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:

$$S_0 \quad (\mathrm{s}_0\text{: low entropy, high structure}), \qquad S_1 \quad (\mathrm{s}_1\text{: high entropy, structural loosening}).$$

The midpoint and entropy span are:

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

3 Dynamical Sector (EFC-D)

The energy-flow field is defined as:

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

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 Φ 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

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

The effective speed of light is then

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

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 $S \to S_0$ (focusing).
- $c(S)$ increases smoothly as $S \to S_1$ (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 γ 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.

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

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 Φ, 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.