shows, reframing often precedes revolution.

Paradigm Shifts: An Inflection Point in Science

Scientific progress is not linear. As Thomas Kuhn observed, periods of “normal science” operate within paradigms—shared conceptual frameworks that guide research, define problems, and validate solutions. But when anomalies accumulate and no minor revision will suffice, science enters a state of crisis. At such inflection points, the very terms of inquiry can change. What was once foundational becomes obsolete; what was fringe becomes central.

The current state of cosmology—and, more broadly, fundamental physics—bears many hallmarks of such a transition. Precision measurements reveal tensions that can no longer be comfortably attributed to error margins. Standard models, like Λ CDM, increasingly rely on layered assumptions and ad hoc fixes to maintain coherence. A proliferation of parameters, each introduced to accommodate new data, risks turning a once-powerful framework into a tautology.

This is not unusual. Late Ptolemaic astronomy produced similarly elaborate mechanisms—epicycles within epicycles—to sustain a geocentric model. Eventually, the pressure of anomalies could not be absorbed without altering the underlying frame. A conceptual shift, not a technical refinement, became necessary.

Recursive Gradient Physics steps into this moment not as a finished theory, but as a new lens—one that renders the anomalous lawlike by shifting our understanding of what drives structure and evolution in the universe. Rather than positing additional constants, particles, or fields, RGP proposes that we look to the recursive dynamics of gradients to explain emergence.

This perspective does more than interpret anomalies. It particularly offers coherence across disciplines. If the same recursive mechanisms that underlie galaxy formation also structure neural dynamics, social systems, and AI architectures, then RGP provides a unifying principle where other paradigms compartmentalize.

Importantly, the call for paradigm change is not a dismissal of existing science. Newtonian mechanics remains valid within its domain, as does Λ CDM within certain observational windows. But like all paradigms, their reach is finite. RGP invites exploration beyond those limits—not by asserting superiority, but by offering a framework that may better accommodate what comes next.

We are, perhaps, at a moment when resistance to new ideas—understandable as it is—must give way to deeper curiosity. The scientific community has seen this pattern before: tension, denial, resistance, disillusionment, reframing, then liberating insight. The case for RGP is not yet empirical, but conceptual—and history shows that such conceptual steps often lead the way.

Beyond Cosmology: RGP's Cross-Disciplinary Promise

While RGP emerges from tensions in cosmology, its real power lies in its generality. Recursive gradient feedback is not a cosmological curiosity—it is a universal dynamic observable across systems where structure emerges from imbalance. By framing physical, biological, cognitive, and social processes in terms of recursively interacting gradients, RGP offers a unifying language that transcends disciplinary boundaries.

- Artificial Intelligence

Machine Learning typically operates on gradient principles—optimizing through gradient descent. RGP invites a deeper framing: that intelligence itself may emerge through recursive refinement of internal gradients. This points toward architectures capable of self-evolving goals, representations, and learning strategies—moving beyond static objective functions toward systems that reshape their own informational landscapes over time. In this view, intelligence arises not from complexity alone, but from the ability to recursively structure gradients of perception, attention, and action.

- Neuroscience and Psychology

The brain is an ecosystem of gradients—electrochemical, metabolic, and informational. Learning adjusts synaptic weights in response to discrepancies between prediction and outcome—minimizing surprise, a form of inequality. Tsuda's chaotic itinerancy shows how the brain doesn't lock into fixed states but instead flows through metastable regimes. RGP provides a generalizable logic for this: cognition as recursive gradient reconfiguration. This could deepen our understanding of consciousness, memory, and adaptability—and open new avenues in computational neuroscience.

- Complex Systems and Society

In economics, ecosystems, and institutions, inequality drives flow—of capital, energy, information. These flows reshape the very gradients that caused them, creating feedback loops that can stabilize or destabilize. RGP reframes this not as metaphor, but as shared mechanism. A social network's virality, an urban system's growth, or a financial market's volatility may all result from recursive amplification of underlying gradients. By modeling such systems through RGP lenses, we may identify leverage points for policy, resilience, and innovation.

- Philosophy of Science

At a foundational level, RGP reopens long-standing debates: Is causality linear or circular? Are systems reducible, or do wholes emerge with new properties? RGP offers a principled stance between reductionism and holism: systems self-organize not through top-down control or bottom-up assembly, but through recursive interaction of constraints. This perspective resonates not only with developments in theoretical physics and systems biology, but also with work in anthropology and history—such as that of David Graeber and David Wengrow, who have shown that human societies evolve not through linear progressions but through haphazard experimentation, reversals, and discontinuous innovation. RGP thus complements and reinforces a broader epistemic shift toward viewing emergence as recursive, contingent, and plural—not predetermined.

By drawing attention to the recursive nature of inequality resolution—how resolving one gradient alters the next—RGP articulates a logic that is already implicit in many domains. It doesn't claim to replace existing models, but to connect them—to show how behavior, structure, and evolution might share a common engine across vastly different scales and materials.

Conclusion: Rediscovering the Logic of Emergence

The path from *The Next Scientific Revolution* to *Recursive Gradient Physics* or *Processing* has been one of distillation rather than departure. What began as an intuitive recognition—that inequality and least resistance govern behavior—has matured into a framework capable of linking insights across cosmology, neuroscience, artificial intelligence, and social systems. Along the way, the tension between substance and process, between fixed models and adaptive realities, became impossible to ignore.

Through conversations, observations, and conceptual synthesis, the realization took shape: structure is not imposed—it emerges. And what drives that emergence, consistently across scales, is the recursive interaction of gradients. RGP gives voice to this logic not by introducing a new ontology of things, but by highlighting the dynamics that give rise to them.

This is not just a theoretical proposal. It is a shift in perspective. It asks: *What if we have mistaken utility for truth?* What if the elegance of existing models has masked their foundational limitations? And what if the anomalies we now face—in cosmology, in cognition, in the design of intelligent systems—are best understood not as threats to be patched, but as invitations to rethink what we consider fundamental?

History teaches us that such moments matter. Paradigm shifts occur not when every detail is worked out, but when a simpler, more coherent picture begins to render the anomalous inevitable. RGP aims to do just that: to show that emergence, feedback, and hierarchy are not complications to be modeled after the fact—but central features of nature's logic.

Whether *Recursive Gradient Physics* evolves into a full scientific paradigm or not, it already serves a critical purpose: it makes room again for foundational questioning. It reconnects inquiry with imagination. And it reminds us that science, at its best, does not merely describe the world—it reveals new ways to see it and invites us to move with it.

Acknowledgments

This paper emerged from a collaboration with ChatGPT that blends human insight with machine-generated reasoning, illustrating the evolving synergy between human cognition and artificial intelligence. This partnership demonstrates the potential of interdisciplinary exploration, uniting the depth of human intuition with the precision of computational reasoning to address complex, foundational questions across domains.

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