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Spacetime reduction of large N flavor models: A fundamental theory of emergent local geometry?

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Abstract

We introduce a novel spacetime reduction procedure for the fields of a supergravity–Yang–Mills theory in generic curved spacetime background, and with large N flavor group, to linearized forms on an infinitesimal patch of local tangent space at a point in the spacetime manifold. Our new prescription for spacetime reduction preserves all of the local symmetries of the continuum field theory Lagrangian in the resulting zero-dimensional matrix Lagrangian, thereby obviating difficulties encountered in previous matrix proposals for emergent spacetime in recovering the full nonlinear symmetries of Einstein gravity. It also obviates the challenges that must be faced by any proposal for a fundamental theory, holographic or topological, where gravity emerges instead as an induced interaction. We conjecture that the zero-dimensional matrix model obtained by this prescription for spacetime reduction of the circle-compactified type I–I′–mIIA–IIB–heterotic supergravity–Yang–Mills theory with sixteen supercharges and large N flavor group, and inclusive of the full spectrum of Dp-brane charges, $-2 \leqslant p \leqslant 9$, offers a potentially complete framework for nonperturbative String/M theory. We analyze the matrix Lagrangian in detail, comparing with the results of traditional planar reduction, and clarifying the emergence of the spacetime continuum in the large N limit of the zero-dimensional matrix model. We explain the relationship of our conjecture for a fundamental theory of emergent local spacetime geometry to recent investigations of the hidden symmetry algebra of M theory, stressing insights that are to be gained from the algebraic perspective. We conclude with a list of open questions and directions for future work.

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1. Introduction

In this paper, we present a zero-dimensional matrix Lagrangian with sixteen supercharges, and an extended symmetry group, which we will argue has the potential to describe a multi-dimensional emergent local spacetime geometry in the large N limit, and which might also give a unified framework for all of the weakly-coupled string and field theory limits of nonperturbative String/M theory. This new matrix Lagrangian belongs to a much more general class of matrix models conjectured to exist on the basis of algebraic symmetries alone in [1].[2] The matrix Lagrangian discussed in this paper is therefore distinguished by its simplicity: the $U(N)$ symmetry is assumed to be a flavor symmetry, commuting with the global symmetries that assume the role of target spacetime (supersymmetry) $\times$ (Lorentz) $\times$ (Yang–Mills) symmetry in the continuum target-space Lagrangian obtained in the large N limit.

In what follows, we will explain the appearance of such novel matrix Lagrangians with extended symmetry from the perspective of supergravity hidden symmetry algebras [3,4], on the one hand, and from the notion of a modified prescription for the planar reduction of large N field theories [2] on the other. We will show that a subset of the matrix Lagrangians introduced by us in [1] can be derived by a novel spacetime reduction procedure for the spacetime fields of a higher-dimensional supergravity–Yang–Mills field theory to linearized forms on an infinitesimal patch of local tangent space at a single point in the spacetime manifold. The result of our new prescription for spacetime reduction of a continuum Lagrangian with large N flavor symmetry is in each case a zero-dimensional matrix model Lagrangian, where the large N index originates in the auxiliary large N flavor symmetry introduced in the higher-dimensional supergravity–Yang–Mills theory. We should emphasize that the quantum dynamics of the higher-dimensional classical field theory Lagrangian with large N flavor group is of *no* interest to us; the introduction of the auxiliary

[2] In the analysis of the matrix superalgebra at finite N outlined in [1], the parameters for infinitesimal supersymmetry and $SL(n, \mathbf{R})$ transformations were assumed, more generally, to transform as non-singlets under the flavor $U(N)$ group. While we know of no reason to rule out such exotic extensions from the perspective of the matrix Lagrangian, such an extension is not necessary for the problem at hand. We should clarify that the matrix Lagrangian given in [1] was guessed at by intuition alone; the detailed checks of the symmetry transformations necessary to confirm the closure of such an exotic matrix algebra from first principles are quite beyond this author's ability, although we encourage the reader to try. An alternative route that can reproduce the form of the matrix Lagrangian first given in [1] is provided in this paper, based upon the spacetime reduction of a supergravity–Yang–Mills Lagrangian with large N flavor symmetry. Such a derivation obviates the necessity for a first principles check of the matrix superalgebra at finite N, while also illuminating the connection to continuum physics in the large N limit. Notice that, for the more general class of matrix superalgebras described in [1], the large N limit would have to correspond to an exotic (nonlinear) extension of the Nahm classification of spacetime linear superalgebras in n target spacetime dimensions. I am grateful to Bernard de Witt for pointing out this distinction. The idea of motivating the matrix Lagrangian from a generalized spacetime reduction procedure, combining insights from both supergravity dimensional reduction [3,4] and Eguchi–Kawai rigid Yang–Mills planar reduction [2], was inspired by Hermann Nicolai's comments in [14].