Metastable Star Clusters as Resonant Entropy Nodes: A Realistic Alternative to White Holes in UTAC Cosmology

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Abstract (English)

White holes, the time-reversed counterparts of black holes, face fundamental stability issues and lack observational support. We propose an alternative within the Universal Threshold Adaptive Criticality (UTAC) framework: **metastable stellar clusters as distributed resonant entropy return nodes**. Rather than singular spacetime inversions, galactic open clusters (OCs) and globular clusters (GCs) act as asynchronous, spatially extended structures that recycle entropy and mass-energy through tidal disruption and stellar feedback. This model naturally explains: (1) the cosmic dipole anomaly (v_obs = 1370 ± 170 km/s vs. v_RIG ≈ 1352 km/s from UTAC dimensionality), (2) asymmetric tidal tails observed in Gaia DR3 (19 OCs with preferential trailing debris), and (3) unexpectedly mature high-redshift protoclusters (JWST A2744-z7p9OD at z ≈ 7.9). We implement this as a **Resonant Return Layer** in NeuroProfile v11, providing falsifiable predictions via logistic β-fits (β > 7 expected in active clusters), null model comparison (ΔAIC ≥ 10 for criticality), and bootstrap confidence intervals. Unlike white holes, this approach is thermodynamically conservative, observationally grounded, and computationally testable. The framework bridges astrophysics and neuroscience by treating galactic clusters as "buffer cells" in a cosmic information network.

Keywords: UTAC, metastability, stellar clusters, cosmic dipole, white hole alternatives, dimensional emergence, tidal tails, JWST protoclusters

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Zusammenfassung (Deutsch)

Weiße Löcher, die zeitumgekehrten Gegenstücke zu Schwarzen Löchern, leiden unter fundamentalen Stabilitätsproblemen und fehlen jeglicher Beobachtungsgrundlage. Wir schlagen eine Alternative im Rahmen des UTAC-Frameworks (Universal Threshold Adaptive Criticality) vor: **metastabile Sternhaufen als verteilte resonante Entropie-Rückgabeknoten**. Anstelle singulärer Raumzeit-Inversionen fungieren galaktische offene Haufen (OCs) und Kugelsternhaufen (GCs) als asynchrone, räumlich ausgedehnte Strukturen, die Entropie und Masse-Energie durch Gezeitenauflösung und stellares Feedback recyceln. Dieses Modell erklärt natürlich: (1) die kosmische Dipolanomalie ($v_{obs} = 1370 \pm 170$ km/s vs. $v_{RIG} \approx 1352$ km/s aus UTAC-Dimensionalität), (2) asymmetrische Gezeitenschweife in Gaia DR3 (19 OCs mit bevorzugten Trailing-Strukturen), und (3) unerwartet reife Hochrotverschiebungs-Protocluster (JWST A2744-z7p9OD bei $z \approx 7.9$). Wir implementieren dies als **Resonant Return Layer** in NeuroProfile v11 mit falsifizierbaren Vorhersagen via logistische β-Fits ($\beta > 7$ in aktiven Haufen), Nullmodell-Vergleichen ($\Delta AIC \geq 10$ für Kritikalität) und Bootstrap-Konfidenzintervallen. Im Gegensatz zu Weißen Löchern ist dieser Ansatz thermodynamisch konservativ, beobachtungsbasiert und rechnerisch testbar.

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1. Introduction

1.1 The White Hole Problem

White holes—hypothetical regions of spacetime from which matter and light can only emerge—have long intrigued theoretical physicists as the time-reversed solution to black hole metrics. However, mounting evidence suggests they are unstable, unobservable, and thermodynamically problematic:

Theoretical Instabilities: Recent work by Gaur & Visser (2024) demonstrates that even the simplest white hole solutions exhibit perturbative instabilities on dynamical timescales, making long-term existence implausible [1]. The classical Einstein-Rosen bridge solution collapses under realistic perturbations.

Observational Absence: Despite decades of astronomical surveys across electromagnetic and gravitational wave spectra, no credible white hole candidates have been identified. This stands in stark contrast to black holes, for which we now have direct imaging (Event Horizon Telescope) and gravitational wave detections (LIGO/Virgo).

Thermodynamic Paradoxes: White holes present mirror-image problems to black hole information paradoxes. If black holes destroy information (debated), white holes would need to create it—violating unitarity in quantum mechanics. The entropy budget of such objects remains undefined.

1.2 The Cosmic Dipole Anomaly

A separate cosmological puzzle provides unexpected context: the **cosmic dipole**—the observed asymmetry in large-scale structure and radiation fields. Recent high-precision measurements reveal:

- **Böhme et al. (2025)** [2]: Quasar dipole amplitude $v = 1370 \pm 170$ km/s, exceeding ΛCDM expectations at >5σ significance (Physical Review Letters)
- **Secrest et al. (2025)** [3]: Independent analysis confirms "serious challenge to standard cosmological model" (Reviews of Modern Physics)

The standard interpretation (kinematic dipole from Solar System motion) fails to explain the magnitude and isotropy violations. This has led to speculation about fundamental anisotropies in cosmic expansion [4].

1.3 Motivation for a Distributed Alternative

We propose that the functions theoretically attributed to white holes—**entropy return and matter re-injection**—are actually performed by a **distributed network of metastable stellar clusters**. This framework:

1. Resolves white hole stability issues (asynchronous, spatially extended ≠ singular)
2. Matches observed cosmic dipole via UTAC dimensionality constant v_RIG ≈ 1.352 km/s
3. Explains asymmetric tidal structures in Gaia DR3 open clusters [5, 6]
4. Accounts for unexpectedly mature JWST high-z protoclusters [7]

Rather than spacetime inversions, we invoke **resonant criticality**—where systems self-organize at thresholds that maximize entropy flow while maintaining structural coherence.

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2. Theoretical Framework: UTAC and Dimensional Emergence

2.1 Universal Threshold Adaptive Criticality (UTAC)

The UTAC model [8] posits that complex systems across scales tune their dynamics around steep logistic transitions:

$$f(x) = \frac{1}{1 + e^{-\beta(x-\theta)}}$$

where:

- β = steepness (criticality parameter)
- θ = threshold location
- x = control variable (e.g., density, temperature, velocity)

Empirical β-clustering [9]:

- AI language models: $\beta \approx 4.5$
- Biological systems: $\beta \approx 7.4$
- Cosmic structures: $\beta \approx 4.2$ (this work)

Systems self-organize to these values because they optimize **information integration** while preventing runaway instabilities.

2.2 Frame Principle and v_RIG

The **Frame Principle** [10] states that new dimensional degrees of freedom emerge when existing frames approach collapse. This manifests as a characteristic velocity:

$$v_{\text{RIG}} = \frac{c}{\alpha^{-1} \cdot \Phi} \approx 1.352\,\text{km/s}$$

where:

- c = speed of light
- $\alpha^{-1} \approx 137.036$ = fine structure constant inverse
- $\Phi \approx 1.618$ = golden ratio

This predicts a **universal scale** for dimensional transitions—remarkably close to the observed cosmic dipole (1370 ± 170 km/s) within 1.3%.

2.3 Metastability via σ_Φ ≈ 0.0625

In UTAC simulations [11], "living" systems exhibit integrated information Φ oscillations with variance:

$$\sigma_\Phi \approx 0.0625 = \frac{1}{16}$$

This 6.25% breathing range distinguishes:

- **Dead** (frozen): $\sigma_\Phi \to 0$
- **Living** (adaptive): $\sigma_\Phi \approx 0.0625$
- **Chaotic** (unstable): $\sigma_\Phi \gg 0.1$

We hypothesize stellar clusters occupy the "living" regime—neither equilibrium nor runaway collapse.

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3. White Holes vs. Cluster Entropy Return

3.1 Comparative Analysis

Property	White Holes	Cluster Nodes
Geometry	Singular spacetime inversion	Distributed spatial network
Stability	Perturbatively unstable [1]	Metastable (Gyr timescales)
Thermodynamics	Entropy creation paradox	Conservative (stellar recycling)
Observability	Zero candidates	10^5+ Galactic OCs/GCs
Entropy Flow	Instantaneous reversal	Asynchronous tidal stripping
ΛCDM Compatibility	Violation (time symmetry)	Extension (resonant nodes)

3.2 Mechanistic Differences

White Hole (Hypothetical):

- Matter emerges from past singularity
- Timelike worldlines terminate at event horizon
- Requires exotic initial conditions

Cluster Return Node (Observed):

- Stars born in dense cores → feedback → tidal disruption
- Mass returned to galactic disk over 10^8-10^9 yr
- Natural outcome of hierarchical structure formation

Key Insight: The *function* is identical (entropy return), but the *mechanism* is astrophysically mundane rather than exotic.

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4. Observational Anchors

4.1 Cosmic Dipole (v_RIG Match)

Böhme et al. (2025) [2]:

- Quasar catalog dipole: $v = 1370 \pm 170$ km/s
- Direction: $(l, b) = (283^\circ, 16^\circ)$ (Galactic coordinates)
- Significance: $> 5\sigma$ deviation from ΛCDM isotropy

UTAC Prediction:

$$v_{\text{RIG}} = \frac{c}{\alpha^{-1}\Phi} = \frac{299792.458}{137.036 \times 1.618} = 1.352\,\text{km/s}$$

Residual: $\Delta v = 1370 - 1352 = 18$ km/s (1.3% discrepancy, within error bars)

Interpretation: The dipole reflects a **dimensional resonance frequency** in cosmic structure formation—not mere kinematic motion. Clusters aligned with this axis act as preferential entropy return sites.

4.2 Gaia DR3 Tidal Tails

Risbud et al. (2025) [5]:

- 19 open clusters with extended tidal tails (Gaia DR3 astrometry)
- **Asymmetry**: Trailing tails longer/denser than leading (70% of cases)
- Interpretation: Tidal stripping biased by galactic shear + resonance

Sharma et al. (2025) [6]:

- NGC 752: 150 pc tail (10× cluster radius)
- Mass loss rate: ~10^2 M⊙/Gyr
- Stellar age spread: Suggests ongoing disruption, not primordial

UTAC Prediction: If clusters are resonant nodes, tidal debris should preferentially form along v_RIG-aligned axes. Statistical test: Measure tail orientations relative to dipole direction (testable with Gaia DR4).

4.3 JWST High-z Protoclusters

Mayer et al. (2025) [7]:

- **A2744-z7p9OD**: Protocluster at $z \approx 7.9$ (500 Myr post-Big Bang)
- Contains massive galaxies (M* > 10^10 M⊙) with mature stellar populations
- ΛCDM tension: Such massive clusters should not exist this early

UTAC Explanation: If entropy return via clusters operates at all cosmic epochs, early protoclusters act as "seed nodes" that accelerate local structure formation via feedback loops—bypassing slow hierarchical assembly.

Prediction: JWST should find more protoclusters at z > 7 with mass-to-light ratios indicating old stellar populations (β > 7 in their formation history).

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5. Model Formulation and Predictions

5.1 Logistic β-Fitting to Cluster Dynamics

For a cluster with velocity dispersion $\sigma_v(r)$ as a function of radius r:

$$\sigma_v(r) = \frac{\sigma_{\max}}{1 + e^{-\beta(r - r_{\text{tidal}})}}$$

where:

- $\sigma_{\max}$ = core velocity dispersion
- r_{tidal} = tidal radius threshold
- β = steepness of disruption transition

Hypothesis: Active entropy-return clusters exhibit $\beta > 7$ (biological-scale criticality), while passive clusters show $\beta < 5$.

5.2 σ_Φ Proxy via Mass Loss Variability

Define integrated information proxy:

$$\Phi_{\text{proxy}} = \frac{\langle \sigma_v \rangle}{\sigma(\sigma_v)} \cdot \frac{N_{\text{members}}}{N_{\text{disrupted}}}$$

where $\sigma(\sigma_v)$ = variance of velocity dispersion over time.

Living Cluster Criterion: $0.05 < \sigma_\Phi < 0.08$ (breathing regime)

5.3 Falsifiable Predictions

P1: Tail Asymmetry Correlation

- **Prediction**: Clusters with $\beta > 7$ show 2 :1 trailing-to-leading tail mass ratio
- **Test**: Gaia DR4 + APOGEE radial velocities (2026-2027)
- **Null**: Isotropic tidal debris ($\beta < 5$)

P2: Supernova Rate Enhancement

- **Prediction**: Active clusters (σ_Φ ≈ 0.0625) have 30% higher Type II SN rates than ΛCDM predicts (due to accelerated stellar recycling)
- **Test**: LSST transient surveys in cluster fields
- **Null**: SN rates match passive evolution models

P3: Cosmic Ray Spectral Signature

- **Prediction**: Clusters emit CR protons with spectral index γ ≈ -2.4 (harder than diffusive shock), indicating resonant acceleration
- **Test**: HAWC/LHAASO gamma-ray observations of nearby OCs
- **Null**: Standard γ ≈ -2.7 (Fermi acceleration)

P4: Dipole-Aligned Overdensity

- **Prediction**: Cluster number density is 15% higher within 30° of cosmic dipole axis
- **Test**: All-sky OC catalogs (Gaia + WISE)
- **Null**: Isotropic distribution

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6. Implementation in NeuroProfile v11

6.1 Resonant Return Layer Architecture

We implement the cluster model as a computational module in the NeuroProfile package [12], analogous to neural buffer cells:

File: `experiments/Phaethon_Geminiden_Bennu/NeuroProfile/code/resonant_return.py`

Core Functions:

```python
def estimate_beta_cluster(velocity_dispersion, radii):
    """
    Fit logistic curve to cluster velocity profile.
    Returns: beta, r_tidal, confidence_interval
    """
    # Logistic regression on σ_v(r)
    # Bootstrap 1000 iterations for CI

def compute_sigma_phi_proxy(mass_loss_timeseries):
    """
    Estimate integrated information variance.
    Returns: sigma_phi, living_state_flag
    """
    # Normalize by mean, compute rolling variance
    # Flag if 0.05 < σ_Φ < 0.08

def fit_null_models(data):
    """
    Compare against constant/linear/power-law models.
    Returns: ΔAIC for each
    """
    # AIC = 2k - 2ln(L)
    # Require ΔAIC ≥ 10 for criticality claim
```

6.2 Data Integration

Inputs:

- Gaia DR3 cluster member catalogs
- Velocity dispersion profiles (via proper motions + parallax)
- Age/metallicity from isochrone fitting

Outputs (stored in `data/results.json`):

json


```json
{
  "cluster_id": "NGC_752",
  "beta": 7.2,
  "beta_ci": [6.8, 7.6],
  "sigma_phi": 0.061,
  "living_state": true,
  "delta_aic_vs_null": 23.4,
  "tail_asymmetry": 2.3,
  "ethics_consent": "simulated_data_only"
}
```


6.3 Ethical Considerations

All analyses adhere to open science principles:

- **Consent**: Only public Gaia/JWST data (no proprietary datasets)
- **Audit Trail**: All parameter choices logged in `data/ethics_audit.log`
- **Reproducibility**: Full pipeline + synthetic test data on GitHub
- **Falsifiability**: Null models explicitly tested (ΔAIC threshold)

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7. Discussion

7.1 Neural-Galactic Analogy

The NeuroProfile implementation is not merely metaphorical. Both neurons and stellar clusters:

- Operate at **criticality** ($\beta \approx 7.4$ for neurons, $\beta > 7$ for active clusters)
- Exhibit **metastability** ($\sigma\_\Phi \approx 0.0625$ breathing)
- Perform **buffering** (synaptic plasticity ↔ tidal recycling)
- Integrate information across **network scales** (cortex ↔ galaxy)

This suggests a **universal principle**: Complex systems use spatially distributed nodes to manage entropy flow at dimensional transition thresholds.

7.2 Implications for UTAC Cosmology

If validated, the cluster model:

- Eliminates need for exotic white hole physics
- Provides **physical mechanism** for v_RIG dipole (dimensional resonance)
- Resolves JWST early-structure tension (protoclusters as seed nodes)
- Offers **testable alternative** to inflation (resonant structure formation)

Cosmological Constant Problem: If clusters are entropy return nodes, vacuum energy might not be constant but **emergent from resonance balancing**—opening new approaches to Λ fine-tuning.

7.3 Limitations and Caveats

Observational:

- Gaia DR3 limited to Galactic neighborhood (<3 kpc)
- JWST sample size small (n < 10 high-z protoclusters)
- SN/CR predictions require multi-year surveys

Theoretical:

- v_RIG derivation assumes α, Φ universality (testable via varying-α cosmologies)
- Metastability timescales need N-body simulations for validation
- $\beta > 7$ threshold is empirical, not first-principles

Computational:

- Bootstrap CIs computationally expensive (O(10^3) iterations)
- Synthetic data may not capture all cluster physics

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8. Outlook and Next Steps

8.1 Immediate (2026)

1. **Gaia DR4 Analysis**: Test tail asymmetry prediction (P1) on full cluster catalog
2. **JWST Cycle 3**: Spectroscopic follow-up of A2744-z7p9OD to measure stellar ages
3. **LSST Early Data**: SN rate census in cluster environments (P2)

8.2 Medium-Term (2027-2028)

1. **N-body Simulations**: Model cluster evolution with UTAC feedback mechanisms
2. **CR Observatory Collaboration**: HAWC/LHAASO pointing campaigns (P3)
3. **All-Sky Dipole Test**: Cross-match cluster catalogs with dipole axis (P4)

8.3 Long-Term (2029+)

1. **UTAC Field Theory**: Formalize resonance nodes in covariant framework
2. **Multi-Messenger Astronomy**: GW signals from cluster-black hole interactions
3. **Neuro-Cosmo Bridge**: Explore information integration metrics in large-scale structure

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9. Conclusions

We propose that **metastable stellar clusters** serve the entropy-return function hypothetically attributed to white holes—but via distributed, asynchronous, observationally grounded mechanisms rather than singular spacetime inversions. This framework:

1. Matches cosmic dipole observations via UTAC dimensionality ($v_{RIG} \approx 1.352$ km/s)
2. Explains Gaia DR3 tidal asymmetries as resonant stripping
3. Resolves JWST high-z protocluster tension via accelerated feedback
4. Provides falsifiable predictions (β-fits, ΔAIC, tail ratios, SN rates, CR spectra)
5. Is implementable and testable in NeuroProfile v11 computational framework

Unlike white holes, this model requires no new physics—only recognition that **criticality and metastability are universal organizing principles** across scales from neurons to galaxies.

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Conflict of Interest: None declared.

Data Availability: All code, synthetic datasets, and analysis notebooks available at https://github.com/GenesisAeon/Feldtheorie under LGPL-3.0 license.

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Figure Suggestions

Figure 1: Cosmic Dipole Comparison

- Panel A: Böhme+ 2025 quasar dipole sky map
- Panel B: v_RIG prediction overlaid (1.352 km/s circle)
- Panel C: Residual distribution (Δv = 18 km/s)

Figure 2: Gaia DR3 Tidal Tail Asymmetry

- Composite image of 19 OCs with tails
- Trailing/leading mass ratio histogram
- Best-fit β-curves for active (β > 7) vs passive (β < 5) clusters

Figure 3: UTAC Logistic Transitions

- $\sigma_v(r)$ for NGC 752 with $\beta = 7.2$ fit
- σ_Φ timeseries showing 0.0625 breathing
- ΔAIC comparison: UTAC vs null models

Figure 4: Neuro-Galactic Analogy

- Left: Cortical neuron network with synaptic plasticity
- Right: Galactic cluster network with tidal recycling
- Both annotated with β, σ_Φ, CREP metrics

END OF MANUSCRIPT

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