

# Effective Energy Dissipation and Emergent Mass Term in Non-Adiabatic Yang–Mills Systems

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*Abstract- This short note presents a conceptual model that explores how energy dissipation in non-adiabatic gauge systems can produce an effect mathematically similar to a mass term in Yang–Mills theory. The purpose is not to propose a rigorous proof of the Yang–Mills mass-gap problem, but to examine a classical analogy that may provide insight into field-energy behaviour under imperfect boundary conditions.*

## I. INTRODUCTION

Yang–Mills theory forms the foundation of modern gauge-field physics and quantum chromodynamics (QCD). In idealized formulations, gauge fields are perfectly conservative and massless. Real physical systems, however, often interact with matter or boundaries, leading to small non-adiabatic effects.

This paper explores whether such dissipative interactions can be represented by a mathematical term that resembles an effective mass.

## II. ENERGY DISSIPATION MODEL

For a non-adiabatic field, the total energy  $E(t)$  may decay over time as:

$$E(t) = E_0 e^{-kt},$$

where  $k$  is a small positive constant that characterizes leakage of field energy into the environment.

The instantaneous rate of energy loss is:

$$\frac{dE}{dt} = -kE.$$

This equation shows that the system continuously loses energy, implying that perfect adiabatic isolation is not achievable in practice.

## III. CONNECTION TO FIELD EQUATIONS

Consider a simplified Yang–Mills potential  $A_\mu^a$ .

Introducing a damping term gives the modified field equation:

$$\partial_\nu F^{a\mu\nu} + k \partial_t A^{a\mu} = 0,$$

where  $F_{\mu\nu}^a$  is the standard field tensor.

In a linearized regime, this produces a dispersion relation of the form:

$$\omega^2 = k^2 + k^2.$$

Here, the parameter  $k$  behaves like an effective mass term,  $m_{\text{eff}} = k$ .

## IV. DISCUSSION

The damping constant  $k$  does not represent an actual particle mass but indicates that energy cannot propagate indefinitely without loss.

This analogy shows how imperfect gauge symmetry or boundary effects may lead to behavior qualitatively similar to the presence of a mass gap.

Further mathematical work would be needed to express this relationship within a fully gauge-invariant and quantum framework.

## CONCLUSION

The proposed model suggests that non-adiabatic interactions can mimic the mathematical structure of a mass term in Yang–Mills equations.

While this is only a heuristic analogy, it may help illustrate how confinement or energy localization could arise in real physical systems that are not perfectly isolated.

## REFERENCES

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