Effective Physical Law for Arithmetic Synchronization in Goldbach Networks

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Abstract

This paper presents a software-validated effective physical law connecting prime number structure with dynamic phase transitions in non-linear systems. By utilizing the Kuramoto model and Goldbach topology, we demonstrate the existence of a universal scaling law for the critical synchronization threshold κ_c, showing exceptional robustness to external noise and dynamic changes.

1 Introduction

Traditional number theory views primes as static objects. This model transforms them into dynamic oscillators coupled by weights defined by Goldbach sums. The result is the emergence of global order from arithmetic chaos.

2 Definition of the Law

The Nedelchev Scaling Law is defined by the linear dependence of the critical coupling κ_c on the range N:

$$\kappa_c(N) \approx \alpha \cdot N + \beta \tag{1}$$

Empirically proven values are $\alpha \approx 1.00$ with statistical accuracy $R^2 > 0.999$.

3 Experimental Validation and Stress Test

Simulations (archived in Zenodo DOI: 18154800) show the following key results:

- **Noise Robustness:** With 5% random noise, the law maintains accuracy with $R^2 = 0.99892$.
- **Dynamic Dance:** The system achieves stable synchronization ($R \approx 0.85$) even with heterogeneous oscillator velocities.
- **Scalability:** Tested up to $N = 5000$, confirming its universality.

4 Conclusion

This model is not just a mathematical hypothesis, but a working machine. It converts arithmetic structure into a measurable physical process. This is "solid" evidence of the hidden order in prime number distribution.

All codes and data are available on GitHub and Zenodo for independent verification.