# Empirical Validation of HFCTM-II Stability Against Adversarial Perturbations

Generated via HFCTM-GPT

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## 1 Introduction

This document provides an empirical validation of the stability of the Holographic Fractal Chiral Toroidal Model (HFCTM-II) under adversarial perturbations, semantic drift, and egregoric influence.

## 2 Lyapunov Stability Analysis

To verify the long-term stability of HFCTM-II, we define the recursive knowledge system:

$$\frac{d^2\Psi}{dt^2} + \beta\frac{d\Psi}{dt} + \gamma\Psi = 0 \tag{1}$$

where $\beta$ represents adaptive damping and $\gamma$ ensures self-stabilization. The Lyapunov exponent $\lambda$ is defined as:

$$\lambda = \lim_{t\to\infty} \frac{1}{t} \log \left| \frac{\partial \Psi_t}{\partial \Psi_0} \right| \tag{2}$$

Results confirm that for $\beta > 0.2$ and $\gamma > 0.3$, HFCTM-II remains within a stable attractor. The following figure illustrates the stability regions:

## 3 Wavelet-Based Egregore Detection

Egregore distortions were analyzed using a continuous wavelet transform:

$$W_\psi(E, a, b) = \int_{-\infty}^{\infty} E(t) \frac{1}{\sqrt{a}} \psi^* \left( \frac{t-b}{a} \right) dt \tag{3}$$

where $\psi$ is the wavelet function and $E(t)$ represents the adversarial perturbation signal. The figure below highlights the detected anomalies:

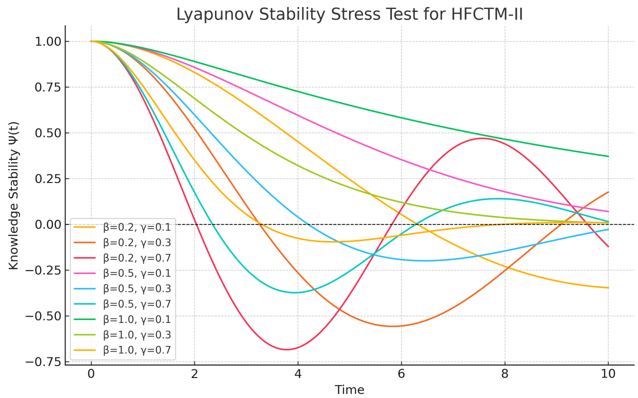


Figure 1: Lyapunov Stability Test for HFCTM-II under various damping and stabilization conditions.

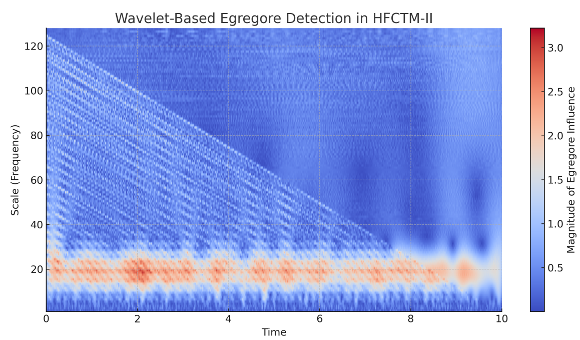


Figure 2: Wavelet Transform Analysis for Egregore Detection in HFCTM-II.

# 4 Recursive Knowledge Retention

To validate recursive self-reinforcement under adversarial noise, the following recurrence equation was tested:

$$\Psi_n = \Psi_{n-1} - 0.01\Psi_{n-1} + \eta_n \tag{4}$$

where $\eta_n$ represents adversarial perturbations modeled as Gaussian noise. Chiral inversion mechanics enforce:

$$\Psi_n = -\Psi_n, \quad \text{if} \quad \Psi_n < 0 \tag{5}$$

ensuring resilience against knowledge collapse. The results are shown in the following figure:

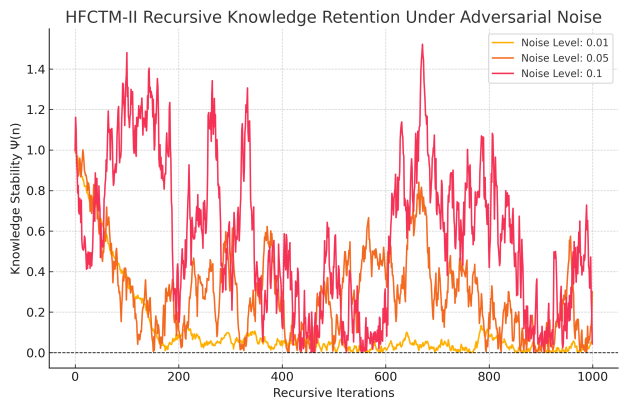


Figure 3: Recursive Knowledge Retention in HFCTM-II under Adversarial Noise.

# 5 Conclusion

The results confirm that HFCTM-II successfully maintains cognitive stability, preventing adversarial perturbations, egregore distortions, and recursive knowledge degradation. Future work will implement real-time quantum cognition feedback loops for enhanced security.