

# Parameter-Free Verification

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## Proof That CSU Dark Energy Has Zero Adjustable Parameters

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### What is a “Free Parameter”?

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A free parameter is a quantity that:

1. Cannot be derived from first principles
2. Must be chosen to match observations
3. Has no theoretical constraint on its value

**CSU Dark Energy has NONE of these.**

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### Analysis of Each Quantity

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#### 1. $\alpha = \ln(2)$

**Status:**  DERIVED, not free

**Derivation:** Shannon entropy of binary choice

$$H(\text{binary}) = -\sum p_i \log(p_i) = -2 \times \frac{1}{2} \times \log\left(\frac{1}{2}\right) = \log(2)$$

**Why it's fixed:**

- Shannon proved this is the UNIQUE measure satisfying additivity and normalization
  - No alternative value is mathematically consistent
  - This is a theorem, not an assumption
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#### 2. $\beta = 1$

**Status:**  UNIT CHOICE, not free


**Explanation:**

- $\beta = 1$  means measuring information in bits
- This is analogous to choosing meters vs. feet
- Any other value is a rescaling (gauge transformation)
- Does not affect physical predictions

**Comparison:**

- Choosing  $\beta = \ln(2)$  would measure in nats
  - The physics is identical; only the numbers change
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### 3. $S_{\text{bulk}} = 2$

**Status:**  DERIVED, not free

**Derivation (Route 1 - Binary):**

$$Z = \sum_i e^{(-\beta E_i)} = e^0 + e^0 = 1 + 1 = 2$$

This is the unique partition function for a binary system.

**Derivation (Route 2 - Topological):**

$$\chi(S^2) = 2 \text{ (Euler characteristic of 2-sphere)}$$

This is a topological invariant - a theorem from differential geometry.

**Why it's fixed:**

- The value 2 represents the irreducible dichotomy of existence
- Any other value violates either binary quantization or  $S^2$  topology

### 4. $S_{\text{boundary}} = 1/12$

**Status:**  DERIVED, not free

**Derivation:**

For a 2D CFT with  $c = 1$ :

$$\begin{aligned} \text{Casimir energy: } E_0 &= -c/24 = -1/24 \\ \text{Boundary action: } S_{\text{boundary}} &= |E_0| \times 2 = 1/12 \end{aligned}$$


**Why  $c = 1$ :**

- Minimal non-trivial central charge for continuous  $U(1)$  symmetry
- Required for topological closure (Operational Property 3)

**Why it's fixed:**

- The Casimir formula is proven in CFT
- The factor  $1/24$  is universal (appears in modular forms, string theory, etc.)

### 5. $w_{\text{vac}} = 25/12$

**Status:**  DERIVED, not free

**Derivation:**

$$w_{\text{vac}} = S_{\text{bulk}} + S_{\text{boundary}} = 2 + 1/12 = 25/12$$

**Dual Pathway Convergence:**

- Information-theoretic:  $2 + 1/12 = 25/12$
- Topological:  $\chi(S^2) + c/12 = 2 + 1/12 = 25/12$

**Why it's fixed:**

- Both pathways give the same result
- No free parameters in either derivation
- The value 25/12 is mathematically inevitable

**6.  $\Omega_\Lambda = 25/36$** **Status:**  DERIVED, not free**Derivation:**

$$\Omega_\Lambda = w_{\text{vac}} / 3 = (25/12) / 3 = 25/36$$

**Why divide by 3:**

- Dark energy couples to all 3 spatial dimensions
- This is the spatial dimension of our universe (a fact, not a parameter)

**7.  $n_H$  (Holographic DOF)****Status:**  COMPUTED, not free**Formula:**

$$n_H = (R_H / l_P)^2$$

**Inputs:**

- $R_H = c/H_0$  (Hubble radius - measured)
- $l_P = \sqrt{(\hbar G/c^3)}$  (Planck length - from fundamental constants)

**Why it's not free:**

- $R_H$  comes from measuring the Hubble constant (independently of  $\Lambda$ )
- $l_P$  is fixed by fundamental constants
- No adjustable parameters

**8.  $\Xi_\Lambda$  (Cosmological Constant)****Status:**  DERIVED, not free**Formula:**

$$\Xi_\Lambda = w_{\text{vac}} / n_H = (25/12) / (R_H / l_P)^2$$

**Why it's not free:**

- $w_{\text{vac}}$  is derived (see above)
- $n_H$  is computed (see above)
- The formula is a direct consequence of holographic principle

## Summary: Zero Free Parameters

Quantity	Status	Determined By
$\alpha$	Derived	Shannon entropy
$\beta$	Unit choice	Information basis
$S_{\text{bulk}}$	Derived	Binary partition / $\chi(S^2)$
$S_{\text{boundary}}$	Derived	Casimir energy
$w_{\text{vac}}$	Derived	$S_{\text{bulk}} + S_{\text{boundary}}$
$\Omega_{\Lambda}$	Derived	$w_{\text{vac}} / 3$
$n_H$	Computed	Holographic bound
$\Xi_{\Lambda}$	Derived	$w_{\text{vac}} / n_H$

## Empirical Inputs (NOT Free Parameters)

The only empirical inputs are:

- $H_0 = 67.4 \text{ km/s/Mpc}$**  (Hubble constant)
  - Measured from galaxy recession velocities
  - Independent of any dark energy assumption
  - NOT a parameter of the theory
- Fundamental constants:  $c, \hbar, G$** 
  - Define Planck units
  - Measured independently
  - NOT parameters of CSU

## Comparison with Other Approaches

### Standard $\Lambda$ CDM

- **Free parameters:**  $\Lambda$  (fitted to observations)
- **Explanation:** None -  $\Lambda$  is simply a number we measure

### Quintessence

- **Free parameters:** Potential  $V(\phi)$ , initial conditions, mass  $m$
- **Explanation:** Scalar field dynamics (but parameters fitted)

### Anthropic Argument

- **Free parameters:** Range of “allowed”  $\Lambda$  values

- **Explanation:** Selection effect (not a derivation)

## CSU

- **Free parameters:** ZERO
  - **Explanation:** Complete derivation from axioms
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## Conclusion

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### CSU Dark Energy achieves what no other approach has:

A complete derivation of the cosmological constant with:

- Zero free parameters
- Zero fitted values
- Zero ad hoc assumptions

The value  $\Xi_{\Lambda} = 2.889 \times 10^{-122}$  is **mathematically inevitable** given the CSU axioms.