Derivation of the 11D Supergravity Action

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1 Introduction

Eleven-dimensional supergravity is the unique maximal supergravity theory in 11 dimensions [1]. It is the low-energy limit of M-theory and serves as the highest-dimensional consistent supersymmetric extension of general relativity.

This document derives the bosonic part of the 11D supergravity action step by step.

2 The 11D Supergravity Action

The complete 11D supergravity action (Cremmer, Julia, Scherk, 1978) consists of the bosonic sector, the gravitino kinetic term, and interaction terms [2]. The bosonic part is

$$S_{\text{bosonic}} = \frac{1}{2\kappa_{11}^2} \int d^{11}x \sqrt{-G} \left[R - \frac{1}{48} F_{\mu\nu\rho\sigma} F^{\mu\nu\rho\sigma} \right] - \frac{1}{12\kappa_{11}^2} \int C_3 \wedge F_4 \wedge F_4, \tag{1}$$

where G_{MN} is the 11D metric ($M, N = 0, 1, \ldots, 10$), R is the 11D Ricci scalar, $F_4 = dC_3$ is the 4-form field strength of the 3-form gauge field C_3, and κ_{11} is the 11D gravitational coupling constant. The last term is the Chern-Simons term required for supersymmetry.

The full action also includes the gravitino ψ_M kinetic term and gravitino-boson interaction terms, but the bosonic sector above is the starting point for classical analysis.

3 Field Content

The bosonic fields of 11D supergravity are:

- The metric g_{MN} (graviton),

- The 3-form gauge potential C_{MNP},
- The 4-form field strength $F_{MNPQ} = \partial_{[M} C_{NPQ]}$.

The fermionic field is the gravitino ψ_M, a Majorana spinor-vector.

The action is invariant under local supersymmetry transformations, which is the defining feature of supergravity.

4 Dimensional Reduction and Lower-Dimensional Theories

When the 11D theory is compactified on a 7-torus (T^7) or other manifolds, it reduces to lower-dimensional supergravity theories [5]. The most famous reduction is to 4D $\mathcal{N} = 8$ supergravity, which unifies gravity with all other forces through supersymmetry.

The reduction process involves Kaluza-Klein modes, with the 3-form C_3 giving rise to various gauge fields and scalars in lower dimensions.

5 Comparison with SFIT

11D supergravity is a fundamental ultraviolet theory that unifies gravity with other forces through supersymmetry and higher-dimensional geometry. SFIT is an effective low-energy description focused on resonant information dynamics in four dimensions [6].

While 11D supergravity operates at the Planck scale, SFIT makes concrete predictions at laboratory energies (1.20134 mHz resonance, testable in ultra-cold neutron experiments). A possible synthesis is that 11D supergravity (or M-theory) provides the deep microscopic structure, while SFIT describes the emergent resonant behavior when that structure interacts with a macroscopic gravitational field [3].

The 1.20134 mHz Quantum Heartbeat and the coupling kernel $K = 1.060$ could be collective modes arising from the compactified dimensions or supersymmetric degrees of freedom when observed at laboratory scales [4].

6 Conclusion

The 11D supergravity action is the unique maximal supersymmetric extension of gravity in eleven dimensions. Its bosonic sector consists of the Einstein-Hilbert term, the kinetic term for the 3-form gauge field, and the Chern-Simons term required for supersymmetry.

Dimensional reduction of this action yields various lower-dimensional supergravity theories, including 4D $\mathcal{N} = 8$ supergravity. SFIT offers a complementary approach based on information dynamics at laboratory scales, with clear experimental predictions.

Future ultra-cold neutron experiments (GRANIT) have the potential to test SFIT's predictions and indirectly illuminate aspects of higher-dimensional supergravity at laboratory energies [7].

References

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