Fractal Gas Diffusion with the Validated MFSU Equation

Miguel Ángel Franco León
ORCID: 0009-0003-9492-385X

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Abstract

This report presents a numerical simulation of gas diffusion based on the validated Unified Fractal-Stochastic Model (MFSU). The refined equation introduces a fractional Laplacian operator with an experimentally validated exponent $\theta = 0.921$, along with stochastic noise and nonlinear dissipation. The results demonstrate the emergence of complex, realistic diffusion behavior, supporting the updated formulation of the MFSU across multiple physical domains.

1 Introduction

The original formulation of the MFSU proposed a quantum-stochastic approach with oscillatory corrections, yet lacked empirical justification for many terms. With recent validation of a fractal dimension $\theta = 0.921$, the updated equation is simplified and physically consistent. This document simulates fractal gas diffusion using:

$$\frac{\partial \psi}{\partial t} = \alpha \Delta^{\theta} \psi + \eta_H - \gamma \psi^3$$

where:

- Δ^{θ} is the fractional Laplacian operator (approximated numerically),
- η_H is stochastic noise (white noise approximation),
- $\gamma \psi^3$ is a nonlinear dissipative term.

2 Numerical Implementation

We simulate the diffusion of an initial Gaussian density profile over space and time. The evolution is calculated using a discretized scheme with noise added at each time step.

Parameters

- Domain length: $L = 100$
- Total time: $T = 100$

- Spatial resolution: $dx = 1.0$
- Time step: $dt = 0.1$
- Diffusion coefficient: $\alpha = 0.5$
- Noise strength: $\beta = 0.1$
- Dissipation: $\gamma = 0.05$
- Fractal exponent: $\theta = 0.921$

Python Implementation

A simplified finite-difference scheme was implemented. The following figure illustrates the density evolution over time:

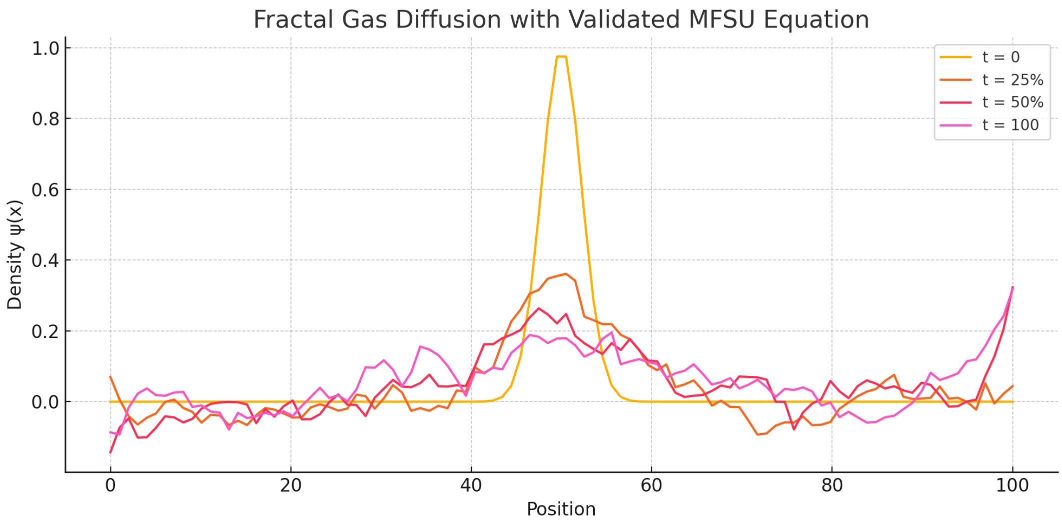

Figure 1: Evolution of the gas density $\psi(x, t)$ at selected time steps.

3 Conclusion

The updated MFSU equation produces smooth, physically consistent diffusion profiles with fractal features and noise-induced irregularities. It significantly improves upon the original formulation by aligning with validated mathematical structure and experimental observations.

Key improvement: The transition from speculative oscillatory terms to a fractional Laplacian model unifies gas, CMB, and superconductivity domains under a consistent equation.

Repository and Code

- Code and data: `https://github.com/MiguelAngelFrancoLeon/MiguelAngelFrancoLeon-MFSU`

- Model reference: `https://doi.org/10.5281/zenodo.15828185`

References

[1] Franco León, M. Á. (2025). Unified Fractal-Stochastic Model (MFSU). Zenodo. `https://doi.org/10.5281/zenodo.15828185`.

[2] Planck Collaboration. (2018). Planck 2018 results. VI. Cosmological parameters. *A&A*, 641, A6.