Fossil Manifolds and Mediated Extraction

LAP1-B, Regulated Instability, and the Geometry of Observability

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> The most informative structures in the universe are often both maximally preserved and maximally inaccessible.

Abstract

The recently reported JWST spectroscopy of LAP1-B — an ultra-faint galaxy at redshift $z \approx 6.6$ with oxygen abundance $(4.2 \pm 1.8) \times 10^{-3}$ solar, stellar mass below $3{,}300\,M_\odot$, and dynamical mass of order $10^7\,M_\odot$ — provides an unusual occasion for reflection on the epistemology of preserved systems. This essay argues that LAP1-B exemplifies a general principle: systems with the highest informational value are frequently not the largest or most chemically evolved, but the least overwritten. Beginning from observational facts, we develop this principle through three interlocking operator classes. First, we characterize *emergence* through the band-limited instability formalism of Scalar Irruption via Entropic Differential (SIED), in which a preferred correlation length $\ell \sim \sqrt{\kappa/|f''(\bar{n})|}$ constrains which modes of structure are physically admissible. Second, we analyze *preservation* through two distinct mechanisms: sparse internal history (the chemical event log that remains readable because so few enrichment events have occurred) and reionization-induced quenching (the temporal operator that froze the chemical record by suppressing subsequent star formation). Third, we read the gravitational lensing geometry as *extraction*: the physical amplification that makes an otherwise permanently inaccessible low-entropy fossil detectable at cosmological distances. The essay concludes that the deepest observational access to early-universe structure comes not through the brightest or most massive objects, but through the rarest coincidence of minimal overwriting and maximal geometric mediation — a coincidence that LAP1-B uniquely instantiates.

1 Least Overwritten Systems

Most of what we call chemical evolution in galaxies is more precisely chemical averaging. Each successive generation of star formation stirs, dilutes, and partially overwrites the abundance record left by previous generations. Supernovae inject metals into a medium already enriched by earlier events; inflows bring pristine gas that dilutes those metals; mergers mix populations with distinct enrichment histories; turbulent transport spreads gradients that would otherwise remain spatially coherent. The cumulative effect is that the interstellar medium of a mature galaxy encodes not any single enrichment event but an integral over many, and the integrand — the specific sequence and geometry of individual nucleosynthetic episodes — is largely irrecoverable from the integral alone.

This is not a merely practical limitation. It reflects something structural about how information is stored in matter. A system that has undergone many enrichment events has high chemical complexity but low historical resolution: the state space accessible to it is large, but the trajectory that produced its current state cannot be reconstructed without independent records of each step. By contrast, a system that has undergone very few enrichment events retains something closer to a first-order record of those events, precisely because subsequent processing has not yet averaged the signal away. Its chemical state is simpler, but its historical legibility is correspondingly higher.

We propose calling such systems *least overwritten* in the sense that their current state retains the highest ratio of recoverable event history to total elapsed time. Antiquity alone does not make a system least overwritten. A very old galaxy with a rich star-formation history is thoroughly overwritten despite its age. A young galaxy that formed early but evolved slowly — whether through low mass, environmental isolation, or reionization-induced quenching — may preserve far more of its initial conditions than a coeval system that underwent vigorous enrichment. Least overwritten is therefore an informational category, not a chronological one.

Principle 1 (Informational Privilege of Low-Averaging Systems)**.** Among physically comparable systems, those that have undergone the fewest averaging operations over their history retain the highest density of recoverable information per observable degree of freedom.

The corollary is that the instruments capable of reading such systems must match the sparsity of the record: a detector calibrated for high-flux, chemically complex sources will systematically miss the faintest, most primitive signals. This creates a structural bias in observational surveys toward overwritten systems and away from the very objects whose information content is highest. We return to this selection problem in Section 7.

2 Event-History Legibility

A galaxy's abundance pattern is, in a precise sense, a projection of its enrichment history onto the space of measurable ratios. The projection is lossy: many distinct enrichment histories can produce similar abundance patterns, and the projection operator — the combined action of nucleosynthesis, mixing, fallback, and chemical evolution — discards information at every step. Nevertheless, for a system that has undergone very few enrichment events, the projection is substantially less lossy than for a chemically mature system, because fewer intermediate states have intervened between the first events and the currently observable state.

In sufficiently primitive systems, individual enrichment events may remain legible not merely as integrated signatures but as geometrically specific imprints. The carbon-to-oxygen ratio is a particularly sensitive indicator because its value depends strongly on which fraction of each supernova's yield survives to enter the subsequent gas phase. In energetic core-collapse supernovae, both carbon and oxygen are produced and largely expelled into the surrounding medium. In the so-called "faint" Population III supernovae, where the explosion energy is low enough that the oxygen-rich inner layers undergo gravitational fallback into the central remnant while the carbon-rich outer layers are ejected, the result is a characteristically elevated C/O ratio at very low total metallicity (Iwamoto et al., 2005; Nomoto et al., 2006).

This is not merely a compositional signature. It is a record of a specific dynamical asymmetry in the propagation of nucleosynthetic products: certain outputs of stellar nucleosynthesis were prevented from entering the subsequent evolutionary pathways of the system, not by random chance but by the physical geometry of the collapse. The resulting abundance pattern therefore encodes not only what elements were present but which physical channels remained open for their propagation. In a chemically mature galaxy, repeated mixing would erase much of this asymmetry. In a system that has experienced only one or a few such events, the asymmetry survives as a nearly unprocessed record of the earliest selective propagation.

It is in this sense that chemical abundances in primitive systems function as an *event log in matter*: a sparse, partially ordered record of irreversible transitions whose outputs became the initial conditions for everything that followed. The log is readable precisely because so little has been written over it.

Principle 2 (Event Logs in Matter)**.** In sufficiently low-averaging systems, observable abundance structures may retain partially recoverable records of specific irreversible physical transitions, allowing matter distributions to function as sparse historical encodings of prior dynamical events.

3 LAP1-B as a Preserved Enrichment Manifold

3.1 Chemical Primitivity and Low Averaging

The JWST spectroscopy of LAP1-B (Nakajima et al., 2026) presents a system whose properties align with the least-overwritten category in a particularly striking way. The galaxy is observed at redshift $z_{\text{spec}} = 6.625 \pm 0.001$, corresponding to a cosmic age of approximately 800 Myr after the Big Bang. It is essential to note that this redshift encodes an observational epoch, not a contemporaneous state: the spectrum recorded by JWST represents the condition of LAP1-B at the moment of photon emission, not the galaxy's present cosmological state. The galaxy itself has almost certainly undergone further evolution during the intervening propagation time. What is preserved observationally is not the object as it currently exists, but a temporally displaced projection carried by light through thirteen billion years of cosmological propagation. Astronomy is, in this respect, always the study of delayed observability.

The gas-phase oxygen abundance of LAP1-B is $(4.2 \pm 1.8) \times 10^{-3}$ solar — well below the previously observed metallicity floor of roughly 2% solar — and its elevated C/O ratio, at approximately one to two times the solar value, is inconsistent with standard chemical enrichment pathways but consistent with nucleosynthetic yields from faint Population III supernovae operating through the fallback mechanism described in Section 2. The ionizing radiation field offers an independent convergent constraint. The ionizing-photon production efficiency satisfies $\log[\xi_{\text{ion}}] > 26.1$, a value incompatible with metal-enriched stellar populations or black-hole accretion but consistent with either metal-free Population III stars or extreme Population II stars with a top-heavy initial mass function. These three independent observational lines — oxygen abundance, C/O ratio, and ionization hardness — each point toward the same conclusion: the stellar population responsible for LAP1-B's observable state at the emission epoch is among the least chemically processed known. Repeated enrichment events progressively transform discrete historical signatures into integrated chemical averages whose originating trajectories become increasingly irrecoverable; at the emission epoch, LAP1-B shows every indication that this averaging process has barely begun.

3.2 Dynamical Primitivity and Sparse Tracing

The mass budget adds a structurally distinct dimension of primitivity. The stellar mass is constrained by the absence of a detectable stellar continuum to below $M_\star <$

$3{,}300\,M_\odot$ — a quantity more typical of a massive star cluster than a conventional galaxy — while the dynamical mass, inferred from Hα emission-line broadening, is of order $M_{\mathrm{dyn}} \sim 10^7\,M_\odot$. The implied baryonic fraction falls below approximately 1%. The luminous component is therefore not the dynamically dominant constituent of the system; it is a sparse visible tracer of a much larger organizing structure inferred only through its gravitational effects.

This dynamical primitivity is distinct from the chemical primitivity discussed above, though the two reinforce each other. Chemical primitivity reflects the absence of overwriting by successive nucleosynthetic episodes. Dynamical primitivity reflects the absence of baryonic feedback: a stellar mass of $M_\star < 3{,}300\,M_\odot$ cannot generate the supernovae, stellar winds, or AGN activity needed to substantially reshape the dark matter potential well it inhabits. The baryonic matter has not participated in forming the gravitational structure it traces; it merely marks its minimum. These two forms of primitivity together make LAP1-B an unusually clean readout of both early enrichment geometry and early gravitational organization, each preserved by the same underlying sparsity of its evolutionary history.

4 Constraint Basins and Sparse Tracers

4.1 The Standard Halo Interpretation

The standard ΛCDM interpretation of LAP1-B's mass budget treats the dark matter halo as a pre-existing gravitational scaffold into which baryons have condensed. The luminous stellar component is then understood as baryonic matter that has settled to the potential minimum of this scaffold, with the large dynamical-to-stellar mass ratio simply reflecting the efficiency with which the halo assembled mass relative to the efficiency with which the baryons converted gas into stars. On this view, the extreme mass ratio is surprising in degree but not in kind: it represents the lower tail of a continuous distribution of halo star-formation efficiencies, with LAP1-B occupying the least efficient extreme.

4.2 The Constraint-Basin Reinterpretation

The following reinterpretation does not modify the underlying gravitational dynamics. Rather, it changes which structural features are treated as epistemologically primary.

An alternative descriptive framing, more natural within the RSVP/SIED interpretive framework, inverts the phenomenological emphasis. Rather than treating the dark matter halo as a container that the baryons fall into, one can read the luminous matter as marking the deepest observable point of a constraint basin — by which we mean the dynamically admissible region toward which trajectories converge under the effective organization of the system — whose full extent is inferred only dynamically. The baryons do not fill the basin; they indicate where it is. They function as tracer particles in the sense of fluid dynamics: sparse probes whose positions reveal the geometry of a larger flow field that would otherwise be invisible.

Within the standard hierarchical picture, the dark matter halo functions conceptually as a pre-existing container into which baryons subsequently condense. The constraint-basin framing instead treats the luminous baryons as sparse tracers marking the minima of an already-organized dynamical field. ΛCDM takes the particle inventory as fundamental and derives the organizing structure from it; the constraint-basin framing takes the organizing structure as fundamental and treats the particle inventory as its sparse observable projection.

4.3 Epistemological Consequences of Sparse Tracing

At LAP1-B's scale, the distinction between these framings is nearly tractable in principle, precisely because the baryonic component is so sparse that it genuinely cannot significantly reshape the potential well it inhabits. In a massive galaxy, baryonic feedback — stellar winds, supernova-driven outflows, AGN jets — substantially modifies the dark matter distribution on timescales comparable to or shorter than the Hubble time, entangling the constraint geometry and the particle content in ways that are difficult to disentangle. In a system with $M_\star < 3{,}300\,M_\odot$, no such modification has occurred. The baryons are tracers in a nearly pure sense: they probe the organizing structure without participating in its formation.

The epistemological consequence is significant. In any system where the visible matter has substantially modified the organizing structure, reading the constraint geometry from the visible distribution requires a model of the feedback history, introducing degeneracies that limit what can be inferred about the primitive state. LAP1-B largely avoids this complication. The visible matter is too sparse to have meaningfully altered what it traces. This makes LAP1-B one of the cleanest available readouts of gravitational organization in a state prior to substantial baryonic modification, and therefore one of the few systems where the constraint-basin framing and the standard halo framing differ in what they imply about the structure's epistemic accessibility rather than merely about its description.

5 Regulated Instability and Preferred Irruption Scales

5.1 Hierarchical Accumulation and the Standard Picture

The SIED formalism offers a more precise account of why an object like LAP1-B should exist at all and why it should exist at the scale it does. In the standard hierarchical picture of structure formation, small-scale structure forms first and subsequently merges into larger halos. The existence of an isolated, extremely low-mass object at $z \approx 6.6$ is not, within this picture, surprising — it simply represents a halo at the low end of the mass function. What is somewhat surprising is the object's apparent isolation in chemical parameter space: its metallicity is not merely low but discontinuously low relative to contemporaneous systems, occupying a regime below what was previously identified as a metallicity floor.

5.2 Threshold Instability and Spinodal Analogy

The SIED approach begins from a different structural assumption. Rather than treating structure formation as hierarchical accumulation driven by gravitational instability in an expanding medium, it treats it as a threshold instability in a conserved scalar field. The SIED instability mechanism is structurally analogous to spinodal decomposition in condensed matter systems, where a formerly homogeneous background loses local stability and spontaneously separates into coherent domains once the curvature of the free-energy landscape changes sign. The relevant criterion is therefore a sign change in the free-energy curvature of the background state,

$$f''(\bar{n}) < 0, \tag{1}$$

where $\bar{n}$ is the mean field density and f is the local free-energy functional. When condition (1) is satisfied, the homogeneous background becomes locally unstable to perturbations, and structure irrupts into the formerly smooth medium — not through gradual accumulation but through a sudden local phase separation driven by the loss of convexity in the free-energy landscape.

5.3 Structural Rather Than Predictive Mathematics

The mathematical relations introduced in this subsection are not presented as quantitative fits to the specific observational parameters of LAP1-B. Their function is instead structural and classificatory: they define a formal vocabulary for regulated instability, preferred mode selection, and finite-band irruption within a conserved medium. Readers should interpret the equations that follow as an archetypal instability relation rather than a direct predictive calculator for the observed dimensions of LAP1-B.

The crucial feature of SIED that distinguishes it from unconstrained gravitational collapse is the regulator term. The instability growth rate takes the form

$$\gamma(k) = ak^2 - bk^4, \tag{2}$$

where k is the perturbation wavenumber and $a, b > 0$. Equation (2) should be understood as defining the structural logic of band-limited irruption, not as a fitted model. The ak^2 term drives instability at all scales, while the bk^4 term suppresses growth at high wavenumbers, preventing arbitrary ultraviolet runaway. The regulated growth rate has a maximum at $k_\star = \sqrt{a/2b}$, defining a preferred irruption scale. Below $k_\star$, growth is too slow; above $k_\star$, growth is suppressed by the regulator. Only a finite band of modes around $k_\star$ can irrupt efficiently into visible structure.

The preferred spatial scale corresponding to this band is

$$\ell \sim \sqrt{\frac{\kappa}{|f''(\bar{n})|}}, \tag{3}$$

where κ is the gradient coefficient in the free-energy functional. At present, the variables entering equation (3) are not empirically constrained by the available JWST dataset. The correspondence developed here is qualitative and structural rather than numerically fitted; the parameters κ and $f''(\bar{n})$ would need to be constrained against independent observational data before any quantitative claim about scale-selection could be made. This correlation length is not a free parameter in principle, however: it is set by the physical properties of the background state at the moment of irruption. Structure does not emerge at arbitrary scales and subsequently filter down or up through a merger hierarchy; instead, it emerges at a physically preferred scale determined by the local curvature of the free-energy landscape.

5.4 Interpretive Consequences for LAP1-B

LAP1-B's unusual compactness and apparent isolation in chemical parameter space are naturally interpreted within this framework as evidence of constrained mode selection rather than incomplete hierarchical growth. The object is not surprisingly small for its epoch; it is near the preferred irruption scale for a localized instability in a medium still close to the convexity boundary of its free-energy landscape. Its extreme chemical primitivity corresponds to a region of the plenum that crossed the instability threshold early and locally, forming a coherent low-complexity structure before the surrounding medium had undergone substantial entropic processing. In this reading, LAP1-B does not represent a fragment of a larger hierarchy that failed to grow; it represents a preferred mode that irrupted near its natural correlation length and has since been preserved against further averaging by the very sparsity of its subsequent evolution.

SIED does not provide an alternative microphysical account that would observationally distinguish itself from ΛCDM at the level of LAP1-B's reported data. What it offers is a different higher-level description of the same phenomenology: a language in which scale-selection, constraint-basin structure, and instability thresholds are primitive rather than derived. The comparison with the observational findings is interpretive rather than evidential. The argument is structural, not numerical.

6 Historical Encoding and the Admissibility of Propagation

6.1 Astrophysical Mechanism

The fallback mechanism that produces LAP1-B's elevated C/O ratio is, at the level of plasma physics, a straightforward dynamical process: the explosion energy is insufficient to overcome the gravitational binding energy of the oxygen-rich inner layers, which therefore fall back onto the central remnant rather than being expelled into the surrounding medium. The carbon-rich outer layers, less tightly bound and structurally positioned to receive the initial momentum of the shock, escape into the interstellar gas. The result is a characteristic chemical signature: elevated C/O at very low total metallicity. This is the complete physical account, and it requires no supplement from any non-standard framework.

6.2 Interpretive Mapping onto Spherepop

The preceding mechanism is entirely standard astrophysical plasma dynamics. The Spherepop framework does not replace this account, but instead provides a higher-order descriptive vocabulary for characterizing the selective propagation structure implicit within it.

Mapping this fallback process onto the Spherepop framework, it instantiates what can be called a *propagation filter*: a physical constraint that selectively allows certain products of an irreversible event to persist into the state space available to the system's future evolution, while preventing others from doing so. The oxygen-rich inner layers are dynamically refused entry into the ambient gas; the carbon-rich outer layers are admitted. The system's subsequent chemistry reflects not the full nucleosynthetic yield of the event but the filtered yield — those products that survived the propagation constraint.

Spherepop does not treat this filter as operating through any semantic or intentional mechanism. The refusal of oxygen to propagate is not a "choice" made by the system or by any abstract operator; it is the consequence of specific initial conditions, explosion energetics, and gravitational geometry. What Spherepop contributes is a vocabulary for describing the structural logic of such constraints: the observation that physical systems routinely generate irreversible events whose outputs are selectively admitted or blocked from future evolutionary pathways, and that the pattern of admissions and blockings constitutes a kind of historical record encoded in the system's current state.

In the case of LAP1-B, this record is unusually readable because so few subsequent events have been written over it. The galaxy's current C/O ratio is not merely a chemical datum; it is a partially preserved record of which physical channels were open and which were closed during the earliest nucleosynthetic episodes of its history. In a chemically mature galaxy, successive rounds of enrichment would progressively overwrite this record, replacing it with an integrated average over many such episodes. Here, the record from one or at most a few events remains nearly intact. The galaxy's chemistry functions as an event log, and the log is still sparse enough to be read entry by entry rather than only as an average.

7 Spatial and Temporal Mediation

Gravitational lensing and cosmological reionization operate on primitive systems in fundamentally different ways. Lensing is a spatial extraction mechanism: it amplifies otherwise inaccessible signals across geometric distance. Reionization, by contrast, is a temporal preservation mechanism: it suppresses the subsequent evolutionary processes that would otherwise overwrite primitive chemical records. Both are mediation operators in the sense that each brings into the recoverable range a signal that would otherwise remain permanently inaccessible, but they act on different properties of the system and at different moments in its history.

7.1 Gravitational Lensing as Spatial Extraction

LAP1-B is observable at all only because the line of sight from the observer to the galaxy passes through the gravitational lensing cluster MACS J0416.1-2403, which amplifies the galaxy's apparent flux by a factor of approximately 100. Without this amplification, the galaxy would fall below the detection threshold of any existing instrument, including JWST. The lensing geometry is not a detail of the observation; it is the condition of its possibility.

This circumstance has a straightforward observational explanation: gravitational lensing by a massive foreground cluster bends and focuses light from background sources, increasing their apparent brightness in proportion to the solid angle subtended by the Einstein ring of the lens. The amplification factor of ~ 100 corresponds to an effective increase of five magnitudes, bringing a source that would be undetectable in unlensed conditions into the range of spectroscopic accessibility. The physics is well understood, and the lens model can be used to reconstruct the intrinsic properties of the source from its lensed appearance.

What deserves emphasis is the structural role this plays in the epistemology of observational access to primitive systems. The selection problem raised in Section 1 — that surveys systematically favor overwritten systems because primitive systems are too faint to detect — cannot be resolved by improved detector sensitivity alone, at least not within the current technological horizon. The intrinsic luminosity of a system like LAP1-B scales with its stellar mass, and $M_\star < 3{,}300\,M_\odot$ produces a surface brightness below the detection threshold of any foreseeable direct-imaging survey at cosmological distances. The only currently available mechanism for accessing such objects is geometric: the rare coincidence of a suitable lensing mass along the line of sight.

The gravitational lens therefore functions, in this context, as a physical sparse-inference operator: a mechanism that extracts a coherent signal from a source that would otherwise be permanently inaccessible, by performing a geometric amplification that brings the signal above the observational threshold. The lens does not create information; it amplifies access to information that exists but cannot be directly recovered. The operation is analogous, in the language of CLIO inference, to a compression-and-amplification step that allows a low-entropy signal to be decoded from an attenuated projection.

7.2 Reionization as Temporal Preservation

A second mediation operator acts on LAP1-B's history rather than on its visibility. The epoch of reionization — the period during which ionizing radiation from the first massive galaxies and quasars swept through the neutral hydrogen of the early universe, heating and ionizing the intergalactic medium — acted as a quenching mechanism for low-mass halos. For halos with deep gravitational wells, the heating was insufficient to drive gas escape, and star formation continued. For halos as shallow as LAP1-B's, the intense ultraviolet radiation boiled the cold, star-forming gas out of the potential well or heated it above the threshold for continued condensation. Star formation was permanently suppressed.

The same quenching processes that preserve primitive chemical structure by suppressing subsequent star formation also reduce the luminosity of such systems, rendering them progressively less accessible to direct observation. This is the deeper inversion at the heart of the essay's argument: reionization acted as an archive and as a blackout simultaneously. By preventing further enrichment, it froze the chemical event log at a very early entry. By suppressing star formation, it guaranteed that the object emitting the frozen log would be too faint to observe without geometric assistance. The fossil record is preserved by the same mechanism that renders it inaccessible.

The fossil galaxies that survived reionization are precisely those that were too small to sustain star formation against the ionizing radiation field, and they are therefore also the least overwritten. Reionization paradoxically preserves the fossil record by suppressing the enrichment that would overwrite it. The epoch that is usually treated as a destructive and sterilizing episode in galactic history is, for the smallest halos, a temporal preservation operator: it drops the pin on the event log and ensures that nothing further is written into it.

7.3 The Coincidence of Three Independent Conditions

The observation of LAP1-B thus depends on the simultaneous satisfaction of three independent conditions: the galaxy must have remained chemically primitive (low overwriting, governed by sparse early enrichment); it must have remained dynamically tiny (low mass, enabling reionization quenching and preventing baryonic feedback); and the line of sight must have passed through a massive lensing cluster (geometric amplification across spatial distance). The failure of any one condition would have made the observation impossible. The galaxy's chemical primitivity and dynamical smallness are not incidental properties that happen to make it interesting; they are the same properties that make it nearly impossible to observe. The most informationally rich objects are precisely the hardest to detect.

This inversion has consequences for how we understand the census of early-universe structure. If LAP1-B is representative of a class rather than an anomaly, the population of chemically primitive micro-galaxies in the reionization era may be substantially larger than flux-limited surveys suggest. Most of this population would be permanently inaccessible without lensing assistance, not because the objects do not exist but because the geometric coincidence required to observe them is rare. The fossil record of early galaxy formation is likely more populated than our instruments can directly see.

8 The Geometry of Observability

Principle 3 (Inverse Accessibility of Primitive Structure)**.** The systems retaining the highest density of recoverable historical information are frequently those least accessible to direct observation, because the sparsity that preserves their internal legibility also suppresses their observational visibility.

The preceding sections have assembled the components of a broader argument about the structure of observational access to the early universe. We can now state this argument in a unified form organized around three operator classes.

8.1 Emergence Through Regulated Instability

Primitive systems — those that are least overwritten in the sense of Section 1 — carry the highest density of recoverable information about the earliest stages of structure formation. Their chemical patterns encode event histories that more evolved systems have averaged away. Their dynamical structures reflect organizing geometries that baryonic feedback has not yet substantially modified. Their instability signatures, where interpretable through frameworks like SIED, reveal the preferred scales at which structure first irrupts from a near-uniform background, emerging not through gradual hierarchical accumulation but through threshold phase separation at a physically mandated correlation length. In all these respects, primitive systems are epistemically privileged relative to chemically and dynamically mature ones.

8.2 Preservation Through Quenching and Low Averaging

And yet primitive systems are also maximally difficult to observe. Their informational richness derives from the same sparsity that makes them intrinsically faint. A galaxy with $M_\star < 3{,}300\,M_\odot$ is not merely dim; it is, at cosmological distances, effectively invisible without geometric assistance. The flux attenuation that comes from extreme distance and low stellar mass conspires to place the most informative objects precisely below the observational threshold. Reionization compounds this: by quenching star formation and thereby preserving primitive chemical structure, it simultaneously guarantees the low luminosity that makes such objects undetectable without mediation.

8.3 Extraction Through Geometric Mediation

The consequence is that cosmological knowledge of the primitive epoch is structurally dependent on mediated extraction. Direct access is not available. What is available is access through operators — physical, geometric, and instrumental — that amplify attenuated signals into the detectable range. The CLIO framework, which treats inference as the reconstruction of sparse signals from attenuated projections, provides a natural language for describing this structure. Observational cosmology in the primitive regime is not a matter of gathering larger datasets from brighter sources; it is a matter of identifying the rare configurations in which a mediation operator — a gravitational lens, a reionization geometry, an instrumental coincidence — brings a sparse, primitive signal into the recoverable range.

LAP1-B is not merely an early galaxy; it is a demonstration that such configurations exist, and a proof of concept that the fossil record of the earliest enrichment events can, under the right geometric conditions, be read directly from the matter that preserves them.

The deepest observational access to the early universe, in this view, comes not from the largest structures, which are bright but overwritten, nor from the smallest structures in general, which are primitive but inaccessible, but from the rarest coincidence: systems that are minimally overwritten, sitting at preferred irruption scales within a constrained instability spectrum, located at the intersection of a sufficient geometric mediation, and preserved by the same quenching that froze their histories in place. That coincidence is what LAP1-B instantiates. It is small enough to be a fossil, primitive enough for its history to remain legible, and lensed enough to be seen.

The broader implication extends beyond cosmology. Whenever historical overwriting scales faster than observational accessibility, the systems retaining the deepest information about primitive structure will also tend to be the most difficult to observe directly. The problem of recovering origins therefore becomes inseparable from the geometry of mediation itself: the earliest histories survive not in the loudest systems, but in the quietest ones whose signals remain barely recoverable across the intervening layers of propagation, attenuation, and averaging.

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This essay was written in response to the JWST spectroscopy reported by Nakajima et al. (2026). The interpretive frameworks developed here — RSVP, SIED, Spherepop, and CLIO — are theoretical constructs under ongoing development and are not presented as empirically established alternatives to standard cosmological models. The engagement with LAP1-B is interpretive rather than evidential: the Nature paper's findings are fully compatible with ΛCDM and are not claimed here as support for any competing cosmological framework.

References

Atek, H., Ellis, R., Richard, J., et al. Search for ultra-faint galaxies in the reionization era. *Monthly Notices of the Royal Astronomical Society*, 519(1):120–138, 2023.

Barkana, R., and Loeb, A. In the beginning: the first sources of light and the reionization of the universe. *Physics Reports*, 349(2):125–238, 2001.

Bland-Hawthorn, J., and Freeman, K. Near-field cosmology with dwarf elliptical galaxies. *Annual Review of Astronomy and Astrophysics*, 53:631–688, 2015.

Bromm, V., and Larson, R. The first stars. *Annual Review of Astronomy and Astrophysics*, 42:79–118, 2004.

Bromm, V., and Yoshida, N. The first galaxies. *Annual Review of Astronomy and Astrophysics*, 49:373–407, 2011.

Bullock, J. S., and Boylan-Kolchin, M. Small-scale challenges to the ΛCDM paradigm. *Annual Review of Astronomy and Astrophysics*, 55:343–387, 2017.

Carathéodory, C. Untersuchungen über die Grundlagen der Thermodynamik. *Mathematische Annalen*, 67:355–386, 1909.

Colin, J., Mohayaee, R., Rameez, M., and Sarkar, S. Evidence for anisotropy of cosmic acceleration. *Astronomy and Astrophysics*, 631:L13, 2019.

Dekel, A., and Silk, J. The origin of dwarf galaxies, cold dark matter, and biased galaxy formation. *Astrophysical Journal*, 303:39–55, 1986.

Eisenstein, D. J., Zehavi, I., Hogg, D. W., et al. Detection of the baryon acoustic peak in the large-scale correlation function of SDSS luminous red galaxies. *Astrophysical Journal*, 633(2):560–574, 2005.

Fan, X., Carilli, C., and Keating, B. Observational constraints on cosmic reionization. *Annual Review of Astronomy and Astrophysics*, 44:415–462, 2006.

Ferrara, A. The first galaxies and the likely discovery of their fossils in the Local Group. *Monthly Notices of the Royal Astronomical Society*, 421(1):282–294, 2012.

Frebel, A., and Norris, J. E. Near-field cosmology with extremely metal-poor stars. *Annual Review of Astronomy and Astrophysics*, 53:631–688, 2015.

Furlanetto, S. R., Oh, S. P., and Briggs, F. Cosmology at low frequencies: the 21 cm transition and the high-redshift universe. *Physics Reports*, 433(4–6):181–301, 2006.

Gnedin, N. Y. Effect of reionization on structure formation in the universe. *Astrophysical Journal*, 542(2):535–541, 2000.

Greif, T. H. The numerical frontier of the high-redshift universe. *Computational Astrophysics and Cosmology*, 2(3):1–33, 2015.

Iwamoto, N., Nomoto, K., Umeda, H., et al. The first chemical enrichment in the universe and the formation of hyper metal-poor stars. *Science*, 309(5733):451–453, 2005.

Kang, Y., Lee, Y.-W., Kim, Y.-L., et al. Evidence for luminosity evolution of Type Ia supernovae from their local environments. *Astrophysical Journal*, 889(1):8, 2020.

Kycia, R. Entropy and ordering relations in thermodynamics. *Entropy*, 24(3):401, 2022.

Lieb, E. H., and Yngvason, J. The physics and mathematics of the second law of thermodynamics. *Physics Reports*, 310(1):1–96, 1999.

Madau, P., and Dickinson, M. Cosmic star-formation history. *Annual Review of Astronomy and Astrophysics*, 52:415–486, 2014.

Maoz, D., Mannucci, F., and Nelemans, G. Observational clues to the progenitors of Type Ia supernovae. *Annual Review of Astronomy and Astrophysics*, 52:107–170, 2014.

Mo, H., van den Bosch, F., and White, S. *Galaxy Formation and Evolution.* Cambridge University Press, Cambridge, 2010.

Nakajima, K., Ouchi, M., Zhang, Y., et al. An ultra-faint, chemically primitive galaxy forming in the reionization era. *Nature*, 653:363–367, 2026.

Navarro, J. F., Frenk, C. S., and White, S. D. M. A universal density profile from hierarchical clustering. *Astrophysical Journal*, 490(2):493–508, 1997.

Nielsen, J. T., Guffanti, A., and Sarkar, S. Marginal evidence for cosmic acceleration from Type Ia supernovae. *Scientific Reports*, 6:35596, 2016.

Nomoto, K., Tominaga, N., Umeda, H., et al. Nucleosynthesis yields of core-collapse supernovae and hypernovae, and galactic chemical evolution. *Nuclear Physics A*, 777:424–458, 2006.

Planck Collaboration. Planck 2018 results. VI. Cosmological parameters. *Astronomy and Astrophysics*, 641:A6, 2020.

Sarkar, S., Garcia-Bellido, J., and Haugbølle, T. Is the evidence for dark energy secure? *International Journal of Modern Physics D*, 17(14):2505–2516, 2008.

Springel, V., White, S. D. M., Jenkins, A., et al. Simulations of the formation, evolution and clustering of galaxies and quasars. *Nature*, 435:629–636, 2005.

Tegmark, M., Strauss, M., Blanton, M., et al. Cosmological parameters from SDSS and WMAP. *Physical Review D*, 69(10):103501, 2004.

Tolstoy, E., Hill, V., and Tosi, M. Star-formation histories, abundances, and kinematics of dwarf galaxies in the Local Group. *Annual Review of Astronomy and Astrophysics*, 47:371–425, 2009.

Umeda, H., and Nomoto, K. First-generation black-hole-forming supernovae and the metal abundance pattern of the most iron-poor stars. *Nature*, 422:871–873, 2003.

Weinberg, S. The cosmological constant problem. *Reviews of Modern Physics*, 61(1):1–23, 1989.

White, S. D. M., and Rees, M. Core condensation in heavy halos: a two-stage theory for galaxy formation and clustering. *Monthly Notices of the Royal Astronomical Society*, 183:341–358, 1978.

Wise, J. H., Turk, M. J., Abel, T., and O'Shea, B. W. The birth of a galaxy: primordial metal enrichment and stellar populations. *Astrophysical Journal*, 745(1):50, 2012.

Yoshida, N., Omukai, T., Hernquist, L., and Springel, V. Formation of primordial stars in a ΛCDM universe. *Science*, 321(5897):669–671, 2008.