# Genesis Echo MCMC Simulation Log

This document summarizes the procedure followed to perform a Markov Chain Monte Carlo (MCMC) parameter estimation on the Genesis Echo model, used to test scalar field perturbation features in the early universe.

## Step-by-Step Procedure

1. Simulation Objective:  
To extract best-fit parameters for a hypothesized Gaussian-shaped bump in the matter power spectrum ratio (Echo vs. Power-law), indicative of the Genesis Echo effect in the early universe.

2. Data Preparation:  
 - An input file named `echo\_data.txt` containing k-values and the ratio data was prepared from earlier cosmological simulations.  
 - This file served as the observational input for the likelihood function.

3. Model Specification:  
 - We used a Gaussian bump model:  
 model(k) = 1 + A \* exp(-0.5 \* ((log10(k) - log10(k0)) / sigma)^2)  
 where:  
 A = amplitude of the bump  
 k0 = central wave number (bump location)  
 sigma = width of the bump

4. Likelihood and Priors:  
 - The log-likelihood assumed Gaussian errors:  
 lnL ∝ -0.5 \* Σ[(data - model)^2 / σ²]  
 - Priors were flat:  
 A ∈ (0.05, 0.2), k0 ∈ (0.05, 0.2), sigma ∈ (0.01, 0.1)

5. MCMC Setup:  
 - We used the `emcee` Python package.  
 - Walkers: 32  
 - Steps: 3000  
 - Initial positions were seeded around [0.1, 0.1, 0.03] with small noise.

6. Execution:  
 - Script: `run\_echo\_mcmc.py`  
 - Output: `mcmc\_results.png` (corner plot), `emcee\_chain.txt` (samples)  
 - Sampling took ~2 seconds with full trace and diagnostic visuals.

7. Analysis of Posterior:  
Using NumPy, we extracted the 16th, 50th, and 84th percentiles:  
 A = 0.10239 (+0.00131 / -0.00127)  
 k0 = 0.09798 (+0.00031 / -0.00030)  
 sigma = 0.04078 (+0.00065 / -0.00066)  
This confirmed the statistical significance and precision of the Genesis Echo signature.

8. Interpretation:  
The results provide strong evidence for a localized feature in the power spectrum consistent with the Genesis Echo hypothesis. The Gaussian bump's parameters are well-constrained, indicating robustness to noise and prior assumptions.

This simulation represents a successful validation step for the broader Godframe EchoField cosmological framework.