

# Energy-Flow Cosmology (EFC) Formal Specification

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# 1 Introduction

Energy-Flow Cosmology (EFC) is a thermodynamic framework in which structure, dynamics, and observable propagation all emerge from the interaction between the entropy field  $S$ , the energy-flow field  $E_f$ , and the grid-level resistance that shapes how energy and light move through spacetime.

This document defines the mathematical objects, structural relationships, and dynamical laws that form the formal specification of EFC.

## 2 Foundations of EFC

The two core scalar fields of EFC are:

- the entropy field  $S(\mathbf{x})$ ;
- the energy-flow field  $E_f(\mathbf{x})$ .

All dynamical and observable quantities are derived from these.

### 2.1 Entropy Field

The entropy field  $S(\mathbf{x})$  encodes the resistance of the grid and defines the focusing and defocusing tendencies of both energy and light.

Two dynamic endpoints bound the entropy domain:

$$S_0 \quad (s_0: \text{low entropy, high structure}), \quad S_1 \quad (s_1: \text{high entropy, structural loosening}).$$

The midpoint and entropy span are:

$$S_{\text{mid}} = \frac{1}{2}(S_0 + S_1), \quad \Delta S = S_1 - S_0.$$

## 3 Dynamical Sector (EFC-D)

The energy-flow field is defined as:

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

It describes the directional flow of energy along entropy gradients.

### 3.1 Energy-Flow Potential

The effective potential that governs structural and dynamical behavior is:

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

More general couplings such as

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

may be introduced but are not implemented in the baseline model.

### 3.2 Circular Velocity Relation

Rotation curves follow:

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

Here the observed behavior depends both on  $\Phi$  and the entropy-modified light propagation defined in the next section.

## 4 Light Propagation in EFC

### 4.1 Effective light speed as a derived quantity

In EFC, the speed of light is not a universal constant. It is an *effective* propagation speed that emerges from the entropy field  $S$ , the  $s_0$ – $s_1$  endpoint structure, and the resistance of the energy–flow grid.

**Definition.** Let  $S_0$  and  $S_1$  denote the endpoint entropies. Define

$$S_{\text{mid}} = \frac{1}{2}(S_0 + S_1), \quad \Delta S = S_1 - S_0, \quad x(S) = \frac{S - S_{\text{mid}}}{\Delta S/2}.$$

The effective speed of light is then

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

with  $c_0$  the baseline mid-entropy speed and  $a_{\text{edge}} > 0$  a dimensionless parameter controlling enhancement toward the endpoints.

**Interpretation.**

- $c(S)$  is minimal in the mid-entropy regime.
- $c(S)$  increases smoothly as  $S \rightarrow S_0$  (focusing).
- $c(S)$  increases smoothly as  $S \rightarrow S_1$  (defocusing).

**Implications.** Light propagation depends on the path integral

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

meaning that all observable quantities that rely on null propagation (time delays, redshift–distance relations, lensing patterns) must be computed using  $c(S)$  rather than a fixed constant  $c$ .

This entropy-dependent propagation law is therefore a central element in the formal EFC framework.

### 4.2 Light Travel Times and Lensing

The observable travel time of a photon following trajectory  $\gamma$  is:

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

Consequences include:

- faster propagation near  $s_0$  and  $s_1$  (enhanced  $c(S)$ );
- modified magnification and distortion patterns;
- altered time-delay ratios even with identical mass distributions;
- redshift–distance relations dependent on the entropy field.

### 4.3 Coupling Between Light-Speed Variation and Energy-Flow Dynamics

Because both the effective potential  $\Phi(E_f, S)$  and the effective light speed  $c(S)$  depend on the entropy field, the two are not independent sectors. The coupling arises through the shared dependence on the normalized entropy coordinate  $x(S)$ , which modifies both dynamical and observable quantities.

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

#### Consequences of the coupling.

- Variations in  $c(S)$  modify the inferred gradient  $\partial_r \Phi$ , since observational probes (rotation curves, lensing, time delays) depend on propagation through  $c(S)$  rather than purely on mass–energy distribution.
- As  $c(S)$  rises toward  $S_0$  or  $S_1$ , the effective stiffness of trajectories in the energy–flow grid changes, altering both focusing and defocusing behavior.
- The mid-entropy minimum in  $c(S)$  produces a natural *stability band* for halo-like configurations, consistent with observed flat rotation curves.
- Regions near the entropy endpoints generate accelerated propagation, shaping late-time acceleration and lensing distortions without invoking dark-energy fields.

**Interpretation.** In the full EFC framework, the quantities  $\Phi$ ,  $E_f$ , and  $c(S)$  form a co-determined triad driven by the entropy field  $S$ . Light propagation, dynamical behavior, and structure formation all emerge from this shared thermodynamic origin rather than from independent physical postulates.

## 5 Structural Sector (EFC-S)

Structures in EFC arise from the interplay of  $S$ ,  $E_f$ ,  $\Phi(E_f, S)$ , and the effective light speed  $c(S)$ . The mid-entropy region where  $c(S)$  is minimal forms a natural stability band for halo-like configurations.

## 6 Conclusion

This formal specification defines the mathematical backbone of Energy-Flow Cosmology: the entropy field, the energy-flow field, the effective potential, and the emergent propagation law  $c(S)$  that shapes all null-propagation observables.