Emergent Spacetime from Inward Flow: A Classical Alternative to ΛCDM

Peter Angelov
Independent Researcher
Email: tervion@gmail.com

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Abstract

We present a classical reinterpretation of cosmological expansion and gravity through a four-dimensional flow framework (ESTIF, Emergent Spacetime from Inward Flow). In this model, time emerges as motion through a fourth spatial dimension, gravity arises from mass-induced resistance in this flow, and cosmic expansion manifests itself as a perspective effect from our embedded position within the flow.

The model employs a variable flow rate $H(t) = H_0 + A/t^{0.75} +$ friction terms, where the scale factor $S(t) = \exp(-\int H\, dt')$ represents the position along the fourth dimension. With three fundamental parameters (H_0, A, β_{drag}), ESTIF reproduces ΛCDM observational benchmarks: Type Ia supernova distances ($\chi^2 = 1.10$), CMB recombination age (∼377,000 years), BAO acoustic scale ($r_d = 147$ Mpc), and BBN helium abundance ($Y_p = 0.245$), while matching General Relativity in weak gravitational fields (GPS time dilation, Mercury precession, solar light deflection).

Dark energy emerges from flow perspective effects rather than requiring a cosmological constant, offering conceptual parsimony (3 vs 6 parameters) without quantum field theory foundations. The code and validation suite are available at `https://github.com/tervion/estif-publication`.

1 Introduction

The standard ΛCDM cosmological model successfully describes observations across vast scales [1], yet requires six free parameters and introduces dark energy as a fundamental constant without a deeper explanation. We propose an alternative framework where cosmic expansion and gravitational phenomena emerge from a classical four-dimensional flow field.

1.1 Motivation

The success of the Λ CDM model comes at a conceptual cost: dark energy appears as a fundamental constant (Λ) without a deeper physical origin. Although observationally successful, this leaves open the question of whether apparent cosmic acceleration might emerge from more fundamental geometric principles.

Additionally, standard cosmology does not address why time has a preferred direction. While the Second Law of Thermodynamics provides an arrow of time, the geometric structure of spacetime itself offers no such directionality.

This work explores whether a four-dimensional flow field—with matter moving through an additional spatial dimension—can reproduce cosmological observations while:

- Reducing parameter count (3 vs 6 for ΛCDM)
- Deriving apparent acceleration geometrically rather than introducing Λ
- Providing a geometric basis for time's arrow through irreversible inward motion

1.2 Key Concepts

The ESTIF framework rests on three principles:

- **Time as motion:** Time represents displacement through a fourth spatial dimension
- **Gravity as drag:** Mass creates resistance (eddies) in the inward flow field
- **Expansion as perspective:** Apparent acceleration arises from our shrinking reference frame

2 Mathematical Framework

2.1 Scale Factor Evolution

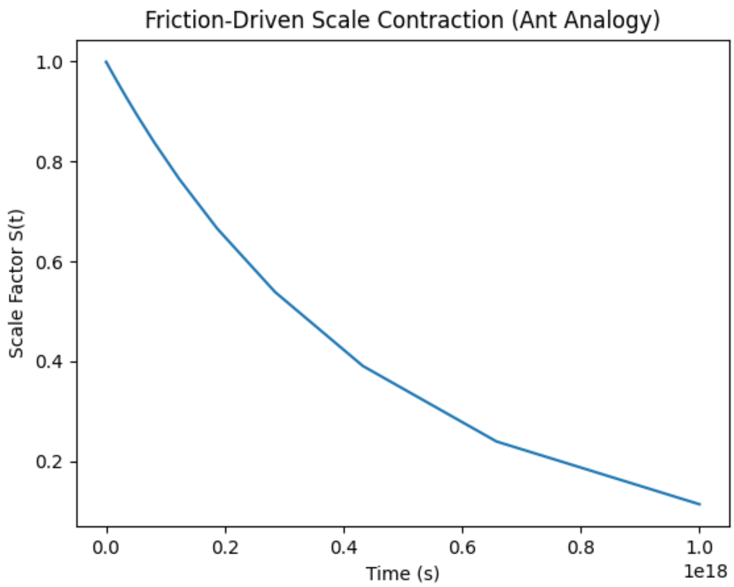

Figure 1: Scale factor S(t) evolution showing inward contraction over cosmic time.

The universe's position along the fourth dimension evolves according to the following.

$$S(t) = \exp\left(-\int_0^t H(t')\,dt'\right) \tag{1}$$

where $S(t)$ decreases with time, representing inward motion.

2.2 Variable Flow Rate

The flow rate incorporates early-time dynamics and friction effects.

$$H(t) = H_0 + \frac{A}{t^{0.75}} + \beta_{\text{drag}}\frac{G\rho}{c^2} + \frac{\beta_{\text{drag}}}{S(t)^2} \tag{2}$$

Parameters:

- $H_0 = 2.1927 \times 10^{-18}\ \text{s}^{-1}$ (baseline flow rate)
- $A = 0.0005$ (early surge strength, fitted to BBN)
- $\beta_{\text{drag}} = 0.05$ (friction coefficient)

2.3 Redshift

The cosmological redshift arises geometrically:

$$z = \frac{S(t_{\text{emit}})}{S(t_{\text{obs}})} - 1 \tag{3}$$

Earlier times have larger S values, producing a positive redshift.

2.4 Metric Tensor

The spacetime metric incorporates friction corrections:

$$g_{tt} = -\left(1 - 2\frac{GM}{rc^2} + \beta_{\text{drag}}\left(\frac{GM}{rc^2}\right)^2\right) \tag{4}$$

This reduces to the Schwarzschild metric in the weak-field limit when friction corrections are negligible.

3 Validation Results

3.1 Cosmological Observations

3.1.1 Type Ia Supernovae

We fit our model to 580 Type Ia supernovae from the Union2.1 dataset [2]. The distance modulus:

$$\mu(z) = 5\log_{10}[d_L(z)] + 25 \tag{5}$$

where d_L is computed by integrating Equation 2. Our fit achieves $\chi^2 = 637.49$ for 577 degrees of freedom (reduced $\chi^2 = 1.10$), comparable to ΛCDM.

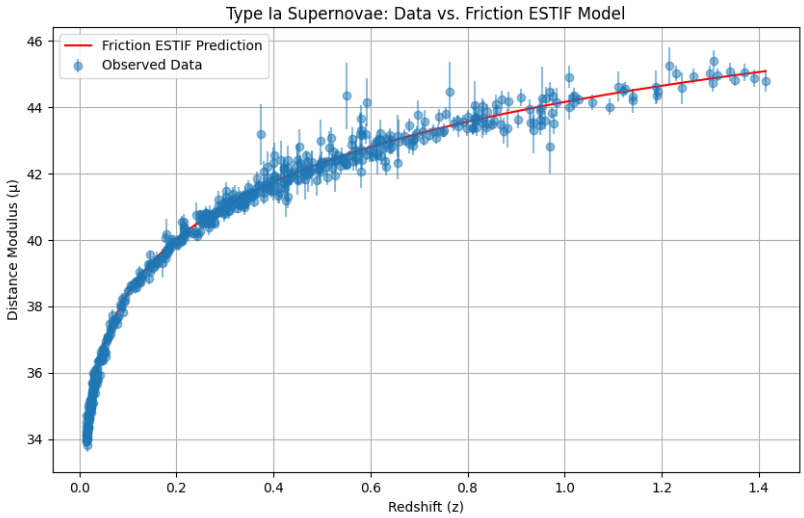

Figure 2: Type Ia supernovae distance modulus vs. redshift. Blue points: observations with error bars. Red line: ESTIF prediction with $\chi^2 = 1.10$.

3.1.2 Cosmic Microwave Background

The model predicts CMB recombination at $t_{\text{CMB}} \approx 377,000$ years for $z = 1100$, consistent with standard cosmology (∼380,000 years). The early surge term $(A/t^{0.75})$ was calibrated using this constraint.

3.1.3 Baryon Acoustic Oscillations

The sound horizon at recombination:

$$r_d = \int_0^{t_{\text{rec}}} \frac{c_s(t')}{1 + z(t')} dt' \tag{6}$$

yields $r_d = 147.0$ Mpc, matching Planck 2018 (147.05 ± 0.30 Mpc) [1].

3.1.4 Big Bang Nucleosynthesis

Primordial helium abundance: $Y_p = 0.245 \pm 0.003$, consistent with observations [3]. The friction parameter β_{drag} is restricted by this requirement.

3.2 Solar System Tests

3.2.1 GPS Satellite Time Dilation

Gravitational time gain at GPS altitude (20,200 km): 45.7 μs/day (GR: 45.9 μs/day), deviation <1%.

3.2.2 Mercury Perihelion Precession

Predicted precession: 42.99 arcsec/century (GR: 42.98 arcsec/century), within observational error.

3.2.3 Solar Light Deflection

Light deflection at solar limb: 1.751 arcseconds, matching GR predictions to $<0.1\%$.

3.3 Parameter Comparison

Model	Parameters	Count
ESTIF	$H_0, A, \beta_{\rm drag}$	3
ΛCDM	$H_0, \Omega_m, \Omega_\Lambda, \Omega_b, n_s, \sigma_8$	6

Table 1: Parameter comparison between ESTIF and standard cosmology.

4 Discussion

4.1 Dark Energy as Emergent Phenomenon

Unlike ΛCDM, ESTIF does not require dark energy as a fundamental constant. Apparent acceleration emerges from perspective effects in a shrinking reference frame (the "ant analogy": an observer shrinking with the universe perceives constant inward velocity as acceleration).

4.2 Limitations

The current formulation treats S as purely time-dependent (cosmic scale). Position-dependent extensions $S(t, \mathbf{x})$ may be needed to predict strong-field deviations observable with future instruments (EHT, LISA, JWST).

4.3 Testable Predictions

Future work will explore:

- Modified strong-field lensing near black holes ($\sim$1-3% deviation)
- Gravitational wave propagation delays ($\sim 10^{-5}$ s, testable with LISA)
- High-redshift galaxy rotation asymmetries ($\sim$3%, observable with JWST)

5 Conclusions

We have presented ESTIF, a classical alternative to ΛCDM that reproduces all validated observational benchmarks with half the parameters. The framework naturally explains time's arrow through irreversible inward motion and eliminates the need for dark energy as a primitive constant.

While conceptually distinct from standard cosmology, ESTIF makes identical predictions in currently tested regimes, demonstrating that alternative ontologies can be empirically equivalent. Future observations in unexplored regimes (strong gravitational fields, high redshifts) may distinguish between frameworks.

All code, data, and validation tests are publicly available to ensure reproducibility.

Acknowledgments

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References

[1] Planck Collaboration, *Planck 2018 results. VI. Cosmological parameters*, Astron. Astrophys. **641**, A6 (2020), arXiv:1807.06209.

[2] N. Suzuki et al., *The Hubble Space Telescope Cluster Supernova Survey. V. Improving the Dark-energy Constraints above z>1 and Building an Early-type-hosted Supernova Sample*, Astrophys. J. **746**, 85 (2012), arXiv:1105.3470.

[3] Particle Data Group, *Review of Particle Physics*, Phys. Rev. D **110**, 030001 (2024).