

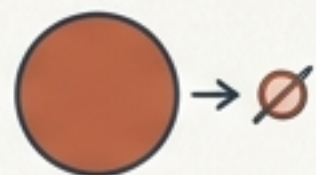
Astrophysics After the Uniform Object

Stratification, Burst Cycles, Reservoirs, and Reachability from Compact Stars to the Cosmic Web

Across scales—from nuclear-density matter to the cosmic web—observational astrophysics is converging on a structural shift. The “uniform object” is giving way to layered, bursty, reservoir-constrained, and connectivity-structured descriptions.

The Core Thesis: Death of the Uniform Object

The Old Astrophysics (The Uniform Object)



- Model: Object \rightarrow Intrinsic properties \rightarrow Observed behavior

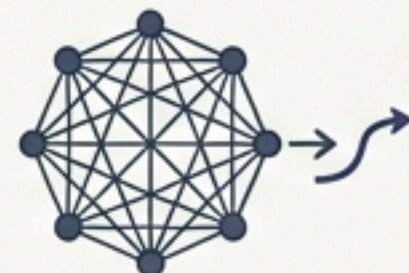


- View: Objects are fundamental, isolated entities.

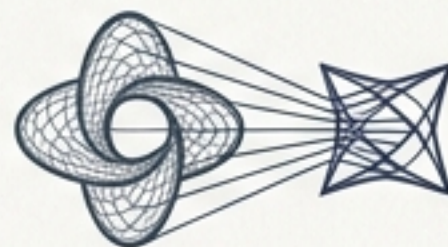


- Approximations: A neutron star is a single thermodynamic phase. A galaxy sits in a fixed spectral taxonomy.

The New Astrophysics (Configuration Spaces)



- Model: Configuration \rightarrow Constraints \rightarrow Trajectories \rightarrow Observed behavior



- View: Objects are projections of admissible structure, shaped by geometry.



JWST & ALMA
Precision

- Approximations: Replaced by stratified gradients, bursty trajectories, and reachable manifolds forced by JWST and ALMA precision.

The Central Claim

$$\text{STRUCTURE} = \text{Constraint} + \text{Reservoir} + \text{Transition} + \text{Reachable Future}$$

Constraint

The geometric boundaries of what configurations are physically admissible.

Reservoir

The latent capacity or “fuel” quantified as a compressed process record.

Transition

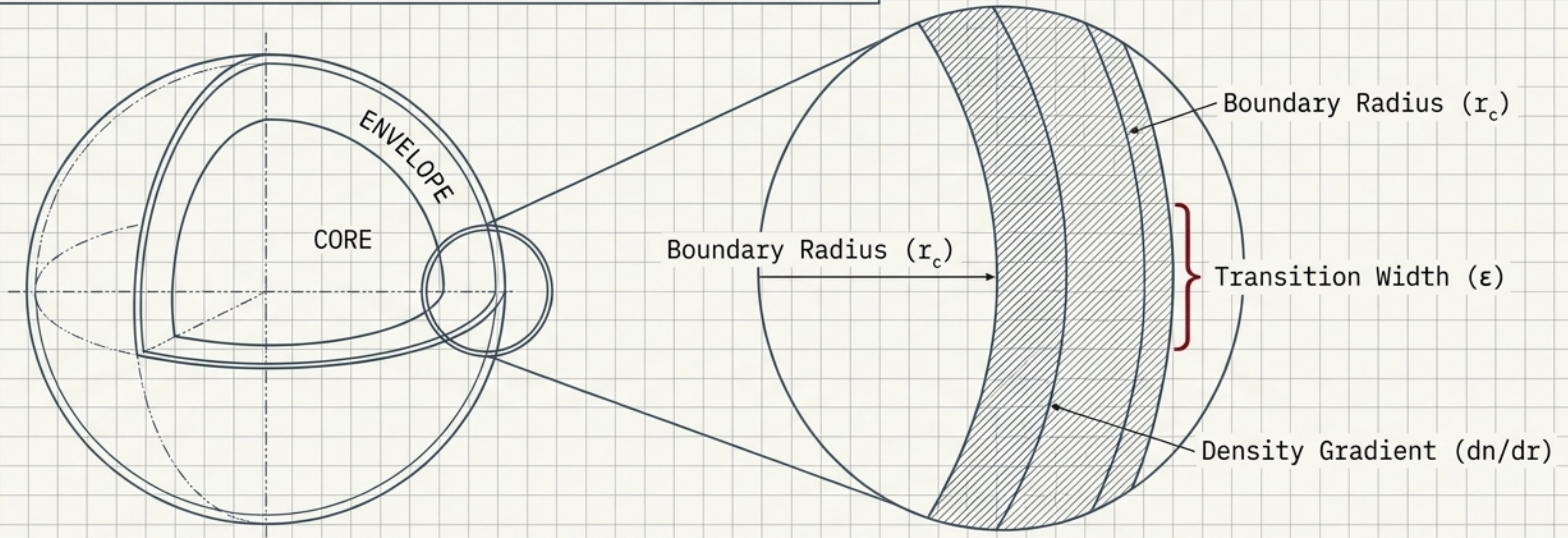
The critical boundary gradients ($d\Phi/dt$ or dn/dr) between locally coherent phases.

Reachable Future

The projected subset of the configuration space a system can access over time.

Physical objects are not isolated things; they are the projected intersection of admissible pasts and admissible futures.

Scale 1: Nuclear Density & Stratified Equilibrium

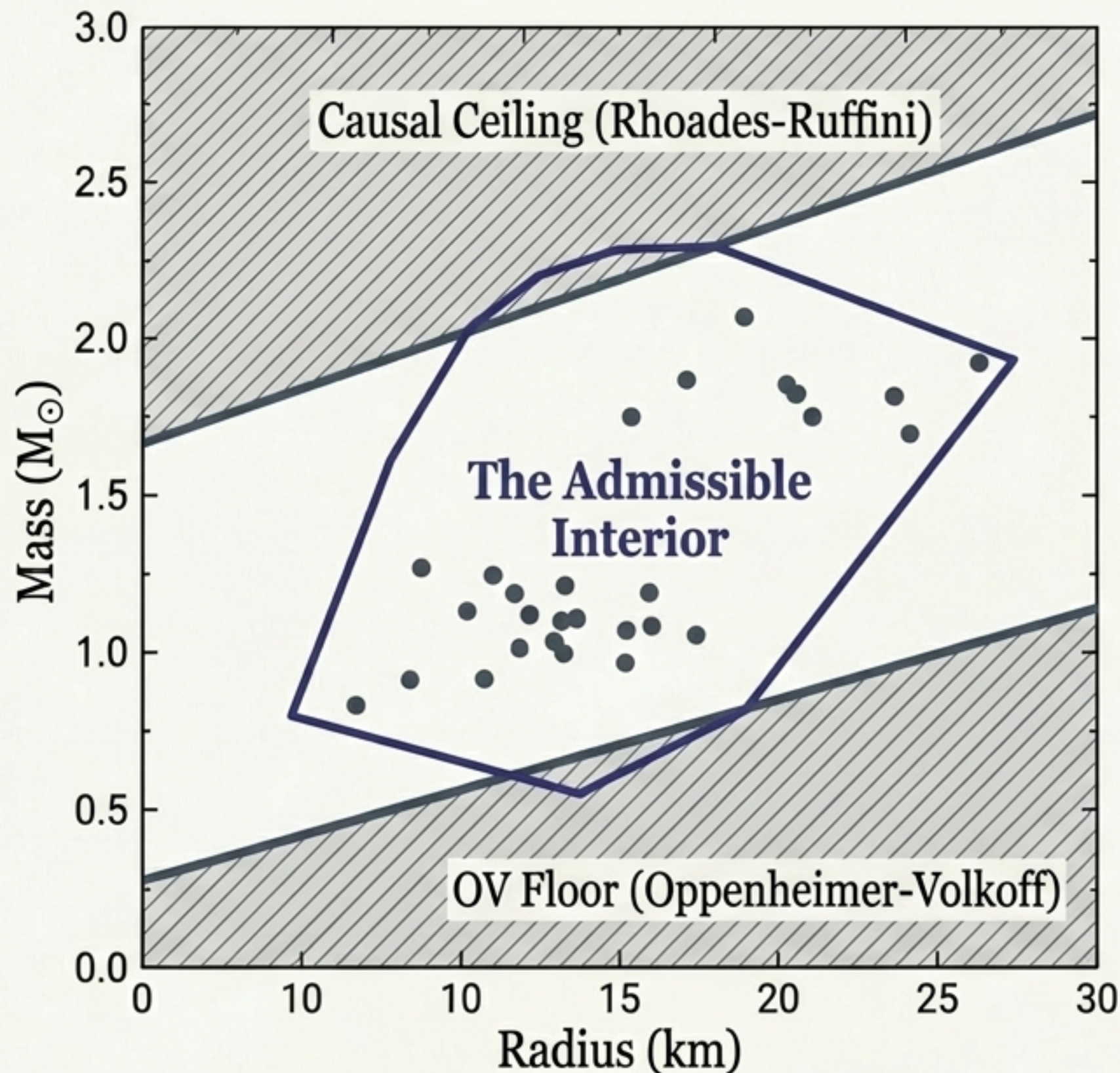


- Based on Nouh et al. (2026), compact star modeling is abandoning globally constant polytropic indices.
- **The Shift:** The CTOV (Composite Tolman-Oppenheimer-Volkoff) framework replaces a single equation of state with a radially varying one: $n(r)$.
- **Key Insight:** Observable stellar properties are determined more by the geometry of the transition region (its width ϵ and boundary radius r_c) than by the bulk core or envelope values. The transition carries the explanatory power.

Reversing Explanatory Order: The Admissible Frontier

The older view asked: What are the intrinsic properties of this star?

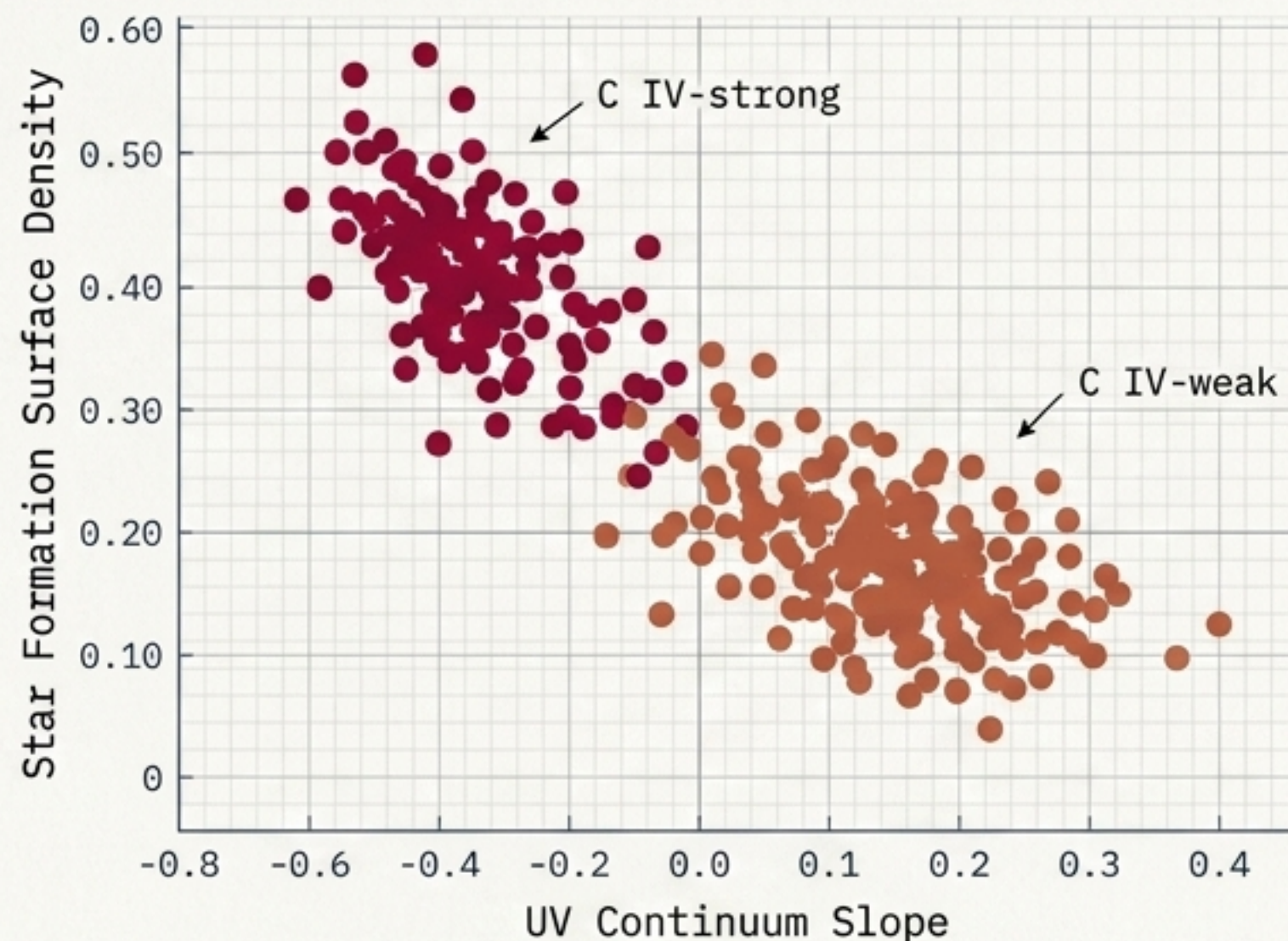
The new view asks: What is the geometry of the admissible space this star inhabits?



Takeaway: The stars do not define the space. The geometric boundaries of stability, causality, and thermodynamics carve out an 'admissible region' in parameter space.

The observed neutron-star mass-radius distribution is merely an observational projection of this underlying geometry.

Scale 2: Early Galaxies & Bursty Time



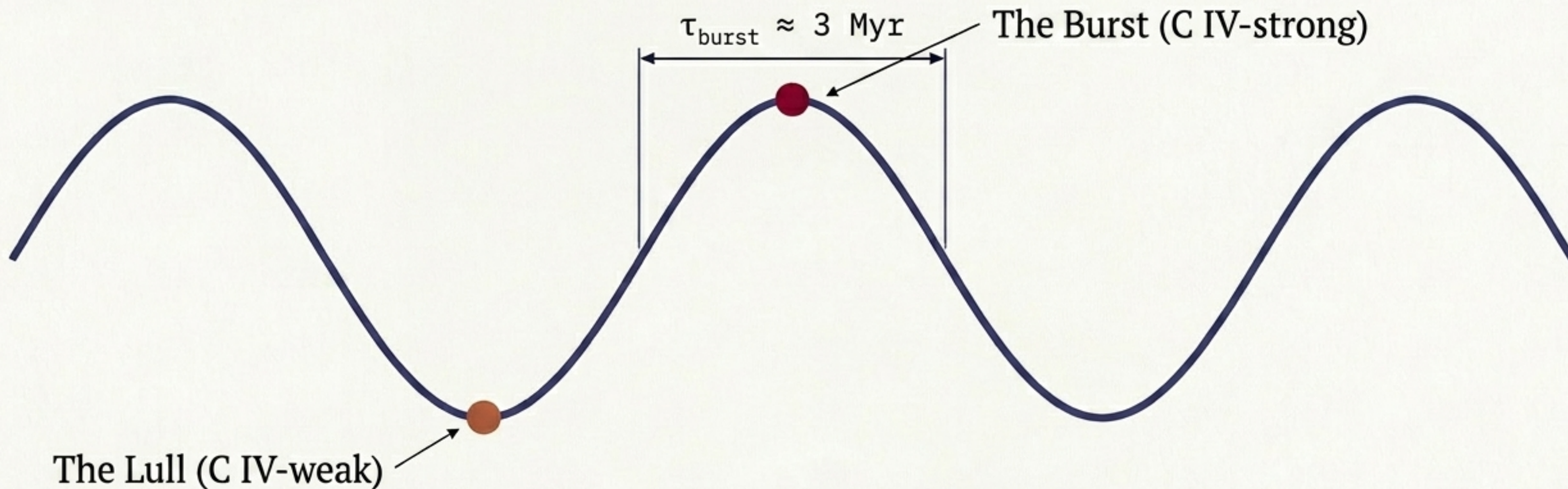
Context

JWST spectroscopy reveals immense diversity in galaxies within the first 500 million years. Some exhibit intense C IV emission lines; others are devoid of them.

The Mystery

The primary predictor of strong C IV emission is not metallicity, dust content, or AGN activity. Why do these physically similar galaxies look so categorically different?

Diversity as Temporal Stratification



The C IV-weak and C IV-strong distinction is not a taxonomic classification of different objects. It is a phase-position indicator along a single, shared evolutionary trajectory.

Key Insight:

Just as the neutron star replaced bulk state with a spatial transition (ϵ), early galaxies replace fixed types with a temporal transition (τ_{burst}). The observable spectrum is merely a frozen snapshot of a galaxy moving through burst space.

Scale 3: The Interstellar Medium & Latent Reachability

Context

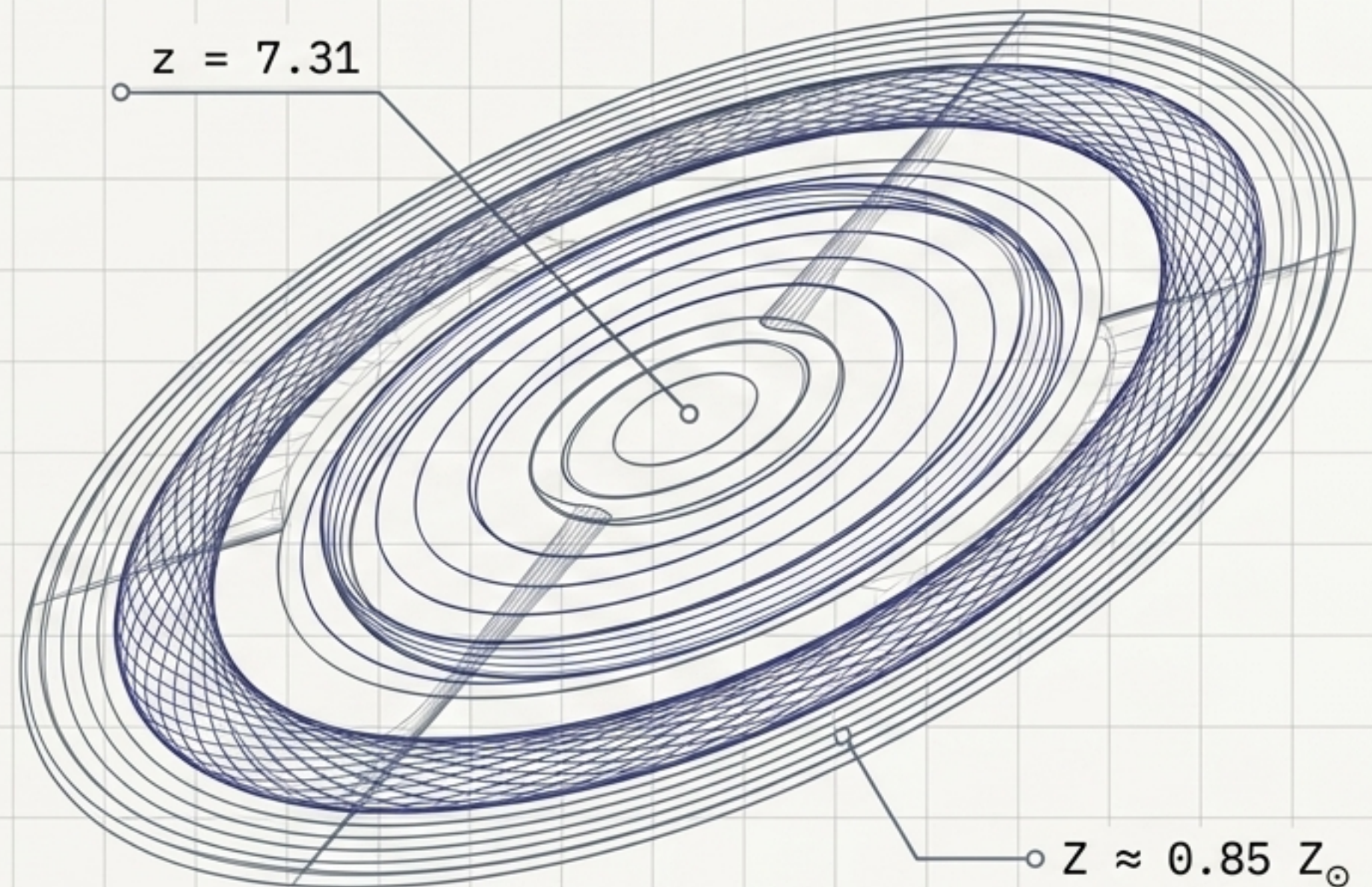
Introducing Cescon et al.
The detection of a dynamically cold, massive molecular gas reservoir in REBELS-25 via CO emission.

The Data

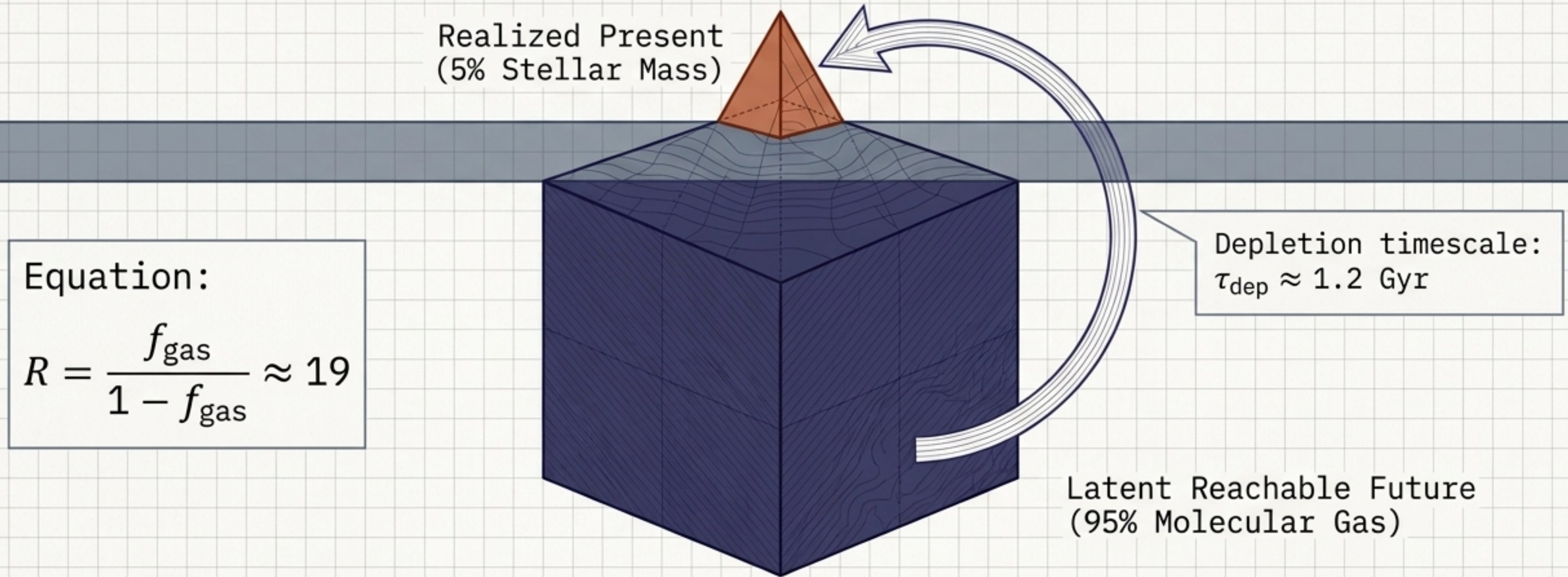
The galaxy has an enormous gas fraction of $f_{\text{gas}} \approx 0.95$ and a depletion timescale of $\tau_{\text{dep}} \approx 1.2$ Gyr.

The Shift

The object is fundamentally defined not by the stars that currently exist, but by the massive reservoir of fuel waiting to be converted. The galaxy is a state plus a quantified future capacity.



The Reachability Functional (R)



REBELS-25 contains roughly 19 times more latent stellar mass than realized stellar mass. This is the **Reachability Functional**: a quantitative measure of accessible future capacity under current dynamical conditions. The galaxy is not defined merely by its present state, but by its coordinate on a reachable-future manifold.

Scale 4: The Cosmic Web & Disordered Heterogeneity



Macro-Scale: Hyperuniformity (Smooth)



Micro-Scale: Antihyperuniformity (Clustered Network)

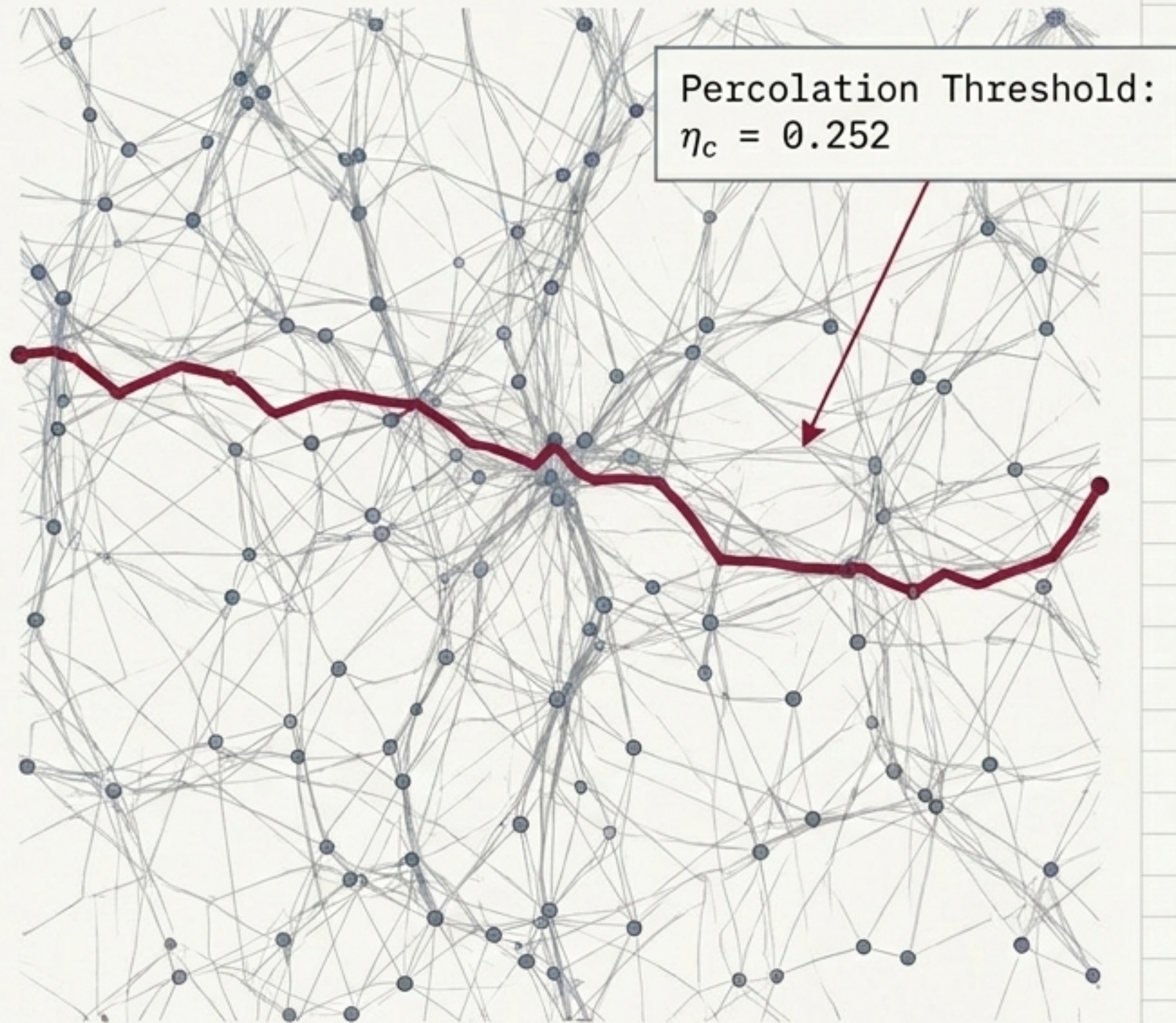
Context

Philcox and Torquato map the large-scale distribution of matter as a disordered heterogeneous medium rather than relying on simple two-point correlation functions.

The Shift

The cosmic web simultaneously satisfies large-scale hyperuniformity (imposed by primordial physics) and small-scale percolation structure (imposed by gravitational clustering).

Reachability in the Cosmos



The standard Poisson threshold for percolation is 0.343 . However, cosmological simulations percolate much earlier, at a reduced density of $\eta_c = 0.252$.

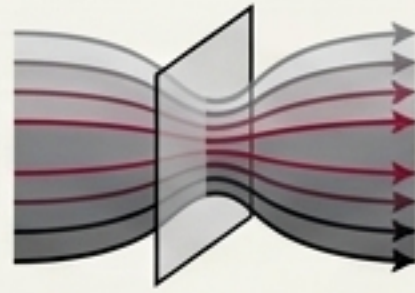
Key Insight: The pair-connectedness function $P_2(r; \eta)$ acts as a massive reachability statistic. It contains cosmological information equivalent to observing 25 times more galaxies. It asks: *which configurations in the admissible space are mutually reachable through the percolating structure?*

THE SYNTHESIS ARC

PHYSICAL SCALE	KEY VARIABLE	THE OLD UNIFORM VIEW	THE NEW STRUCTURED VIEW
Compact Stars (Nucleonic)	ϵ (Transition Width)	Global Equation of State	Stratified Equilibrium Boundaries
Early Galaxies (Galactic)	τ_{burst} (Burst Timescale)	Fixed Spectral Taxonomy	Bursty Temporal Phase
Interstellar Medium (Interstellar)	R (Latent Reachability)	Isolated Tracers	Reservoir / Future Capacity
Cosmic Web (Cosmological)	η_c (Percolation)	Two-Point Correlation	Percolating Constraint Geometry

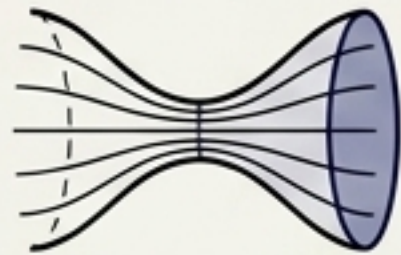
Takeaway: Across four orders of magnitude, the structural role remains identical: transition scales, reservoirs, and connectivity replace uniform bulk properties.

The Interpretive Vocabulary



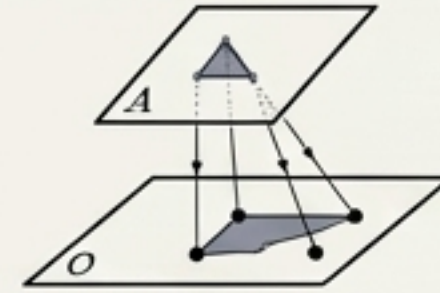
RSVP (Relativistic Scalar-Vector Plenum)

Stratification is primary, not accidental. Observable structure is determined more strongly by the **gradients** $\nabla\Phi$, $\nabla\mathbf{v}$, \mathbf{v} , ∇S at transition regions than by bulk values within coherent phases. **Transition boundaries** carry more explanatory information than the apparent bulk.



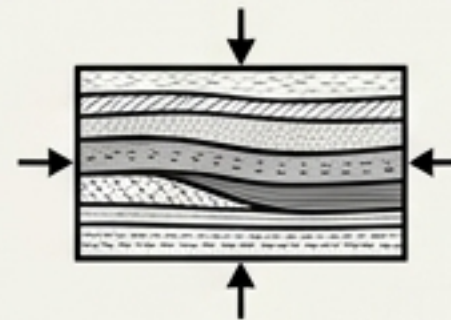
Admissibility

The explanatory order is reversed relative to ordinary dynamical systems theory. Rather than deriving constraints from trajectories, trajectories are interpreted as paths through a pre-existing **admissible region** A whose geometry—volume, **curvature**, **bottlenecks**, **connectivity**—determines what evolutions are possible. The admissible set is conceptually prior to any particular trajectory.



CLIO

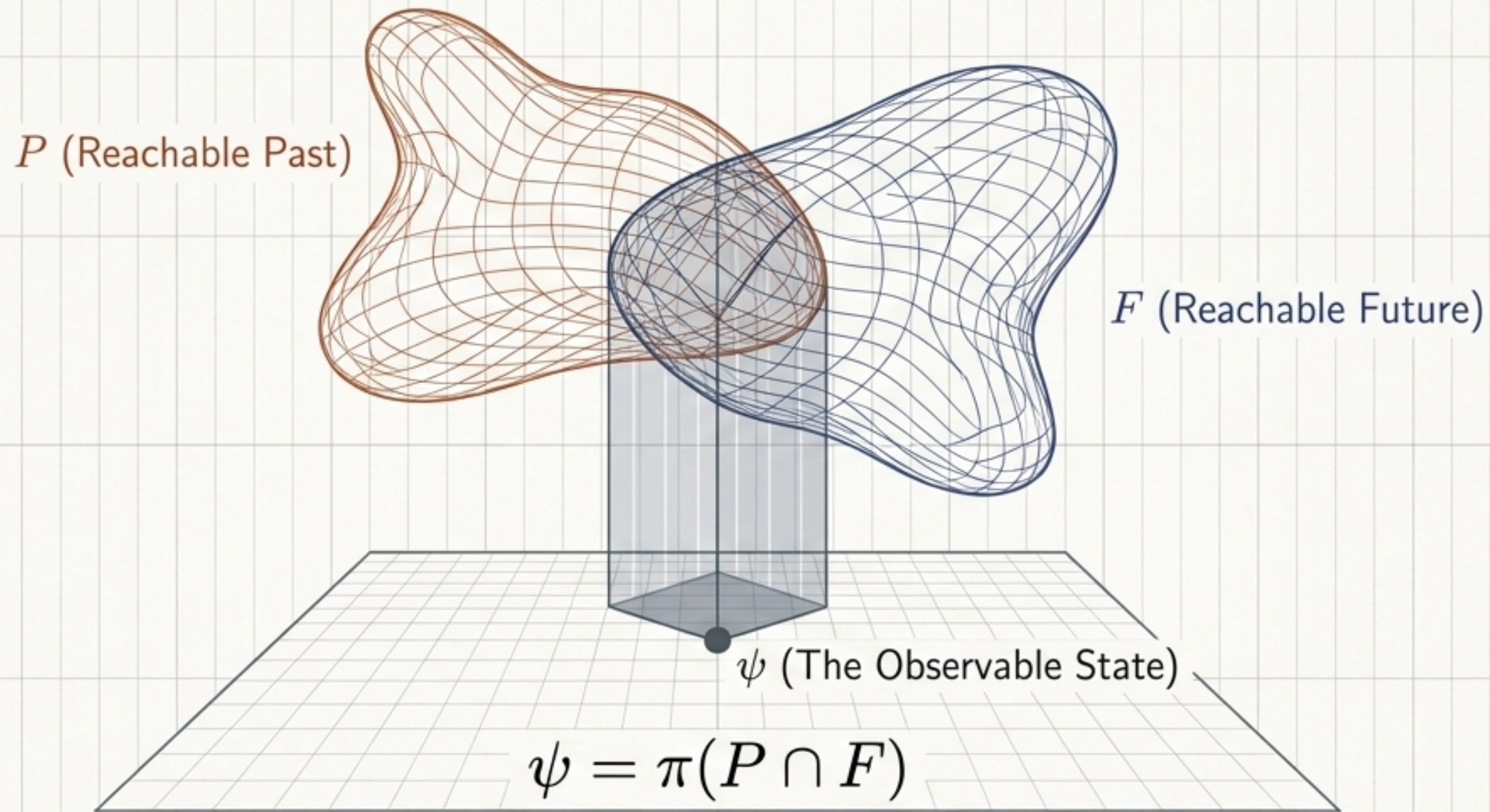
The fundamental object is the **admissible configuration space** A , not any particular state. Observations are projections $\pi: A \rightarrow O$ of that space onto the observable manifold. Physical objects are images of admissible structure under observational projection, not primary entities.



Frozen Processes

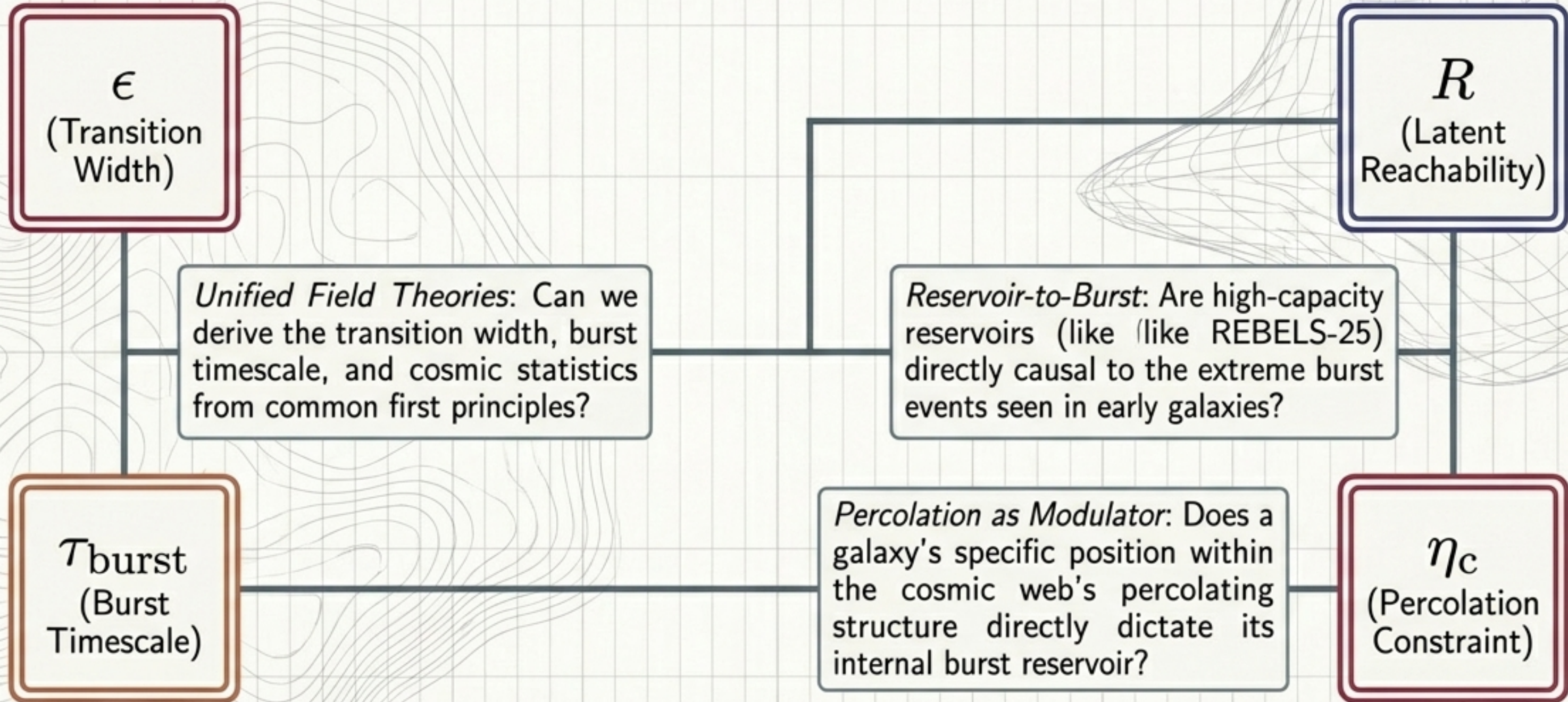
An object is a compressed process: $\psi = C[\gamma]$, where γ is a **historical trajectory** and C is a **compression operator** preserving only dynamically stable information. The object is not a thing that has a history; it is the history, stabilised at its current stage.

The Reachability Decomposition



A physical object is not a fundamental entity. It is the projected intersection of its **reachable past** and its **reachable future**. Its observable properties are purely determined by how much of its **admissible past** has been traversed, how much of its future remains accessible, and what transitions connect the two.

Open Questions & The Future of Astrophysics



*The grammar of configuration spaces is already present in the data.
The next era of astrophysics will be writing the language to read it.*