Complex Dynamics and Foundational Physics: New Developments

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Abstract

This is a brief rundown on some of my research projects that are currently in the planning stage. My goal is to further explore the conjecture that *complex dynamics of nonlinear systems* lies at the heart of foundational physics. The anticipated completion timeframe for these contributions is the end of 2024.

HIGH ENERGY THEORETICAL PHYSICS

Unphysical Objects in Particle Theory

Over the years, particle theory has seen a steady overflow of proposals targeting physics beyond the Standard Model (BSM). The bulk of these proposals postulate new objects (elementary fields or bound states) or hidden symmetries that allegedly break down somewhere above the Standard Model scale. This report lists few trendy BSM theories that, despite being mathematically motivated, are so far disfavored by experiments.

Key words: Beyond Standard Model physics, Weyl fermions, spin 3/2 fermions, low energy superpartners, Dirac monopoles, axions, preons, WIMP's, Georgi's unparticles, KK gravitons, higher than 2 spin models, sterile neutrinos, glueballs, leptoquarks, technifermions, composite Higgs, multiple Higgs, dark photon, Z' bosons, photophobic and photophilic particles, Weyl bosons as Dark Matter candidates, X 17 boson, Hidden Valley states.

Classical Chaos and Non-Perturbative Physics

It is generally believed that perturbative field theory breaks down somewhere in the deep Terascale sector of particle physics, as well as below the hadronization scale. The key premise of this work is that *chaos* and *multifractality* are bound to develop near the unstable attractors of the Renormalization Group flow. Appealing to nonintegrability and by analogy with the Anisotropic Kepler Problem (AKP), here we argue that *classical chaos* underlies the non-perturbative limit of elementary processes such as electron-positron scattering and quark-antiquark interaction.

Key words: classical chaos, multifractality, nonintegrability, nonperturbative field theory, Anisotropic Kepler Problem.

Universal Bifurcations and the Standard Model

This work is a synthesis of research carried out between 1990 and 2022 and is based on the following contributions:

https://www.researchgate.net/publication/357093467

https://www.researchgate.net/publication/357093456

https://www.researchgate.net/publication/344417174

https://www.researchgate.net/publication/344036923

https://www.researchgate.net/publication/343863324

https://www.researchgate.net/publication/343686626

Hamiltonian Chaos and the Physics of Feynman Diagrams

We explore here the link between perturbative Quantum Field Theory and the chaotic dynamics of Hamiltonian systems. The premise is that, on appropriate time scales, particle absorption and emission events in Feynman diagrams are *persistent resonant processes* mirroring the mechanism of coupled resonances in Hamiltonian chaos.

Demanding marginal stability of Feynman vertices produces novel nonperturbative constraints connecting particle masses and coupling strengths.

Key words: Hamiltonian chaos, Feynman diagrams, persistent scattering, Poincaré resonances, Beyond the physics of the Standard Model.

Arnold Diffusion and the Breakdown of Hamilton's Principle

As long-cherished postulate of theoretical physics, *Hamilton's principle* is the backbone of relativistic dynamics and Quantum Field Theory. The goal of this report is to argue that the instability of near-integrable Hamiltonian systems known as "*Arnold diffusion*" is prone to override Hamilton's principle outside the range of effective field theory.

Key words: Arnold Diffusion, Hamiltonian Chaos, Least Action Principle, Effective Field Theory

GRAVITATIONAL DYNAMICS AND FIELD UNIFICATION

On Nonintegrability and the Challenges of Field Unification

We examine several instances in which the principle of stationary action fails to hold and leads to the breakdown of conventional Lagrangian field theory. S*ensitivity to initial*

conditions makes the variation of the action functional ill-defined. Likewise, systems endowed with *nowhere-differentiable* trajectories, systems exhibiting *Hamiltonian chaos* or *self-organized criticality* are nonintegrable in the conventional sense. Nonintegrable dynamics is prevailing in Nature and its successful description requires the methodology of chaos, multifractals, and fractional calculus. Our analysis offers a contrasting viewpoint on the physics beyond the Standard Model and on the field unification program.
Key words: Least action principle, sensitivity to initial conditions, Hamiltonian chaos, fractional dynamics, self-organized criticality, multifractals, unified field theory

Standard Cosmology and Self-Organized Criticality

Self-organized criticality (SOC) reflects the ability of large-scale dynamical systems to self-sustain critical behavior outside equilibrium. Here we argue that SOC underlies the evolution of the early Universe and sheds new light on the inner workings of the Friedmann-Robertson-Walker (FRW) cosmology.
Key words: Self-organized criticality, universality classes, early Universe cosmology, FRW model, cosmological constant, Dark Matter.