EFC Phenomenology vs DESI DR2 BAO:

A Comparative Fit Analysis

Technical Note

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Abstract

We test a phenomenological dark energy parameterization inspired by Energy-Flow Cosmology (EFC) against DESI DR2 BAO measurements. Within the models tested, the EFC-inspired form yields the lowest χ^2 (3.60), compared to w_0w_aCDM (4.49) and ΛCDM (23.71). This constitutes a necessary but not sufficient condition for EFC validation. Next steps include deriving $w(z)$ from first principles and multi-probe analysis with full covariance.

1 Introduction

The DESI DR2 BAO results suggest that a cosmological constant (ΛCDM) provides a poor fit to the data, pointing instead toward dynamical dark energy. We examine whether an entropy-driven transition model, motivated by Energy-Flow Cosmology, can accommodate these observations.

This is a phenomenological parametrization inspired by EFC; the next step is to derive the functional form from the EFC field equations and test it in a multi-probe analysis (BAO + SN + CMB) with full covariance.

2 Data

We use seven DESI DR2 BAO distance measurements (D_V/r_d) spanning $z = 0.30$ to $z = 2.33$ with diagonal errors only. Full covariance treatment is deferred to future work.

3 Models Tested

3.1 ΛCDM

Standard cosmological constant with $w = -1$ at all redshifts.

3.2 w_0w_aCDM

CPL parametrization:

$$w(z) = w_0 + w_a \cdot \frac{z}{1+z} \tag{1}$$

using DESI-reported best-fit values.

3.3 EFC-Inspired Form

Smooth transition motivated by entropy-gradient dynamics:

$$w(z) = w_{\text{late}} + (w_{\text{early}} - w_{\text{late}}) \cdot \tanh\left[\frac{z - z_{\text{trans}}}{0.5}\right] \tag{2}$$

Parameters fitted post-hoc to BAO data.

4 Results

4.1 Goodness of Fit

Table 1: χ^2 comparison across models (7 data points)

Model	χ^2	$\Delta\chi^2$ **vs** Λ**CDM**	**Assessment**
ΛCDM	23.71	—	Poor fit
$w_0 w_a$CDM (DESI)	4.49	−19.22	Good fit
EFC (best-fit)	3.60	−20.11	Best fit*

*Within the models tested here.

4.2 EFC Best-Fit Parameters

- $w_{\text{late}} = -0.80$ (dark energy equation of state today)
- $w_{\text{early}} = -1.41$ (at high z)
- $z_{\text{trans}} = 1.07$ (transition redshift)

4.3 $w(z)$ Evolution

Both dynamical models show phantom behavior ($w < -1$) at high redshift, but the EFC form predicts milder evolution: $w(z = 2) = -1.20$ versus $w(z = 2) = -1.33$ for $w_0 w_a$.

5 Interpretation

1. ΛCDM yields a significantly worse BAO fit, consistent with DESI's conclusion that dynamical dark energy is favored.
2. The EFC-inspired parameterization is compatible with DESI DR2 and marginally outperforms $w_0 w_a$CDM within this test.
3. These parameters were fitted post-hoc; this does not constitute a prediction from EFC theory.

6 Limitations

- Diagonal errors only—full covariance matrix not used
- BAO data only—CMB and SN constraints not included
- Post-hoc fitting rather than *a priori* prediction from EFC equations
- Simplified χ^2 comparison—no Bayesian model selection (e.g., BIC, evidence ratio)

7 Next Steps

1. **Derive $w(z)$ from EFC field equations**—replace post-hoc fitting with first-principles prediction
2. **Multi-probe analysis**—combine BAO + Pantheon+ SN + Planck CMB with full covariance
3. **Identify unique EFC signatures**—features that $w_0 w_a$ cannot reproduce
4. **Bayesian model comparison**—BIC or evidence ratio accounting for parameter count

8 Conclusion

An EFC-inspired dark energy parameterization fits DESI DR2 BAO data at least as well as the standard $w_0 w_a$CDM model. This represents a *necessary but not sufficient* condition for validating EFC. To elevate this from phenomenology to prediction, the $w(z)$ form must be derived from EFC equations and tested against combined multi-probe data.

Data and Code Availability: DESI DR2 data from Zenodo (doi:10.5281/zenodo.14733025). Analysis code and supplementary materials available at: `https://github.com/supertedai/EFC`.