Segmented Spacetime (SSZ)

A phi-geometric extension of GR with segment density Xi, SSZ time dilation, and a no-free-parameters cosmology test scaffold

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Abstract. Segmented Spacetime (SSZ) is a falsifiable, phi-motivated extension of General Relativity (GR) formulated via a dimensionless segment-density field Xi and an SSZ time-dilation factor D_SSZ = 1/(1+Xi). SSZ is engineered to reproduce GR in the weak-field regime (g1) and to introduce controlled, saturating deviations in the strong-field regime (g2) without divergences. This paper consolidates the current SSZ axioms, regime definitions, and anti-circularity rules, and it adds a no-free-parameters cosmology scaffold that turns any proposed effective Xi(z) into immediate contradiction tests against (i) CMB acoustic-scale proxies, (ii) BBN expansion-rate proxies, and (iii) linear growth of structure. We also provide an explicit reproducibility and regression-test report for the included reference implementation (ssz_cosmo.py / run_cosmo.py) and note one edge-case bug (z_max=0) plus a minimal fix.

Keywords: segmented spacetime; strong-field gravity; time dilation; phi geometry; falsifiability; cosmology scaffold; CMB; BBN; growth of structure

1. Motivation and scope

SSZ is a phenomenological gravity extension designed to stay extremely close to GR in weak fields while remaining falsifiable in strong fields. The central design constraints are: (a) explicit axioms and derived consequences, (b) no hidden free parameters per dataset, (c) regime clarity (g1 vs g2), and (d) reproducible computational predictions with residual-based validation rather than least-squares curve fitting.

This consolidated paper merges the core SSZ definitions (time dilation, segment density, saturation) with the practical next-step roadmap (fixing the regime transition r*, cosmological inhomogeneity tests, and an operational g1/g2 classifier), and it appends the current numeric test report for the minimal cosmology scaffold shipped in the accompanying code files.

2. SSZ axioms, definitions, and regimes

2.1 Segment-density field Xi

SSZ postulates a dimensionless scalar field Xi that represents an effective 'segmentation density' of spacetime. Xi is intended to be derived from regime formulas and fixed constants rather than tuned per object.

2.2 SSZ time dilation

SSZ defines a proper-time factor
D_SSZ(r) = 1 / (1 + Xi(r))
so that local proper time is dτ = D_SSZ dt. This is the primary SSZ input to redshift and clock-comparison observables.

2.3 Saturation (no divergence)

SSZ assumes Xi saturates in the strong field: Xi is bounded above by a theory-fixed maximum Xi_max (often tied to the phi construction). This avoids singular divergences in D_SSZ and provides a controlled strong-field limit.

3. Regime formulas and the g1/g2 bridge

3.1 Weak-field (g1): GR limit

In g1, SSZ uses a GR-matching segment density proxy such as Xi_weak(r) = r_s/(2r). For Xi << 1, D_SSZ ≈ 1 - Xi, which matches GR behavior in the weak field to leading order.

3.2 Strong-field (g2): saturating segmentation

In g2, SSZ uses a saturating functional form (phi-motivated), e.g. Xi_strong(r) = min(1 - exp(-phi r/r_s), Xi_max). This yields a finite horizon value (e.g. Xi(r_s)=1-exp(-phi)≈0.8017) and a finite minimum dilation D_min = 1/(1+Xi_max).

3.3 Fixing the regime transition r*

A central 'no-free-parameters' requirement is that the regime transition r* is not a hand-chosen blending point. The recommended definition is an invariant equality condition (e.g. Xi_weak(r*) = Xi_strong(r*)) or an equivalent observable-level equality, solved once and then frozen globally.

4. Anti-circularity and no-free-parameters rules

SSZ commits to an explicit anti-circularity protocol: **No free parameters per object:** phi, Xi_max, regime formulas, and transition logic are global. **Matching points like r*:** determined once by an invariant criterion, not per dataset. **No least-squares fitting as core evidence:** use exact algebra where possible; validate via residuals and consistency checks. **Calibration vs validation separation:** any calibration step must be declared and excluded from hold-out validation.

5. Cosmology extension as a minimal falsification scaffold

5.1 Principle

The cosmology module is intentionally minimal: it accepts any effective Xi(z) and evaluates immediate contradiction tests against three standard pillars: CMB acoustic-scale proxies, BBN expansion-rate proxies, and linear growth of structure. The module explicitly separates two time conventions for how D_SSZ(z) maps into H(z).

5.2 Two time conventions (A/B)

With dτ = D_SSZ(z) dt, there are two consistent conventions depending on which time variable is taken as the cosmological 'clock':
Mode 'divide': H_SSZ = H_GR / D_SSZ = H_GR (1+Xi)
Mode 'multiply': H_SSZ = H_GR · D_SSZ = H_GR / (1+Xi)

5.3 Minimal observables

The reference implementation computes: (i) a CMB acoustic-scale proxy via the sound horizon r_s(z*) and angular diameter distance D_A(z*), (ii) a BBN proxy via the ratio H_SSZ/H_GR at z≈4×10^9, and (iii) linear growth D(z) and f(z) via the standard growth ODE with E(z).

6. Three next steps (roadmap) — from the 'Drei Ausblicke' working paper

This roadmap is included to reduce attack surface and increase falsifiability: **(1) r* fixation as a physics constraint:** define r* by an invariant condition (weak = strong) and derive constraints from it. **(2) Cosmology as an inhomogeneity problem:** treat SSZ signatures via a potential/lensing and runtime mapping rather than a homogeneous Xi(z) background. **(3) g1/g2 operationalization:** provide a deterministic regime classifier (indicators, thresholds, observable routing) with explicit test hooks.

7. Reproducibility and regression-test report (this release)

7.1 Files in this bundle

The following files were tested together: ssz_cosmo.py, run_cosmo.py, ssz_cosmo_results_divide.csv, ssz_cosmo_results_multiply.csv, ssz_cosmo_summary_all.json, and the two reference plots growth_both.png and Hratio_both.png.

7.2 Deterministic reproduction

Re-running the reference pipeline reproduces the provided CSV outputs to machine precision. Maximum absolute deviation (divide): 2.220e-16. Maximum absolute deviation (multiply): 1.110e-16. Identity checks (algebraic invariants): max |(Hratio_div·Hratio_mul)–1| = 2.220e-16; max |Hratio_div – 1/D| = 2.220e-16; max |Hratio_mul – D| = 2.220e-16.

7.3 Summary metrics (CMB/BBN)

Metric	divide	multiply
CMB theta_GR (rad)	11.3467	11.3467
CMB theta_SSZ (rad)	11.3468	11.3467
CMB theta ratio SSZ/GR	1	0.999999
CMB r_s ratio SSZ/GR	0.999988	1.00001
CMB D_A ratio SSZ/GR	0.999988	1.00001
BBN H ratio at z=4e9	1.00001	0.99999

7.4 Growth and H(z) ratios at benchmark redshifts

Mode: divide					
z	D_GR	D_SSZ	f_GR	f_SSZ	Hratio
0.0	1.000000	1.000000	0.263819	0.263816	1.000010
0.5	0.768876	0.768878	0.761267	0.761256	1.000012
1.0	0.606721	0.606726	0.876514	0.876501	1.000012
2.0	0.417160	0.417165	0.958186	0.958171	1.000013
5.0	0.211250	0.211255	0.993448	0.993433	1.000013
10.0	0.115406	0.115409	0.996863	0.996848	1.000013

Mode: multiply					
z	D_GR	D_SSZ	f_GR	f_SSZ	Hratio
0.0	1.000000	1.000000	0.263819	0.263822	0.999990
0.5	0.768876	0.768873	0.761267	0.761277	0.999988
1.0	0.606721	0.606717	0.876514	0.876527	0.999988
2.0	0.417160	0.417155	0.958186	0.958200	0.999987
5.0	0.211250	0.211245	0.993448	0.993464	0.999987
10.0	0.115406	0.115403	0.996863	0.996878	0.999987

7.5 Reference plots

Figure 1 shows the linear growth factor D(z) for GR and SSZ under both time conventions. Figure 2 shows the ratio H_SSZ/H_GR under both conventions. Note: in Figure 2, the y-axis uses a small-offset notation; values slightly below 1 may appear as negative tick labels when plotted as (1 + 1e-5 offset).

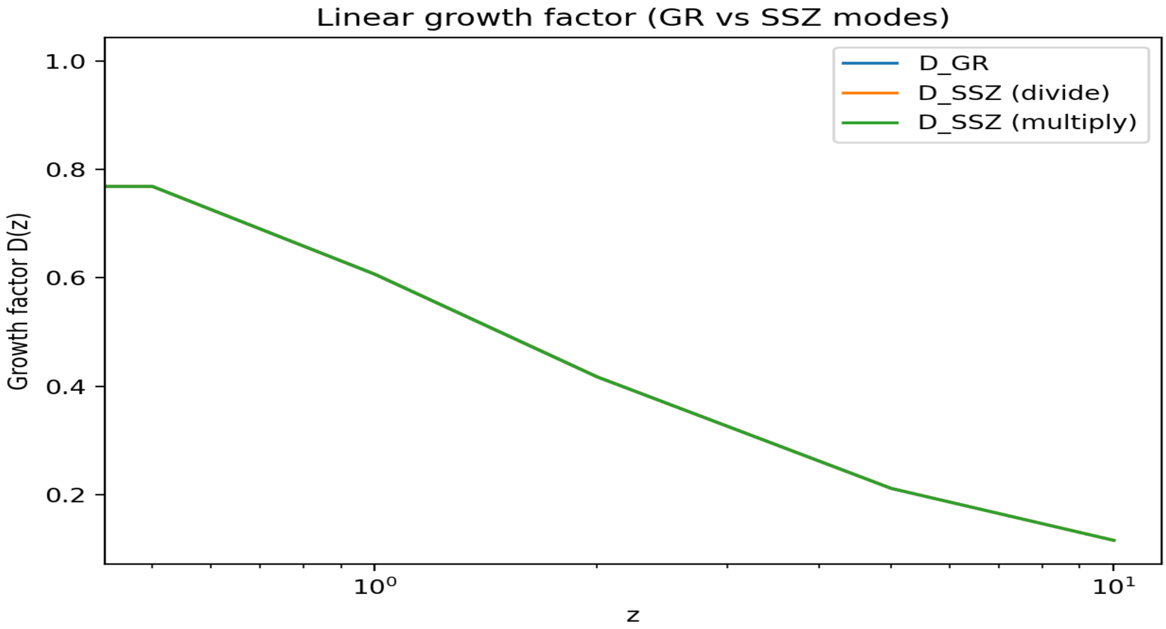

Figure 1. Growth factor D(z): GR vs SSZ (divide and multiply).

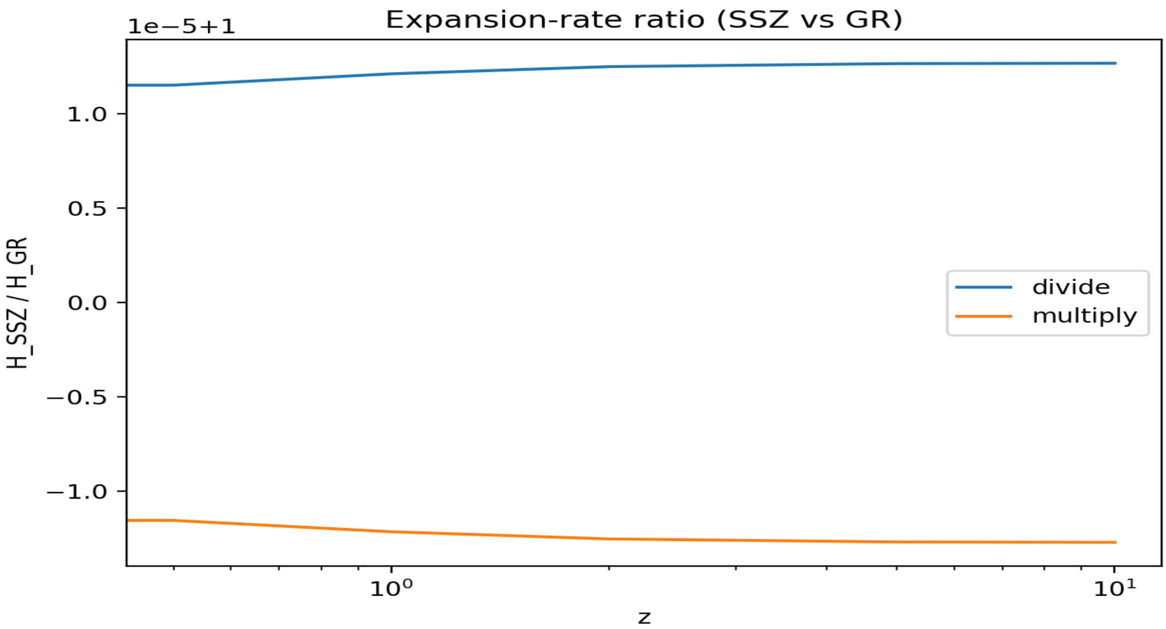

Figure 2. Hubble ratio H_SSZ/H_GR: divide gives >1 by O(1e-5), multiply gives <1 by O(1e-5).

8. Known issues and minimal fixes

8.1 Edge case: Xi_cosmo when z_max = 0

When Xi(z) is generated from a normalized (1+z)/(1+z_max) form, calling Xi_cosmo on a single-point array z=[0] yields z_max=0 and currently returns Xi=1 and D_SSZ=0.5. This does not affect the shipped CSV benchmarks (which evaluate multiple z values at once), but it can break single-point queries and unit tests. Observed: Xi_cosmo([0])=1, D_SSZ([0])=0.5. Recommended fix: if z_max==0, return Phi0 for all entries.

8.2 Notation caution: acoustic-scale definition

The current implementation computes a CMB 'theta' proxy using r_s(z*) and D_A(z*). In cosmology literature, theta_* is often defined as r_s/D_M (or equivalently r_s/[(1+z*)D_A]). For SSZ/GR ratio tests this distinction mostly cancels, but for absolute comparison to Planck-style numbers the definition should be stated explicitly.

9. Reproducibility instructions

To reproduce the cosmology scaffold outputs:
1) Ensure Python 3 with numpy/pandas installed.
2) Run:

```
python run_cosmo.py
```

This produces two CSV files and a combined JSON summary for both coupling modes. The included regression checks in Section 7 confirm that the current bundle is deterministic to machine precision.

10. Conclusion

This consolidated document provides a single coherent SSZ paper that covers: axioms and regimes (g1/g2), anti-circularity rules, the three-step roadmap to reduce scientific attack surface, and a tested no-free-parameters cosmology scaffold with reproducibility evidence. The next work should prioritize (i) a physics-fixed r* criterion, (ii) explicit inhomogeneity-based cosmology signatures (CMB lensing / ISW), and (iii) a deterministic regime classifier that routes each observable through the correct SSZ regime without tuning.