

Energy-Flow Cosmology

Master Formal Specification

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1 EFC-D: Energy-Flow Dynamics

2 EFC-D: Dynamical Sector

The dynamical sector EFC-D describes how the energy-flow field E_f , the effective potential $\Phi(E_f, S)$ and the expansion rate H emerge from the entropy field S and its gradients. It forms the bridge between thermodynamics and the observable evolution of structures.

2.1 Energy-Flow Field

We define the scalar energy-flow field

$$E_f : \mathbb{R}^3 \rightarrow \mathbb{R},$$

which encodes the strength and directionality of energy transport along entropy gradients. In regions with strong gradients ∇S , the magnitude $|E_f|$ is large, while in nearly uniform regions E_f approaches zero.

To leading order the flow aligns with the negative gradient of entropy,

$$E_f \propto -\nabla S,$$

reflecting the tendency of energy to organize along entropy-driven channels.

2.2 Effective Potential $\Phi(E_f, S)$

The effective potential is defined as

$$\Phi(E_f, S) = A_\Phi E_f (1 + S),$$

where A_Φ is a constant setting the amplitude. This baseline form captures how the interaction between energy flow and the entropy level builds the potential landscape.

A more general non-linear family is given by

$$\Phi(E_f, S) = A_\Phi E_f (1 + S^\beta),$$

where β modulates the strength of the coupling. The baseline implementation adopts the linear case $\beta = 1$.

2.3 Expansion Rate $H(E_f, S)$

EFC defines an effective expansion rate as a derived quantity:

$$H(E_f, S) = \sqrt{|E_f|} (1 + S). \tag{1}$$

This functional form reflects two contributions:

- $\sqrt{|E_f|}$ captures how the magnitude of energy flow sets the dynamical scale.
- $(1 + S)$ represents the thermodynamic modulation of expansion.

In this formulation, late-time acceleration can arise naturally from changes in (E_f, S) without introducing an external dark-energy component.

2.4 Rotation Curves and the Potential Gradient

For stationary configurations, the effective circular velocity at radius r follows from the potential gradient:

$$v(r) = \sqrt{r \frac{\partial \Phi}{\partial r}}.$$

Because Φ depends on both E_f and S , and these are shaped by the entropy landscape, the resulting rotation curves arise as thermodynamic signatures. They do not require additional dark-matter components but emerge from the coupled roles of grid resistance, energy flow and the entropy field.

2.5 Coupling to the Effective Light Speed

The dynamical sector is intrinsically linked to the entropy-dependent effective light speed

$$c(S) = c_0 (1 + a_{\text{edge}} x(S)^2).$$

Even with fixed underlying fields E_f and Φ , the inferred dynamical quantities depend on how light samples $c(S)$ along lines of sight. Observed velocities, accelerations, lensing time delays, and distance measures are all modified through this coupling.

Thus EFC-D and the light-propagation sector form a joint dynamical system rather than independent modules.

2.6 Summary

EFC-D provides thermodynamic definitions of:

- the energy-flow field E_f ,
- the effective potential $\Phi(E_f, S)$,
- the expansion rate $H(E_f, S)$,
- and the coupling of these quantities to the entropy-dependent light speed $c(S)$.

Together these quantities generate large-scale structure evolution, acceleration, and rotation-curve behaviour in a unified framework.

3 EFC-S: Structure Model

4 EFC-S: Structural Sector

EFC-S describes how structures form and persist within the entropy field S and the energy-flow potential $\Phi(E_f, S)$. Structure arises from thermodynamic balance between focusing/defocusing tendencies and the propagation properties encoded in $c(S)$.

4.1 Entropy and Structural Regimes

The entropy endpoints

$$S_0, \quad S_1,$$

mark low-entropy focusing and high-entropy defocusing regimes. The mid-entropy value

$$S_{\text{mid}} = \frac{1}{2}(S_0 + S_1)$$

defines a natural transition zone.

4.2 Entropy-Driven Stability Band

Because the effective light speed $c(S)$ reaches its minimum near the mid-entropy level S_{mid} , propagation slows in this region:

$$c_{\text{min}} = c(S_{\text{mid}}).$$

This creates a natural *stability band* in which energy-flow structures form persistent halo-like configurations. Reduced propagation speed increases effective confinement and stabilizes the rotation-curve plateau without requiring non-baryonic dark matter.

4.3 Coupling to the Potential

Structure formation reflects a balance among:

$$E_f, \quad \Phi(E_f, S), \quad c(S).$$

The potential

$$\Phi(E_f, S) = A_\Phi E_f (1 + S)$$

together with the propagation law $c(S)$ reproduces observed galactic structural features as emergent thermodynamic behavior.

5 s0–s1 Light Propagation Dynamics

s0–s1 Light Propagation Dynamics

Entropy Endpoints

We define two entropy endpoints:

- s_0 : low-entropy, high-structure endpoint
- s_1 : high-entropy, high-diffusion endpoint

The midpoint is

$$S_{\text{mid}} = \frac{1}{2}(s_0 + s_1),$$

and the entropy span is

$$\Delta S = s_1 - s_0.$$

Define the normalized entropy coordinate:

$$x(S) = \frac{S - S_{\text{mid}}}{\Delta S/2}.$$

Speed of Light Variation

The effective speed of light becomes:

$$c(S) = c_0 \left(1 + a_{\text{edge}} x(S)^2\right).$$

Light Travel Time

For a photon moving along a path γ , the travel time becomes:

$$t_{\text{obs}} = \int_{\gamma} \frac{dl}{c(S(l))}.$$

Lensing Behavior

Low-entropy endpoints act as focusing wells; high-entropy endpoints contribute to large-scale defocusing.

This generates a dual-lens profile consistent with observed halo asymmetries.

6 Observables

7 Observables in Energy-Flow Cosmology

Energy-Flow Cosmology (EFC) predicts that all observable quantities are modulated by the entropy field $S(\mathbf{x})$, the energy-flow field $E_f(\mathbf{x})$, and the derived effective light speed $c(S)$. This section summarizes how these quantities appear in observations.

7.1 Light Propagation

The light-travel time along a photon trajectory γ is

$$t_{\text{obs}} = \int_{\gamma} \frac{dl}{c(S(l))},$$

where $c(S)$ is the entropy-dependent effective speed of light.

Because $c(S)$ varies across the grid:

- regions near s_0 (low entropy, high structure) increase the local speed of light, producing focusing;
- regions near s_1 (high entropy, structural loosening) increase $c(S)$ at large scales, producing defocusing;
- mid-entropy regions produce the slowest propagation and the longest delays.

These effects modify classical interpretations of redshifts, distances, time-delays in lensing systems, and luminosity-distance relations.

7.2 Lensing

In GR, lensing depends only on the mass distribution. In EFC, lensing depends on *both* mass and entropy structure:

$$\text{Lensing} = \text{Mass Distribution} + S(\mathbf{x}) + c(S).$$

Consequently:

- focusing from s_0 regions can mimic excess mass;
- defocusing from s_1 regions can mimic mass deficits;
- time-delay ratios between lens images become modified;
- apparent shear patterns depend on how photon paths sample $S(\mathbf{x})$.

7.3 Rotation Curves

Circular velocities follow from the EFC potential:

$$v(r) = \sqrt{r \frac{\partial \Phi}{\partial r}}.$$

Because $\Phi(E_f, S)$ depends on both E_f and S , the resulting rotation curves can flatten without invoking dark matter. In particular:

- stable regions around S_{mid} produce broad bands of self-regulated velocities;
- transitions toward s_0 and s_1 produce characteristic slow variations;
- observational inferences of $v(r)$ must account for entropy-modulated $c(S)$.

7.4 Expansion Rate

The EFC expansion rate is:

$$H(E_f, S) = \sqrt{|E_f|} (1 + S),$$

which implies that cosmic acceleration arises from the joint evolution of (E_f, S) rather than from dark energy or a cosmological constant.

7.5 Diagram of Dependencies

The core dependency chain for observables is:

$$S(\mathbf{x}) \implies E_f(\mathbf{x}) \implies \Phi(E_f, S) \implies c(S) \implies \text{Observables}.$$

This captures the full thermodynamic origin of structure formation, photon propagation, and cosmic expansion within EFC.

8 Figures

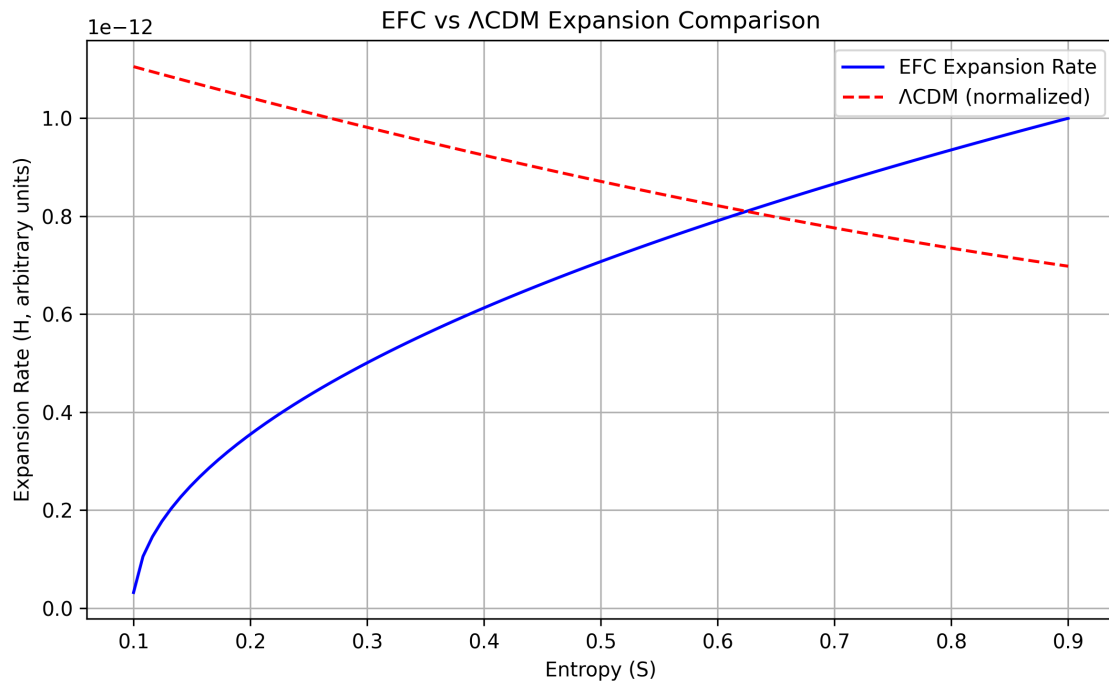


Figure 1: EFC vs. Λ CDM comparison.