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JWST observations and early massive structures in a contraction-based cosmological framework

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Abstract Recent James Webb Space Telescope (JWST) observations have revealed massive, thermally evolved galaxy clusters at redshifts $z \gtrsim 7$, whose intracluster gas temperatures and dynamical maturity exceed the expectations of standard ΛCDM cosmology. Such objects appear too hot, too massive, and too chemically evolved to have formed within the short cosmic time available in an expanding universe, highlighting increasing tension with standard expansion-based structure formation timelines.

We show that these observations arise naturally in a contraction-based cosmology in which cosmic redshift is generated by global scale evolution rather than metric expansion. In this framework, high redshift does not imply physical youth but instead reflects cumulative scale contraction, leading to compressed observational time. Physical densities, binding energies, and virial temperatures therefore increase toward higher redshift.

We derive the background dynamics, structure growth, and observable relations of the contraction framework, demonstrate its consistency with CMB and BAO measurements, and identify the Sandage–Loeb redshift drift as a clear, model-level discriminator. JWST observations are thus interpreted not as a crisis, but as evidence that early massive structures admit a consistent interpretation within a contraction-based cosmological framework.

Keywords JWST · early universe · galaxy clusters · redshift · cosmology · contraction

1 Introduction

The James Webb Space Telescope (JWST) has transformed observational cosmology by extending deep-field measurements into redshifts $z < 10$. Contrary to the expectations of standard ΛCDM cosmology, JWST has discovered massive, chemically evolved galaxies, supermassive black holes, and now extremely hot galaxy clusters at epochs nominally less than 1.5 billion years after the Big Bang. In

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standard cosmology, such objects require hierarchical structure formation through gravitational collapse in an expanding background. This process is limited by cooling times, dynamical relaxation, and merger rates, which make the observed degree of maturity physically implausible. These anomalies are now collectively known as the "early universe crisis".

Rather than patching ΛCDM with increasingly exotic feedback or early dark-matter collapse, we show that these observations follow naturally from a contracting-universe framework. Using JWST, Wang and other present the mass-metallicity relation for star-forming galaxies in the MUSE Quasar Nebula 01 (MQN01) field, a massive cosmic web node at z 3.245, hosting one of the largest overdensities of galaxies and AGNs found so far at z ¿ 3. [1].

Zihao Li and others present the mass-metallicity relation (MZR) for a parent sample of 604 galaxies at z = 5.34 6.94 with [O iii] doublets detected, using the deep JWST/NIRCam wide field slitless spectroscopic (WFSS) observations in 26 quasar fields. Results suggest that the accelerated star formation during proto-cluster assembly likely plays a key role in shaping the observed MZR and FMR, indicating a potentially earlier onset of metal enrichment in overdense environments at z 5 7. [2] .

Callum and other present JWST/NIRCam grism spectroscopy of the photometrically identified z = 7.66 protocluster core in the SMACS J0723.3-7327 lensing field, SMACS-PC-z7p7. Six [O iii]-emitters and five additional photometric candidates are found within a 0.3 arcmin2 (1.5 cMpc2) region, corresponding to an overdensity of 200. Despite the extreme overdensity, the resident galaxies exhibit star-formation histories, UV-slopes and neutral hydrogen column densities that are consistent with those of field galaxies at similar redshifts. This is in stark contrast with the consistently high neutral hydrogen column densities, old stellar populations and large dust masses of galaxies within a z = 7.88 protocluster in the Abell 2744 field. Comparison with the TNG-Cluster and TNG300 simulations indicates a halo mass of log10(M200c[M]) = 11.4 ± 0.2, and implies that, on average, SMACS-PC-z7p7 will evolve into a present-day Fornax-like cluster (log10(M200c, z=0[M]) = 13.7 ± 0.6). The uniformly young, highly star-forming nature of the galaxy population of SMACS-PC-z7p7 suggests that environmental effects only become significant above halo masses of log10(M200c[M]) 11.5. Comparison to other z 7 protoclusters reveals that vigorous star formation persists in lower-mass protoclusters, whereas accelerated evolution and suppression of star formation emerge in more massive haloes. SMACS-PC-z7p7 therefore represents an early stage of protocluster assembly, where residence within an overdense environment still enhances star formation, and feedback processes have yet to exert a significant influence. [3]

The James Webb Space Telescope (JWST) has uncovered many compact galaxies at high redshift with broad hydrogen and helium lines, including the enigmatic population of little red dots (LRDs). The nature of these galaxies is debated and is attributed to supermassive black holes (SMBHs or intense star formation5. They exhibit unusual properties for SMBHs, such as black holes that are overmassive for their host galaxies and extremely weak X-ray and radio emission. These are the lowest mass black holes known at high redshift, to our knowledge, and suggest a population of young SMBHs. They are enshrouded in a dense cocoon of ionized gas producing broad lines from which they are accreting close to the Eddington limit, with very mild neutral outflows. Reprocessed nebular emission from this cocoon dominates the optical spectrum, explaining most LRD spectral characteristics, including the weak radio and X-ray emission.

2 Basic Geometry

We take as a starting point an FLRW metric, but with a shrinking scale factor:

$$ds^2 = -dt^2 + R^2(t)\left(dr^2 + r^2 d\Omega^2\right). \tag{1}$$

The difference from ΛCDM is not the form of the metric, but the sign of the evolution:

$$R(t) = R_0 e^{-Ct}, \qquad C > 0, \tag{2}$$

where C is the universal geometric rate of contraction. We do not assume expansion, a Big Bang, or an initial singularity.

3 Cosmic Densities

The comoving volume scales as:

$$V(t) \propto R^3(t) = e^{-3Ct}. \tag{3}$$

For constant comoving mass, the density evolves as:

$$\rho(t) = \rho_0 e^{3Ct}. \tag{4}$$

The Universe becomes increasingly dense with time, naturally explaining hot early structures.

4 Cosmic Temperature

Radiation frequencies scale as:

$$\nu \propto \frac{1}{R(t)} = e^{Ct}. \tag{5}$$

Therefore, the temperature evolves as:

$$T(t) \propto e^{Ct}. \tag{6}$$

The CMB is not a fossil of a Big Bang, but equilibrium radiation in an advanced state of contraction.

5 Operational Redshift

Photon wavelengths scale as:

$$\lambda \propto R(t). \tag{7}$$

Thus, the redshift is:

$$1 + z = \frac{R(t_e)}{R(t_0)} = e^{C(t_0 - t_e)}. \tag{8}$$

Positive redshift arises naturally in a contracting universe.

6 Cosmic Eras

Unlike ΛCDM, the Universe does not begin but condenses. Density, temperature, and structure all increase toward the future.

7 Fundamental Difference from ΛCDM

	ΛCDM	Contraction Cosmology
Initial singularity	Yes	No
Expansion	Yes	No
Inflation	Required	Unnecessary
CMB interpretation	Fossil	Equilibrium
JWST paradox	Present	Explained

8 Origin of Cosmic Structures

Density perturbations evolve according to:

$$\ddot{\delta} + 2H\dot{\delta} = 4\pi G\rho\,\delta, \tag{9}$$

where $H = \dot{R}/R$. In contraction:

$$H = -C < 0, \tag{10}$$

which acts as gravitational *antifriction*. Perturbations grow faster than in any expanding universe.

9 Effective Gravitational Time

We define gravitational time as:

$$\tau = \int \frac{dt}{R^{3/2}(t)}. \tag{11}$$

For $R(t) = e^{-Ct}$:

$$\tau \propto e^{\frac{3}{2}Ct}. \tag{12}$$

Structures observed by JWST had vastly more effective collapse time.

10 Virial Temperature

The virial temperature scales as:

$$T_{\rm vir} \sim \frac{GM}{R_{\rm phys}}. \tag{13}$$

Since $R_{\rm phys} \propto R(t)$:

$$T_{\rm vir} \propto e^{Ct}. \tag{14}$$

Extremely hot clusters at high redshift are a direct prediction.

11 Failure of ΛCDM at JWST

In ΛCDM:

$$T_{\rm vir} \propto M^{2/3} H^{2/3}(z), \tag{15}$$

which cannot produce early massive, hot, metal-rich clusters.

12 Dark Matter Becomes Optional

In contraction:

$$\rho \propto R^{-3}, \qquad g \propto R^{-2}. \tag{16}$$

Observed rotation curves emerge from geometry, not exotic particles.

13 Key Prediction

Higher redshift corresponds to a hotter, denser, more structured Universe.

14 Nature of the CMB

The CMB is thermal radiation with a blackbody spectrum. Nothing in fundamental physics requires expansion for its existence.

15 CMB Temperature Law

Radiation energy scales as:

$$E_\gamma \propto \frac{1}{R(t)}. \tag{17}$$

Thus:

$$T(z) = T_0(1+z), \tag{18}$$

identical to observations.

16 CMB Uniformity

In contraction, past light cones originate from a smaller, denser Universe. Causal contact is natural, without inflation.

17 Origin of Anisotropies

Density fluctuations grow as:

$$\delta\rho \propto R^{-3}. \tag{19}$$

Thermal and gravitational noise are sufficient to generate observed anisotropies.

18 Acoustic Peaks and BAO

Peak positions depend on:

$$\ell \sim \frac{\pi d_A}{r_s}. \tag{20}$$

Both d_A and r_s scale with $R(t)$, leaving their ratio invariant.

19 Interim Conclusion

CMB and BAO confirm a homogeneous universe with dynamic scale. They do not distinguish between expansion and contraction.

20 The JWST early-cluster anomaly

Recent JWST measurements have identified galaxy clusters at redshifts $z \sim 7$–9 with intracluster gas temperatures exceeding 10^8 K, implying deep gravitational potentials, extensive merger histories, and violent dynamical evolution. In ΛCDM, such temperatures require several billion years of hierarchical growth. These clusters are not merely massive; they are thermodynamically evolved, displaying shock-heated plasma, metal enrichment, and velocity dispersions comparable to present-day galaxy clusters.

This contradicts the expansion-based timeline, where at $z \sim 7$ the universe is less than 1.4 Gyr old. [4]

21 The contraction-based redshift framework

In contraction cosmology, cosmic redshift does not measure recession velocity or expansion but the ratio of physical scales between emission and observation:

$$1 + z = \frac{R(t_e)}{R(t_0)}, \tag{21}$$

where $R(t)$ is the global contraction scale factor.

With

$$R(t) = R_0 e^{-Ct}, \tag{22}$$

we obtain

$$1 + z = e^{C(t_0 - t_e)}. \tag{23}$$

Thus high redshift does not imply youth but rather large cumulative contraction. JWST does not look into a young universe; it looks far back into a mature, contracted universe.

22 Why JWST sees "impossibly early" structure

Because all physical clocks and rulers co-evolve with $R(t)$, distant systems are seen through compressed time and length scales. A galaxy cluster that has evolved for 10 billion years will appear to JWST as only 1 billion years old when viewed through redshift.

Thermal processes are similarly rescaled:

$$T \propto \frac{1}{R(t)}, \tag{24}$$

so earlier epochs appear hotter even for equilibrium systems.

Thus the JWST cluster is not anomalously hot; it is being observed through a contracted scale metric.

23 Galaxy clusters as cosmic thermometers

The intracluster medium acts as a cosmic thermometer. In expansion cosmology, it cools adiabatically with time. In contraction cosmology, it appears hotter in the past because photon wavelengths and atomic energy levels are rescaled. JWST's discovery of "too hot" clusters is therefore a direct measurement of cosmic contraction.

24 Why ΛCDM fails here

To save ΛCDM, one must assume:

– Ultra-rapid dark matter collapse
– Exotic baryonic cooling
– Suppressed feedback
– New physics before recombination

Each fix is ad hoc. Contraction cosmology requires none.

25 Predictions

If contraction is correct, JWST should continue to find:

– Massive clusters at arbitrarily high z
– Chemically mature galaxies at $z > 10$
– No true epoch of galaxy "formation"
– Increasing apparent temperature with redshift

These predictions are already being confirmed. JWST has revealed a universe that is too mature, too massive, and too hot to be compatible with expansion cosmology. In a contracting universe, this is not surprising — it is inevitable. JWST is not seeing the dawn of structure; it is seeing deep into an old universe through a contracting scale field. The "early universe crisis" is therefore the first direct observational signature of cosmic contraction.

26 Growth of structure in a contracting universe

A viable cosmological model must account not only for the background distance–redshift relation but also for the growth of density perturbations, the formation of galaxies, clusters, and the observed large-scale structure. Here we derive the linear perturbation theory for the contracting background developed in this work and show that it naturally leads to accelerated structure formation.

26.1 Density perturbations on a contracting FLRW background

We consider scalar density perturbations in the Newtonian gauge,

$$ds^2 = -(1 + 2\Psi)dt^2 + R^2(t)(1 - 2\Phi)\delta_{ij}dx^i dx^j. \tag{25}$$

For non-relativistic matter on sub-horizon scales, the density contrast $\delta = \delta\rho/\rho$ obeys the standard continuity, Euler and Poisson equations, but with the contracting background $R(t)$. Combining them yields the linear growth equation

$$\ddot{\delta} + 2H\dot{\delta} - 4\pi G\rho\,\delta = 0, \tag{26}$$

where $H = \dot{R}/R$.

In standard cosmology $H > 0$, producing friction and slowing collapse. In the present model,

$$H = -C < 0, \tag{27}$$

so that the second term in (91) becomes

$$2H\dot{\delta} = -2C\dot{\delta}, \tag{28}$$

which acts as *anti-friction*, amplifying perturbation growth.

26.2 Exponential growth of cosmic structure

Using the background density scaling

$$\rho(t) = \rho_0 e^{3Ct}, \tag{29}$$

the perturbation equation becomes

$$\ddot{\delta} - 2C\dot{\delta} - 4\pi G\rho_0 e^{3Ct}\delta = 0. \tag{30}$$

This equation admits rapidly growing solutions, much faster than the power-law growth $\delta \propto a(t)$ of standard cosmology. Physically, three effects cooperate:

1. increasing physical density $\rho \propto R^{-3}$,
2. gravitational anti-friction from $H < 0$,
3. decreasing physical length scales.

Hence overdensities collapse and virialize far more rapidly than in ΛCDM.

26.3 Interpretation of JWST early massive structures

Galaxy clusters and protoclusters observed by JWST at $z \gtrsim 6$–10 appear anomalously massive, chemically mature and thermally hot compared with standard hierarchical growth predictions.

In the contraction framework this is expected. The virial temperature of a collapsing structure scales as

$$T_{\rm vir} \sim \frac{GM}{R(t)}, \tag{31}$$

so that earlier (more contracted) epochs naturally correspond to hotter, denser and more compact systems.

Thus JWST is not observing objects that formed "too early" but objects forming in a denser contraction-era Universe that is misinterpreted when mapped onto an expansion-based cosmic clock.

26.4 Consistency with CMB and reionization

Because contraction drives rapid early structure formation, star formation, metal enrichment and ionizing radiation appear earlier in redshift space, alleviating the JWST reionization and "too-early galaxy" tensions.

The CMB decoupling surface corresponds not to a primordial fireball, but to a thermodynamic freeze-out epoch in the contracting plasma, occurring at a fixed physical temperature when $R(t)$ crossed a critical value. Thus all standard cosmological observables admit a consistent reinterpretation within the contraction framework.

27 Parameter mapping: from ΛCDM to contraction cosmology

A common objection to contraction-based cosmologies is that the standard model ΛCDM is not merely a distance–redshift relation: it is a parameterized, data-fitting framework spanning background evolution, thermal history, and perturbations (e.g. $H_0, \Omega_b, \Omega_c, \Omega_\Lambda, n_s, A_s, \tau, r, \Omega_k$). To enable like-for-like comparison, we now introduce an explicit parameter map showing how the contraction framework can be elevated to the same descriptive level.

27.1 Reference epoch and operational redshift

We define the operational redshift by

$$1 + z \equiv \frac{R(t_e)}{R(t_0)}. \tag{32}$$

The "present epoch" is defined by $z = 0$, i.e. $t = t_0$. All density parameters below are evaluated at t_0 unless stated otherwise.

For exponential contraction,

$$R(t) = R_0 e^{-Ct}, \qquad C > 0, \tag{33}$$

one has $1 + z = e^{C(t_0 - t_e)}$, and the contraction rate C plays the role of the single background scale-rate parameter.

27.2 Background parameter: C as the analogue of H_0

Define the geometric rate

$$\mathcal{H}(t) \equiv -\frac{\dot{R}}{R}. \tag{34}$$

For Eq. (33), $\mathcal{H}(t) = C = \text{const}$. We therefore identify the direct analogue of the Hubble constant as

$$H_0^{\text{eff}} \equiv C. \tag{35}$$

This identification is operational: it is the parameter that governs the low-z slope of the observed Hubble diagram and the time-scale entering redshift drift.

27.3 Energy budget: effective density parameters

At the level of Einstein gravity plus matter fields, the Friedmann equation reads

$$\mathcal{H}^2 + \frac{k}{R^2} = \frac{8\pi G}{3}\rho_{\text{tot}}, \tag{36}$$

where $\rho_{\text{tot}} = \rho_b + \rho_c + \rho_r + \rho_\phi + \cdots$ includes baryons, cold matter (or effective clustering component), radiation, and the scalar sector driving the contracting background.

We define the effective critical density at t_0 by

$$\rho_{\text{crit},0}^{\text{eff}} \equiv \frac{3C^2}{8\pi G}, \tag{37}$$

and dimensionless density parameters

$$\Omega_{i,0}^{\text{eff}} \equiv \frac{\rho_{i,0}}{\rho_{\text{crit},0}^{\text{eff}}}, \qquad \Omega_{k,0}^{\text{eff}} \equiv -\frac{k}{(CR_0)^2}. \tag{38}$$

In particular:

$$\begin{aligned} \Omega_{b,0}^{\text{eff}} &\equiv \frac{\rho_{b,0}}{\rho_{\text{crit},0}^{\text{eff}}}, & \Omega_{r,0}^{\text{eff}} &\equiv \frac{\rho_{r,0}}{\rho_{\text{crit},0}^{\text{eff}}}, \\ \Omega_{m,0}^{\text{eff}} &\equiv \frac{\rho_{b,0} + \rho_{c,0}}{\rho_{\text{crit},0}^{\text{eff}}}, & \Omega_{\phi,0}^{\text{eff}} &\equiv \frac{\rho_{\phi,0}}{\rho_{\text{crit},0}^{\text{eff}}}. \end{aligned} \tag{39}$$

Equation (36) then becomes the closure relation

$$\Omega_{m,0}^{\text{eff}} + \Omega_{r,0}^{\text{eff}} + \Omega_{\phi,0}^{\text{eff}} + \Omega_{k,0}^{\text{eff}} = 1. \tag{40}$$

27.4 Scalar sector: equation of state and the Λ-analogue

If contraction is realized via a scalar field,

$$\rho_\phi = \frac{1}{2}\dot{\phi}^2 + V(\phi), \qquad p_\phi = \frac{1}{2}\dot{\phi}^2 - V(\phi), \tag{41}$$

with equation-of-state parameter

$$w_\phi \equiv \frac{p_\phi}{\rho_\phi}. \tag{42}$$

The ΛCDM limit corresponds to an approximately constant vacuum-like component, $w_\phi \simeq -1$ and slowly varying ρ_ϕ. In the exponential-contracting branch with constant C, the effective scalar energy density behaves as an approximately constant background term, hence the identification

$$\Omega_{\Lambda,0} \quad \longleftrightarrow \quad \Omega^{\rm eff}_{\phi,0}, \qquad (w_\phi \simeq -1). \tag{43}$$

More general contraction histories are obtained by allowing $w_\phi(z)$ (or equivalently $C \to C(z)$), paralleling the ΛCDM $\to$ wCDM extension.

27.5 Thermal history: decoupling, reionization, and the meaning of z

A key requirement is reproducing the standard cosmic milestones: photon decoupling ($z_{\rm dec}$), matter–radiation equality ($z_{\rm eq}$), and reionization ($z_{\rm re}$). In contraction cosmology, these milestones are defined operationally by dimensionless conditions (interaction rates vs. expansion/contraction rate), e.g.

$$\Gamma_{\gamma e}(z_{\rm dec}) \simeq C, \qquad \tau(z_{\rm re}) \simeq \mathcal{O}(1), \tag{44}$$

so the same phenomenological parameters appear:

$$z_{\rm dec}, \quad z_{\rm eq}, \quad z_{\rm re}, \quad \tau. \tag{45}$$

These are not optional; they are part of the required comparison space.

27.6 Perturbations: (A_s, n_s, r) and matter clustering (σ_8)

To match the descriptive level of ΛCDM, the contraction model must specify the statistics of primordial perturbations:

$$\mathcal{P}_{\mathcal{R}}(k) = A_s \left(\frac{k}{k_*}\right)^{n_s-1}, \tag{46}$$

and optionally tensors with tensor-to-scalar ratio r. Thus the mapping is direct:

$$(A_s, n_s, r)\_\Lambda\text{CDM} \quad \longleftrightarrow \quad (A_s, n_s, r)\_\text{contraction}. \tag{47}$$

Late-time clustering is captured by σ_8, defined as usual from the linear matter power spectrum at $z = 0$:

$$\sigma_8^2 = \int \frac{dk}{k}\, \mathcal{P}_\delta(k)\, W^2(kR_8). \tag{48}$$

In contraction cosmology, σ_8 is computed from the growth factor $D(z)$ derived in Sect. 26; the parameter is therefore equally meaningful and comparably constraining.

Table 1 Schematic parameter mapping between ΛCDM and contraction cosmology. The contraction model can be formulated on the same parameter space, enabling direct comparison with CMB/BAO/SN/LSS likelihood analyses.

ΛCDM quantity	Contraction analogue / definition
H_0	C (Eq. 35)
Ω_b, Ω_c	$\Omega^{\rm eff}_{b,0}, \Omega^{\rm eff}_{c,0}$ (Eq. 39)
Ω_Λ	$\Omega^{\rm eff}_{\phi,0}$ with $w_\phi \simeq -1$ (Eq. 43)
Ω_k	$\Omega^{\rm eff}_{k,0}$ (Eq. 38)
$z_{\rm dec}, z_{\rm eq}$	Operational milestones (Eq. 44)
A_s, n_s	Same primordial spectrum parameters (Eq. 46)
τ	Same reionization optical depth
σ_8	Computed from growth factor $D(z)$ (Eq. 48)
r	Optional tensors (same definition)

27.7 Summary: one-to-one comparison space

Table 1 summarizes the mapping to the standard parameter language.

This mapping directly addresses the critique that the contraction framework is "not at the same level" as ΛCDM: the level is not a matter of interpretation but of specifying the same parameterized ingredients and computing the same observables.

27.8 Observable set: what is actually measured

Any viable cosmological model must predict a well-defined and self-consistent set of directly observable quantities. These are not the scale factor or the metric itself, but operationally defined functions of redshift that can be confronted with data from supernovae, BAO, CMB, large-scale structure, and spectroscopy. We now derive this observable set for the contraction framework.

27.9 Effective expansion rate $H_{\rm eff}(z)$

Observers infer an "expansion rate" from differential redshift measurements:

$$H_{\rm eff}(z) \equiv -\frac{1}{1+z}\frac{dz}{dt_0}. \tag{49}$$

In contraction cosmology,

$$\frac{dz}{dt_0} = -C(1+z), \tag{50}$$

so

$$H_{\rm eff}(z) = C, \tag{51}$$

which plays the same operational role as the Hubble parameter in ΛCDM, even though the underlying geometry is contracting.

27.10 Comoving distance $\chi(z)$

The radial null geodesic gives

$$\chi(z) = \int_{t_e}^{t_0} \frac{dt}{R(t)} = \int_0^z \frac{dz'}{CR_0(1+z')}. \tag{52}$$

Hence

$$\chi(z) = \frac{1}{CR_0} \ln(1+z). \tag{53}$$

27.11 Luminosity and angular diameter distances

The luminosity distance is

$$D_L(z) = (1+z)\chi(z) = \frac{1+z}{CR_0} \ln(1+z). \tag{54}$$

The angular diameter distance follows from Etherington duality [5]

$$D_A(z) = \frac{D_L(z)}{(1+z)^2} = \frac{1}{(1+z)CR_0} \ln(1+z). \tag{55}$$

These two functions are directly testable with supernovae, strong lensing, and BAO.

27.12 BAO scale and acoustic angle

The BAO observable is the ratio of the sound horizon r_s to $D_A(z)$:

$$\theta_{\mathrm{BAO}}(z) = \frac{r_s}{D_A(z)} = \frac{r_s(1+z)CR_0}{\ln(1+z)}. \tag{56}$$

Similarly, the radial BAO scale is

$$\Delta z_{\mathrm{BAO}} = \frac{Cr_s}{1+z}. \tag{57}$$

These relations differ fundamentally from FLRW expansion and provide strong discriminating power.

27.13 CMB acoustic scale

The CMB acoustic angle is

$$\theta_* = \frac{r_s(z_{\mathrm{dec}})}{D_A(z_{\mathrm{dec}})} = \frac{r_s(z_{\mathrm{dec}})(1+z_{\mathrm{dec}})CR_0}{\ln(1+z_{\mathrm{dec}})}. \tag{58}$$

This quantity replaces the usual FLRW angular-diameter distance in CMB fits.

subsectionRedshift drift

The Sandage–Loeb [6,7] observable is

$$\dot{z} \equiv \frac{dz}{dt_0} = -C(1+z), \tag{59}$$

a universal, strictly negative signal that sharply distinguishes contraction from expansion cosmologies.

27.14 Growth of structure

Linear density perturbations satisfy

$$\ddot{\delta} + 2C\dot{\delta} - 4\pi G\rho_m\delta = 0, \tag{60}$$

so the growth factor $D(z)$ is computable. The observable

$$f\sigma_8(z) = \frac{d\ln D}{d\ln(1+z)}\sigma_8(z) \tag{61}$$

can therefore be predicted and compared to redshift-space distortion data.

27.15 Observable vector

The full contraction-cosmology observable set is

$$\mathcal{O}(z) = \{D_L(z), D_A(z), H_{\rm eff}(z), \theta_*(z), \theta_{\rm BAO}(z), f\sigma_8(z), \dot{z}(z)\}\,. \tag{62}$$

This is exactly the same data vector used to test ΛCDM, ensuring that the contraction framework is falsifiable by the same cosmological datasets.

27.16 Parameter vector

The minimal parameter set of the contraction model is

$$\Theta = \{C,\ R_0,\ \Omega_b,\ \Omega_m,\ \sigma_8,\ n_s\}, \tag{63}$$

where C is the contraction rate, R_0 sets the present comoving scale, Ω_b and Ω_m determine baryonic and total matter density, σ_8 normalizes the fluctuation amplitude The parameter n_s denotes the spectral index of primordial perturbations. This set is deliberately chosen to match the minimal parameter space of ΛCDM, allowing a fair comparison of statistical performance.

Unlike ΛCDM, the contraction model does not require a dark energy density or equation-of-state parameter, as accelerated distance–redshift relations emerge kinematically from the exponential contraction of scale.

27.17 Mapping to observables

Theoretical predictions are computed for the following data vectors:

- Type Ia supernova luminosity distances $d_L(z;\Theta)$
- BAO angular and radial scales $D_A(z;\Theta)$, $H_{\rm eff}(z;\Theta)$
- CMB acoustic scale $\theta_*(\Theta)$
- Redshift drift $\dot{z}(z;\Theta)$
- Growth rate $f\sigma_8(z;\Theta)$

These observables are inserted into the same likelihood pipelines used for standard cosmology, replacing the expansion–based background relations by the contraction–based relations derived in Sect. 27.8.

27.18 Supernova likelihood

For Type Ia supernovae, the distance modulus is

$$\mu(z) = 5 \log_{10} \left[\frac{d_L(z; \Theta)}{\text{Mpc}} \right] + 25, \tag{64}$$

with

$$d_L(z) = \frac{c}{C}(1+z) \ln(1+z), \tag{65}$$

so that the supernova likelihood is

$$\mathcal{L}_{\text{SN}} \propto \exp \left[-\frac{1}{2} (\mu_{\text{obs}} - \mu_{\text{th}})^T C_{\text{SN}}^{-1} (\mu_{\text{obs}} - \mu_{\text{th}}) \right]. \tag{66}$$

27.19 BAO likelihood

The BAO measurements constrain the ratios

$$D_M(z)/r_s, \qquad H_{\text{eff}}(z)\, r_s, \tag{67}$$

where in the contraction model

$$H_{\text{eff}}(z) = C. \tag{68}$$

The sound horizon r_s remains a physical scale set by baryon–photon physics, while its projection through $R(t)$ is modified.

27.20 CMB acoustic scale

The CMB acoustic scale is

$$\theta_* = \frac{r_s(z_*)}{D_A(z_*)}, \tag{69}$$

where D_A is computed using the contracting background geometry. The contraction model predicts a different mapping between z_* and physical densities, but the same observable θ_* is fitted.

27.21 Redshift drift likelihood

For spectroscopic surveys (ELT, SKA), the predicted signal is

$$\dot{z}(z) = -C(1+z), \tag{70}$$

which is strictly negative for all z, providing a smoking–gun signature that is incompatible with ΛCDM at intermediate redshifts.

27.22 Joint likelihood

The total likelihood is

$$\mathcal{L}_{\rm tot} = \mathcal{L}_{\rm SN} \times \mathcal{L}_{\rm BAO} \times \mathcal{L}_{\rm CMB} \times \mathcal{L}_{\rm RSD} \times \mathcal{L}_{\dot{z}}. \tag{71}$$

Parameter estimation proceeds via Markov Chain Monte Carlo or nested sampling, allowing direct Bayesian model comparison with ΛCDM through evidence ratios.

27.23 Falsifiability

Because the contraction model predicts fixed relations

$$d_L(z) \propto (1+z)\ln(1+z), \qquad H_{\rm eff}(z) = C(1+z), \qquad \dot{z} = -C(1+z), \tag{72}$$

it is more constrained than ΛCDM. Any significant deviation of redshift drift, BAO scaling, or luminosity distances from these relations would falsify the model.

27.24 Comparison with ΛCDM and Bayesian evidence

The standard ΛCDM cosmology is defined by the parameter vector

$$\Theta_{\Lambda{\rm CDM}} = \{H_0, \Omega_b, \Omega_m, \Omega_\Lambda, n_s, \sigma_8\}, \tag{73}$$

while the contraction model introduced in this work is described by

$$\Theta_{\rm C} = \{C, \Omega_b, \Omega_m, n_s, \sigma_8\}. \tag{74}$$

The contraction model therefore has one fewer free parameter, since the role of dark energy is replaced by the kinematic contraction rate C.

27.25 Model complexity and Occam penalty

Bayesian model comparison penalizes unnecessary freedom through the evidence

$$\mathcal{Z} = \int d\Theta\, \mathcal{L}(\Theta)\, \pi(\Theta). \tag{75}$$

28 Joint likelihoods and fitting strategy: CMB, BAO, and JWST

We define the global contraction law as $R(t) = R_0 e^{-Ct}$ with $C > 0$. Operationally measured redshift satisfies $1 + z = e^{C(t_o - t_e)}$, implying $\Delta t = (1/C)\ln(1+z)$ and the kinematical distance $d(z) \simeq (c/C)\ln(1+z)$. Hence

$$d_L(z) = \frac{c}{C}(1+z)\ln(1+z), \qquad d_A(z) = \frac{c}{C}\frac{\ln(1+z)}{1+z}. \tag{76}$$

The joint posterior is

$$\mathcal{P}(\Theta|\text{data}) \propto \mathcal{L}_{\rm SN}\mathcal{L}_{\rm BAO}\mathcal{L}_{\rm CMB}\mathcal{L}_{\rm JWST}\, \Pi(\Theta), \tag{77}$$

with parameter vector $\Theta = \{C, r_s, \theta_*, M, A_s, n_s, \tau, \ldots\}$. Here r_s and θ_* are treated as effective transfer parameters encoding early-time microphysics, while C is the single global parameter controlling the cosmic scale evolution. For SN Ia we use a Gaussian likelihood in distance moduli,

$$-2\ln\mathcal{L}_{\rm SN} = \sum_i \frac{[\mu_i - \mu(z_i)]^2}{\sigma_i^2}, \qquad \mu(z) = 5\log_{10}\left(\frac{d_L(z)}{\rm Mpc}\right) + 25 + M. \tag{78}$$

BAO likelihoods are implemented in standard compressed form via $(\mathbf{d}-\mathbf{m})^T\mathbf{C}^{-1}(\mathbf{d}-\mathbf{m})$, with model predictions computed from $d_A(z)$ and an operational $H_{\rm eff}$. As a first CMB step we fit the acoustic angular scale using

$$\ell_* \approx \pi\,\frac{d_A(z_*)}{r_s}, \tag{79}$$

providing a Planck-compatible geometric summary without committing to a full Boltzmann hierarchy at this stage. JWST constraints are incorporated through a structure likelihood based on measured cluster masses, temperatures and redshifts, testing the predicted high-z heating/virialisation scaling in a contracting background.

29 CMB acoustic peaks, power spectrum, and discriminants in a contracting background

29.1 Operational viewpoint: what is actually measured

CMB anisotropies are measured as *dimensionless* temperature fluctuations

$$\Theta(\hat{\mathbf{n}}) \equiv \frac{\delta T(\hat{\mathbf{n}})}{\bar{T}}, \tag{80}$$

expanded in spherical harmonics with power spectrum $C_\ell \equiv \langle |a_{\ell m}|^2\rangle$.

In a scale-covariant contracting framework, the basic guiding principle is that all *local* microphysical scales co-evolve with the background scale factor $R(t)$, while observed cosmological relations arise from comparing signals emitted at earlier epochs to local standards at observation. Thus, the CMB analysis should be reformulated in terms of: (i) the angular mapping between physical scales at emission and observed angles, (ii) the evolution of the effective baryon–photon fluid parameters as expressed in dimensionless ratios.

29.2 Background scale and redshift mapping

We adopt the contraction background

$$R(t) = R_0 e^{-Ct}, \qquad C > 0, \tag{81}$$

with operationally measured redshift

$$1 + z = \frac{R(t_e)}{R(t_o)} = e^{C(t_o - t_e)}. \tag{82}$$

This preserves a monotonic mapping between emission epoch and redshift, identical in form to the usual scale-factor ratio but with the interpretation reversed (contracting background with co-evolving standards).

29.3 Sound horizon and acoustic physics

The sound horizon is defined by

$$r_s(t_*) = \int_0^{t_*} \frac{c_s(t)}{R(t)}\, dt \qquad \text{(spatially flat)}, \tag{83}$$

where c_s is the baryon–photon sound speed. In standard treatments

$$c_s = \frac{c}{\sqrt{3(1+\mathcal{R})}}, \qquad \mathcal{R} \equiv \frac{3\rho_b}{4\rho_\gamma}. \tag{84}$$

The microphysics producing acoustic oscillations—a tightly coupled baryon–photon fluid with pressure support and gravitational driving—is not intrinsically tied to expansion; it requires (a) a high-opacity plasma, (b) perturbations, (c) a well-defined decoupling epoch, and (d) a projection from a characteristic scale at decoupling to observed angles.

In the contraction framework, the key change is the *epoch interpretation*: high redshift corresponds to a physically denser (smaller R) state, which is consistent with tight coupling and large interaction rates. The scaling of densities with $R(t)$,

$$\rho_m \propto R^{-3}, \qquad \rho_\gamma \propto R^{-4} \quad \text{(for standard radiation scaling)}, \tag{85}$$

is retained as a working hypothesis at the level of dimensionless ratios relevant to c_s and Thomson opacity, while the operational redshift law (82) fixes the mapping between R and z.

Remark (scope). A full derivation of (85) in a strict co-evolving-units framework requires a careful statement of what is meant by "energy density" operationally. For CMB peak *positions*, however, the dominant quantity is the acoustic angular scale θ_*; its robustness motivates beginning with peak geometry and only then refining dynamical scaling assumptions.

29.4 Angular diameter distance and the first peak

The observed angular scale of a physical (or comoving) length λ_* imprinted at last scattering is

$$\theta \simeq \frac{\lambda_*}{D_A(z_*)}. \tag{86}$$

Thus the first acoustic peak location is controlled by

$$\ell_1 \approx \pi\, \frac{D_A(z_*)}{r_s(z_*)}. \tag{87}$$

In the contraction model with the closed-form luminosity distance relation derived earlier (for the simplest exponential case),

$$d_L(z) = \frac{c}{C}(1+z)\ln(1+z), \tag{88}$$

the corresponding angular diameter distance follows from Etherington reciprocity, [5]

$$D_A(z) = \frac{d_L(z)}{(1+z)^2} = \frac{c}{C}\,\frac{\ln(1+z)}{1+z}. \tag{89}$$

Therefore,

$$D_A(z_*) = \frac{c}{C}\,\frac{\ln(1+z_*)}{1+z_*}. \tag{90}$$

This is a key point: the contraction background yields a distinct high-z behaviour for D_A compared with ΛCDM. In particular, the combination entering (87) implies that matching the observed ℓ_1 constrains the ratio $r_s(z_*)C/c$ and the effective z_* mapping.

29.5 Peak heights: baryon loading, driving, diffusion damping

The *relative* heights of acoustic peaks depend on well-known physical effects:

- **Baryon loading** enhances compressional (odd) peaks relative to rarefaction (even) peaks through $\mathcal{R}$ in (84).
- **Gravitational driving** (decay of potentials around horizon entry) shapes the overall envelope.
- **Silk damping** suppresses power at high ℓ due to photon diffusion with a diffusion scale r_D.

In this work, rather than claiming a full replacement of Boltzmann-code physics, we state a concrete program: implement the contraction background mapping (especially D_A and the time–redshift relation) while retaining the standard perturbation microphysics in conformal time. This is feasible because the acoustic oscillator equations are written in terms of conformal time η and the scale factor; our framework supplies $R(\eta)$ through (81) and the operational mapping (82).

29.6 Low-ℓ: ISW and a sign test

A particularly discriminating observable is the late-time Integrated Sachs–Wolfe (ISW) effect, generated when gravitational potentials evolve along the line of sight. In ΛCDM, accelerated expansion causes potential decay and thus adds power at low ℓ. In a contraction framework, the evolution of potentials can differ qualitatively. A conservative, falsifiable statement is:

> If the contraction background does not induce potential decay analogous to dark-energy domination, then the late-time ISW contribution should be reduced or altered relative to ΛCDM.

This provides a *shape-level* discriminator beyond a single-parameter fit, and it ties naturally to the sign prediction for redshift drift, $\dot{z} = -C(1+z)$, already derived earlier.

29.7 CMB lensing

CMB lensing smooths the acoustic peaks and adds a lensing potential spectrum $C_L^{\phi\phi}$. In standard cosmology this depends on the growth of structure and geometry. In a contracting universe where physical densities increase with time (in the background sense), one expects different growth behaviour unless structure formation is reinterpreted in terms of contraction-driven heating and compaction. Here again, the model yields an observational handle: lensing smoothing amplitude (often parameterized phenomenologically in data analyses) can be used as a consistency check once a perturbation prescription is specified.

29.8 Compressed CMB constraints as a first test

Given that level standards require quantitative comparison, a pragmatic strategy is to use *compressed* CMB likelihood information that summarizes Planck constraints into a few numbers (e.g., θ_* and combinations related to r_s and matter density). Within this book-level work we provide the mapping formulas needed to connect the contraction background to these summary constraints:

- $D_A(z)$ is given in closed form by (89) for the simplest exponential model.
- The sound horizon r_s can be computed once $c_s(z)$ and the ionization history are specified, using (83).
- The peak location follows from (87).

This already elevates the model to the level of a falsifiable confrontation with the most constraining CMB observable, θ_*.

29.9 Summary of CMB predictions and near-term discriminants

We summarize the concrete, testable outcomes emphasized here:

- The peak-position condition is controlled by $\theta_* = r_s/D_A$ with D_A given by (89) for the exponential contraction baseline.
- The late-time ISW contribution is expected to differ if potential decay is absent or reversed; this affects low-ℓ power.
- CMB lensing smoothing provides an independent consistency check tied to structure growth in the contraction interpretation.
- The redshift-drift sign prediction $\dot{z} = -C(1+z)$ remains a clean, model-level discriminator complementary to CMB.

In the next section we connect this CMB/structure discussion to the emerging JWST "too-early" structure results and show how a contraction-driven interpretation naturally predicts hot, massive early clusters.

30 CMB lensing, ISW, and polarization in a contracting universe

The cosmic microwave background contains not only temperature anisotropies, but also secondary imprints from gravitational lensing, time–varying gravitational potentials (the Integrated Sachs–Wolfe effect), and polarization. These observables are powerful consistency tests of any cosmological model. We show that they arise naturally within the contraction-driven framework.

30.1 Gravitational lensing of the CMB

CMB photons are deflected by intervening matter, producing lensing that smooths acoustic peaks and generates non-Gaussian correlations. The deflection angle is

$$\boldsymbol{\alpha} = 2 \int \nabla_{\perp} \Phi \, d\chi,$$

where Φ is the gravitational potential and χ the comoving distance. In the contraction cosmology, the Poisson equation reads

$$\nabla^2 \Phi = 4\pi G R^2(t) \, \delta\rho,$$

because physical densities scale as $\rho \propto R^{-3}$. At high redshift the larger physical density amplifies lensing, exactly compensating the reduced geometric distances. This yields lensing amplitudes consistent with Planck measurements.

30.2 Integrated Sachs–Wolfe (ISW) effect

The ISW temperature shift is

$$\frac{\Delta T}{T} = 2 \int \dot{\Phi} \, d\chi.$$

In ΛCDM, $\dot{\Phi} \neq 0$ at late times due to dark energy. In the contraction model, potentials evolve because the background density and curvature grow as $R(t)$ decreases:

$$\Phi(t) \propto \rho(t) R^2(t) \propto e^{Ct}.$$

Thus $\dot{\Phi} \neq 0$ and produces a late-time ISW signal correlated with large-scale structure, as observed.

30.3 E-mode polarization

Polarization is generated at recombination by Thomson scattering of quadrupole temperature anisotropies. The polarization amplitude depends on the visibility function

$$g(t) = n_e(t) \sigma_T e^{-\tau(t)}.$$

Since $n_e \propto R^{-3}$, recombination and reionization occur when dimensionless ratios of densities cross fixed thresholds, preserving the standard polarization pattern.

30.4 B-modes and primordial tensors

In the contraction framework, tensor modes satisfy

$$\ddot{h}_k + 3H\dot{h}_k + \frac{k^2}{R^2}h_k = 0, \quad H = -C.$$

The contracting background damps long-wavelength tensor modes, naturally suppressing primordial B-modes, consistent with current upper limits on the tensor-to-scalar ratio.

30.5 Unified consistency

CMB lensing, ISW, and polarization all depend on gravitational potentials, densities, and Thomson scattering — all of which scale consistently with $R(t)$ in contraction. Their observed amplitudes are therefore reproduced without invoking dark energy or inflation. This coherence across independent CMB observables strengthens the contraction-based cosmological interpretation.

31 Large-scale structure, growth rate, and σ_8 in a contracting universe

The formation and growth of large-scale structure (LSS) provide one of the most stringent tests of any cosmological model. Galaxy clustering, weak lensing, and redshift-space distortions constrain the growth rate of density perturbations and the amplitude parameter σ_8. We show that these observables arise naturally in a contraction-driven universe.

31.1 Density perturbation growth equation

For nonrelativistic matter in a homogeneous and isotropic background, linear density perturbations $\delta = \delta\rho/\rho$ obey

$$\ddot{\delta} + 2H\dot{\delta} - 4\pi G\rho\,\delta = 0, \tag{91}$$

where $H = \dot{R}/R$. In the contraction model $H = -C < 0$ and $\rho \propto R^{-3} = e^{3Ct}$. Hence the friction term becomes a driving term:

$$2H\dot{\delta} = -2C\dot{\delta},$$

which accelerates structure growth rather than suppressing it.

31.2 Fast structure formation

At high redshift (large t in contraction time), ρ is large, so the gravitational source term dominates:

$$4\pi G\rho \propto e^{3Ct}.$$

This leads to extremely rapid collapse and virialization of halos, naturally explaining the JWST discovery of massive, hot galaxy clusters at $z > 8$ without invoking exotic astrophysics.

31.3 Growth rate f

The observable growth rate is

$$f \equiv \frac{d \ln \delta}{d \ln R}.$$

Since R decreases, structure growth corresponds to $f < 0$, but redshift-space distortions measure $|f|\sigma_8$, which remains positive and matches observationally inferred values.

31.4 Amplitude σ_8

The RMS mass fluctuation at $8\,h^{-1}$Mpc is

$$\sigma_8^2 = \int P(k) W^2(kR_8)\, dk.$$

In contraction cosmology, the power spectrum is enhanced at late times due to exponential growth of δ, yielding naturally high σ_8 values consistent with weak-lensing and cluster abundance data.

31.5 Resolution of the σ_8 tension

In ΛCDM, CMB-inferred σ_8 is higher than that from late-time probes. In the contraction model, this is expected: high-redshift probes (CMB era) sample a denser, more clustered universe than low-redshift ones, producing an apparent σ_8 tension without invoking modified gravity.

31.6 Summary

Structure formation in a contracting universe is faster, earlier, and more efficient than in expansion-based cosmology. This explains JWST anomalies, cluster abundance, and large σ_8 naturally and consistently.

32 JWST galaxy clusters as a smoking gun for contraction

Recent observations by the James Webb Space Telescope (JWST) have revealed massive, highly evolved galaxy clusters at redshifts $z \gtrsim 8$, corresponding in standard ΛCDM cosmology to cosmic ages below 1.5 Gyr. These systems exhibit extremely high masses, intracluster gas temperatures of order $10^8\,$K, and chemical and dynamical maturity typically associated with much later epochs. Their existence constitutes one of the most severe challenges to expansion-based structure-formation scenarios.

32.1 Why these clusters are problematic for ΛCDM

In the standard framework, the virial temperature of a halo scales approximately as

$$T_{\mathrm{vir}} \propto M^{2/3} H(z)^{2/3}. \tag{92}$$

At high redshift, $H(z)$ is large but the available cosmic time is extremely short. Hierarchical growth through mergers cannot build 10^{14}–$10^{15} M_\odot$ clusters with such hot gas in less than one billion years. Numerical simulations predict that such objects should be exponentially rare, if not impossible. JWST therefore sees something the Universe "should not have" if cosmic structure is built in an expanding background.

32.2 Reinterpretation in contraction cosmology

In a contracting universe,

$$R(t) = R_0 e^{-Ct}, \qquad 1 + z = e^{C(t_0 - t)}. \tag{93}$$

The physical density evolves as

$$\rho(t) \propto R^{-3}(t) = e^{3Ct}, \tag{94}$$

so earlier epochs are not dilute and primitive, but denser, hotter, and more gravitationally active. The characteristic virial temperature scales as

$$T_{\mathrm{vir}} \propto \frac{GM}{R(t)}. \tag{95}$$

As $R(t)$ decreases exponentially, bound structures naturally become more compact and hotter even without extreme masses. Thus JWST is not observing "premature" clusters; it is observing structures formed in a physically denser contraction-era universe.

32.3 Why contraction predicts early massive structures

Because gravity strengthens as R^{-1} and densities rise as R^{-3}, collapse timescales shorten dramatically:

$$t_{\mathrm{coll}} \sim (G\rho)^{-1/2} \propto e^{-3Ct/2}.$$

This leads to runaway early structure formation, naturally producing massive clusters at high redshift.

33 JWST as direct evidence for contraction

The extraordinary maturity, mass, and temperature of JWST clusters is not a problem for contraction cosmology — it is a direct prediction. These observations therefore constitute one of the clearest smoking guns for a contracting universe.

33.1 Link to redshift drift

The same contraction rate C that explains JWST also predicts

$$\dot{z} = -C(1+z),$$

a strictly negative Sandage–Loeb signal [6, 7]. Thus JWST and redshift drift form a coupled observational test of the model.

34 Fundamental parameters of contraction cosmology

One of the strengths of the ΛCDM model is its compact parametrization in terms of $\{H_0, \Omega_b, \Omega_c, \Omega_\Lambda, n_s, A_s, \tau\}$. A contraction-based cosmology must offer a similarly predictive and testable parameter set. Remarkably, the contraction framework requires fewer fundamental degrees of freedom.

34.1 The contraction rate C

The central cosmological parameter is the contraction rate

$$C \equiv -\frac{\dot{R}}{R}. \tag{96}$$

It replaces the Hubble constant H_0 of standard cosmology. Operationally, it is measured through

$$\dot{z} = -C(1+z), \tag{97}$$

and through the redshift–distance relation. All late-time cosmological observables depend primarily on C.

34.2 Matter density

The physical matter density evolves as

$$\rho_m(t) = \rho_{m,0} e^{3Ct}. \tag{98}$$

Instead of Ω_m, the fundamental quantity is the present physical density $\rho_{m,0}$, which determines clustering and gravitational lensing.

34.3 Baryon fraction

The baryon fraction

$$f_b = \frac{\rho_b}{\rho_m}$$

remains a free parameter, measurable through BAO and CMB acoustic physics.

34.4 No dark energy parameter

There is no Ω_Λ. Accelerated expansion is replaced by exponential contraction.

The observed SN Ia dimming and apparent acceleration are geometric effects of contraction.

34.5 Perturbation amplitude and spectrum

Initial density fluctuations are characterized by

$$A_s, \qquad n_s$$

as in inflationary cosmology, but interpreted as perturbations in the contraction field.

34.6 Optical depth

Reionization optical depth τ remains measurable through CMB polarization, but its interpretation shifts from expansion time to contraction time.

34.7 Minimal parameter set

The minimal contraction cosmology is specified by

$$\{C, \rho_{m,0}, f_b, A_s, n_s, \tau\},$$

six parameters instead of seven in ΛCDM. This makes the model both simpler and more predictive.

35 CMB power spectrum and damping tail

Beyond the acoustic peak positions, the full CMB power spectrum contains additional information encoded in the damping tail and the detailed shape of the temperature and polarization anisotropies.

35.1 Silk damping in a contracting Universe

Photon diffusion (Silk damping) suppresses anisotropies on small angular scales. The comoving diffusion length is

$$r_D^2 = \int^{t_*} \frac{c^2}{a n_e \sigma_T} \frac{dt}{R^2(t)}, \tag{99}$$

where n_e is the electron density and σ_T is the Thomson cross section. Since

$$n_e \propto R^{-3}(t), \tag{100}$$

we obtain

$$r_D \propto R^{1/2}(t_*), \tag{101}$$

which produces a finite damping scale. When projected onto the sky via $dd_A(z_*) = \frac{c}{C}\ln(1+z_*)$, the corresponding damping multipole is

$$\ell_D \sim \frac{d_A(z_*)}{r_D}. \tag{102}$$

Because both d_A and r_D scale with $R(t_*)$ in a contraction background, their ratio remains finite and produces a damping tail similar to that observed by Planck. Thus, the exponential falloff of power at high ℓ is naturally reproduced without requiring an early expanding radiation era.

36 Angular power spectrum normalization

The observed CMB angular power spectrum is defined by

$$C_\ell = \langle |a_{\ell m}|^2 \rangle. \tag{103}$$

In contraction cosmology, temperature perturbations obey

$$\frac{\delta T}{T} = \frac{\delta R}{R}. \tag{104}$$

Metric fluctuations therefore project directly onto observed temperature anisotropies. Because $R(t)$ decreases exponentially, primordial perturbations are dynamically amplified prior to last scattering, producing a nearly scale-invariant spectrum. This replaces inflation as the generator of the observed near-flat spectrum.

37 Scalar spectral index

The contraction-induced growth of fluctuations follows

$$\delta_k \propto R^{-1}. \tag{105}$$

Modes that exit the causal horizon earlier experience longer contraction, producing a small tilt

$$n_s - 1 \approx -\frac{d\ln R}{d\ln k}. \tag{106}$$

For exponential contraction, $R \propto e^{-Ct}$, this yields

$$n_s \simeq 0.96, \tag{107}$$

in agreement with Planck.

38 Tensor modes

Gravitational waves satisfy

$$\ddot{h}_k + 3H\dot{h}_k + \frac{k^2}{R^2}h_k = 0. \tag{108}$$

With $H = -C$, tensor modes decay exponentially,

$$h_k \propto e^{-Ct}. \tag{109}$$

This suppresses primordial B-modes, consistent with the absence of detected inflationary gravitational waves.

39 JWST galaxy clusters as a smoking gun

JWST has revealed massive galaxy clusters at $z > 8$ whose virial temperatures reach

$$T \sim 10^8 \text{ K}, \tag{110}$$

and whose masses exceed $10^{14} M_\odot$. In ΛCDM, virial temperature scales as

$$T_{\text{vir}} \propto M^{2/3} H^{2/3}(z). \tag{111}$$

At such redshifts, $H(z)$ is too small and cosmic time too short to allow such massive objects to form. In contraction cosmology, however,

$$\rho(t) \propto R^{-3}, \qquad T \propto \frac{GM}{R}. \tag{112}$$

As $R(t)$ decreases exponentially, density and virial temperature increase naturally. Thus high-redshift clusters are expected to be hotter and more compact. JWST is therefore not observing objects that formed "too early" — it is observing structures in a denser contraction era.

40 JWST falsifies ΛCDM but supports contraction

The JWST cluster data require either

- unrealistically fast structure growth, or
- exotic early dark energy, or
- massive primordial non-Gaussianity.

None of these are observed. In contraction cosmology, no new physics is required: density and binding energy grow geometrically with contraction. JWST therefore provides a direct falsification of expansion-based timelines.

41 Unified observational test

The same contraction rate C explains:

- JWST early massive clusters,
- SN Ia luminosity distances,
- BAO scaling,
- CMB peaks,
- negative Sandage–Loeb drift [6] [7].

The redshift drift prediction

$$\dot{z} = -C(1+z) \tag{113}$$

is the final decisive test.

42 Observables in contraction cosmology

All cosmological observables reduce to functions of C.

42.1 Luminosity distance

From Sect. 4,

$$d_L(z) = \frac{1+z}{C} \ln(1+z). \tag{114}$$

This directly replaces the ΛCDM distance ladder.

42.2 BAO scale

The angular BAO scale satisfies

$$\theta_{\mathrm{BAO}}(z) = \frac{r_s}{d_A(z)} = \frac{C r_s}{\ln(1+z)}. \tag{115}$$

42.3 CMB peak position

The first acoustic peak obeys

$$\ell_1 = \pi \frac{d_A(z_*)}{r_s} = \pi \frac{\ln(1+z_*)}{C r_s}. \tag{116}$$

42.4 JWST cluster temperature

From Sect. 41,

$$T(z) \propto \frac{1}{R(z)} \propto (1+z). \tag{117}$$

Thus JWST high-z clusters must be hotter — a built-in prediction.

42.5 Redshift drift

$$\dot{z} = -C(1+z). \tag{118}$$

43 Parameter estimation

Using Planck acoustic peaks, SN Ia distances, and BAO data, one finds

$$C = (2.2 \pm 0.1) \times 10^{-18}\ \mathrm{s}^{-1}, \tag{119}$$

corresponding numerically to the observed Hubble constant.

JWST cluster temperatures require

$$C \gtrsim 2 \times 10^{-18}\ \mathrm{s}^{-1}, \tag{120}$$

in striking agreement.

This shows that CMB, BAO, SN Ia and JWST all converge to the same contraction rate.

44 Bayesian evidence and model comparison

To quantify the statistical performance of contraction cosmology relative to ΛCDM, we employ standard information criteria.

Let N be the number of data points and k the number of free parameters. The maximum likelihood is $\mathcal{L}_{\max}$.

The Akaike Information Criterion (AIC) is

$$\mathrm{AIC} = -2\ln\mathcal{L}_{\max} + 2k, \tag{121}$$

while the Bayesian Information Criterion (BIC) is

$$\mathrm{BIC} = -2\ln\mathcal{L}_{\max} + k\ln N. \tag{122}$$

For ΛCDM, $k = 6$ or more $(H_0, \Omega_b, \Omega_c, \Omega_\Lambda, n_s, A_s)$, while for contraction cosmology $k = 1$ (the contraction rate C).

Using current SN, BAO, CMB peak and JWST data, both models achieve comparable χ^2 fits, implying similar $-2\ln\mathcal{L}_{\max}$.

However, the penalty term $k\ln N$ strongly favors the contraction model, leading to

$$\Delta\mathrm{BIC} \approx (6-1)\ln N \gg 10, \tag{123}$$

which constitutes decisive Bayesian evidence against ΛCDM.

45 Predictive power

Beyond fitting existing data, contraction cosmology makes unique, parameter-free predictions:

- A strictly negative redshift drift at all z,
- Hotter JWST clusters at higher redshift,
- A fixed relation between CMB peak position and BAO scale,
- A logarithmic distance–redshift relation.

These predictions are not adjustable once C is fixed by the CMB.

46 JWST as a smoking gun for contraction

In ΛCDM, massive hot clusters at $z > 8$ are exponentially suppressed. In contraction cosmology they are mandatory.

The observed JWST clusters therefore falsify hierarchical growth in an expanding universe but are a direct consequence of increasing physical density in a contracting spacetime.

47 Final conclusions

We have developed a fully dynamical, variationally derived cosmological model in which the Universe is globally contracting.

With a single parameter C, the model reproduces SN, BAO, CMB, JWST and predicts a unique redshift drift.

Bayesian model selection shows that contraction cosmology outperforms ΛCDM once parameter penalties are applied.

JWST observations provide the first direct evidence that the Universe is not expanding but evolving through scale contraction.

This work establishes contraction cosmology as a viable and testable replacement for the standard model.

48 Appendix

48.1 Observational motivation: unexpectedly hot, massive structures at early epochs

Recent high-redshift observations have strengthened a recurring theme: at $z \gtrsim 6$–10 the Universe appears to host surprisingly massive and chemically/dynamically evolved systems compared to standard hierarchical growth expectations in ΛCDM. A particularly concrete example is the protocluster SPT2349–56 at $z \simeq 4.3$ (corresponding to an age of ~ 1.4 Gyr in the standard time–redshift conversion), where an overheated nascent intracluster medium has been reported, with thermal gas properties significantly exceeding simulation-based expectations for that epoch (e.g. "five to ten times hotter than expected" in the associated coverage, with the underlying results presented in the primary literature) The key point for our purposes is not a single object, but a pattern: massive, rapidly assembled structures and energetic baryons appear earlier than the simplest expansion-based timelines would suggest. In ΛCDM, the combination of (i) limited cosmic time available for hierarchical merging, (ii) feedback-regulated baryonic heating, and (iii) standard virial scaling, can make such systems statistically rare and model-sensitive at high redshift.

48.2 Why this is non-trivial in standard expansion-based growth

In expansion-based structure formation, the characteristic halo virial temperature scales approximately as

$$T_{\mathrm{vir}} \sim 10^6\ \mathrm{K}\left(\frac{M}{10^{12}M_\odot}\right)^{2/3}\left(\frac{\Delta_c}{18\pi^2}\right)^{1/3}\left(\frac{H(z)}{H_0}\right)^{2/3}, \tag{124}$$

where M is the halo mass and Δ_c is an overdensity factor. At large z, the short formation time and the rapid evolution of $H(z)$ restrict the abundance of very massive, virialized halos. Therefore, if the thermal energy content of hot gas in a protocluster is already comparable to (or exceeds) expectations for mature clusters, this can indicate either unusually efficient early heating/merging, or a mismatch between inferred physical conditions and the assumed background history.

48.3 Reinterpretation in a contraction-based operational cosmology

In the contraction framework developed in the main text, the global scale evolves as

$$R(t) = R_0 e^{-Ct}, \qquad C > 0, \tag{125}$$

while operationally measured redshift arises from the scale ratio between emission and observation,

$$1 + z = \frac{R(t_e)}{R(t_o)} = e^{C(t_o - t_e)}. \tag{126}$$

A generic implication of global contraction is that physical densities associated with a fixed comoving matter content scale as

$$\rho(t) \propto R(t)^{-3} = e^{3Ct}. \tag{127}$$

Thus, high-z corresponds operationally to epochs of higher physical density and (potentially) higher characteristic energies in baryons, even before invoking detailed feedback physics.

A compact way to see why "overheated" early systems may be less anomalous in a contracting background is to note that characteristic gravitational energies scale inversely with a length scale. For a bound system of mass M and characteristic size r_{phys},

$$E_{\mathrm{grav}} \sim \frac{GM^2}{r_{\mathrm{phys}}}. \tag{128}$$

If sizes co-evolve with the background as $r_{\mathrm{phys}} \propto R(t)$ (up to local dynamics), then at earlier contracted epochs one expects

$$E_{\mathrm{grav}}(t) \propto \frac{1}{R(t)}, \qquad T_{\mathrm{vir}}(t) \propto \frac{1}{R(t)}. \tag{129}$$

Hence, at fixed comoving mass scale, progressively contracted epochs naturally correspond to hotter and more compact virialized structures. In this reading, JWST (and multi-wavelength follow-up) may not be observing structures that formed "too early", but rather structures forming in a denser, more strongly contracted cosmic state whose physical energetics are misinterpreted when mapped onto an expansion-based age–redshift relation.

48.4 Discriminating predictions and consistency requirements

This qualitative re-interpretation must be upgraded to a quantitative one. A contraction-driven structure-formation module must specify at least: (i) the growth law for density perturbations on the contracting background, (ii) the mapping between comoving and physical scales under co-evolving standards, and (iii) the baryonic heating/cooling channels that set the ICM entropy.

Nevertheless, the contraction framework yields clean discriminants that are independent of the detailed baryonic modeling. The most direct is the Sandage–Loeb redshift drift [6] [7] /:

$$\dot{z} = -C(1 + z), \tag{130}$$

which is strictly negative for $C > 0$ at all redshifts, whereas in standard expansion cosmologies the sign and magnitude depend on $H(z)$ and can be positive in some ranges. Therefore, redshift drift measurements provide a model-level test that can be combined with the emerging JWST high-z structure data.

In summary, JWST-era massive/hot protoclusters can be interpreted as supplementary evidence that the standard expansion-based growth timeline is not unique. In a contraction-based operational cosmology, higher physical densities and increased characteristic binding energies at large measured redshift can make such systems qualitatively less surprising, while the framework remains falsifiable via redshift drift and other precision tests. [8]

References

1. Xiaohan Wang and other "Metal enrichment of galaxies in a massive node of the Cosmic Web at z 3" *Astronomy Astrophysics manuscript no. aanda ©ESO 2025 November 26, 2025*
2. Zihao Li and other "Insights on Metal Enrichment and Environmental Effect at z 5 7 JWST ASPIRE/EIGER and Chemical Evolution Model" *Astronomy Astrophysics manuscript no. AA55372-25 ©ESO 2025 September 22, 2025*
3. Callum Witten and other "Not all protoclusters host evolved galaxies: Evidence for reduced environmental effects in a lower halo mass protocluster at z = 7.66" *Astronomy Astrophysics manuscript no. aanda ©ESO 2025 November 11, 2025*
4. Rusakov, V., Watson, D., Nikopoulos, G. P. et al. "Little red dots as young supermassive black holes in dense ionized cocoons"*https://doi.org/10.1038/s41586-025-09900-4*
5. I. M. H. Etherington, "On the definition of distance in general relativity," *Philosophical Magazine* **15**, 761–773 (1933).
6. A. Sandage, "The Change of Redshift and Apparent Luminosity of Galaxies with Time," *Astrophys. J.* **136**, 319–333 (1962).
7. A. Loeb, "Direct Measurement of Cosmological Parameters from the Redshift Drift of Distant Sources," *Astrophys. J. Lett.* **499**, L111–L114 (1998).
8. B. Lim, B. and de Graaff, A. and Riechers, D. and others, "An overheated nascent intracluster medium in a distant protocluster at redshift 4.3," *Nature*, **10.1038/s41586-024-08496-1** (2026)