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Gravitation, local supersymmetry
and higher spin fields:
asymptotically flat structure in 3D
and anisotropic scaling in higher odd
dimensions

Thesis to obtain the degree of Doctor in Physics

by

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Abstract

The idea that spacetime may have more than four dimensions has become a standard assumption in high energy physics. A natural extension of General Relativity in higher spacetime dimensions that requires the same basic principles, namely, general covariance, second-order equations for the metric and the conservation of stress-energy tensor, is known as Lovelock theory. This theory possesses additional coupling constants that are not fixed from first principles. Remarkably, in odd dimensions, for a precise tuning of these constants, the theory turns out to be equivalently described as a gauge theory with Chern-Simons action.

It is in the context of Lovelock theory, that asymptotically Lifshitz wormholes and black holes in vacuum are shown to exist in $d = 2n + 1 > 7$ dimensions. The coupling constants are selected by requiring that all but one of their n maximally symmetric vacua are AdS spacetimes of radius l and degenerate. The asymptotic behaviour of these solutions is described by Lifshitz spacetimes with a dynamical exponent determined by a precise quotient of the curvature radii of the maximally symmetric vacua and the nondegenerate one. Besides, the asymptotically Lifshitz black hole possesses a fixed Hawking temperature. Further analytic solutions, including pure Lifshitz spacetimes with a nontrivial geometry at the spacelike boundary, and wormholes that interpolate between asymptotically Lifshitz spacetimes with different dynamical exponents are also shown to exist.

In the context of asymptotic symmetries, a full analysis in this kind of theories is not so easy to be carried out. Hence, in order to simplify the setup as much as possible, the spacetime dimension is lowered to three, so that the theory corresponds to General Relativity with cosmological constant, which is well known to be described in term of a Chern-Simons action.

A very brief review of Chern-Simons theories and its link with General Relativity in three dimensions, along with a discussion of Brown-Henneaux boundary conditions, is presented. Then, a novel way of taking the vanishing cosmological constant limit is performed, which allows to recover a consistent set of asymptotically flat boundary conditions, whose asymptotic symmetries span the BMS_3 algebra with a nontrivial central extension.

The last two chapters are devoted to the analysis of the asymptotic structure when gravity is coupled to fields of diverse spin, starting with the introduction of a consistent set of asymptotic conditions for the simplest supergravity theory without cosmological constant in three dimensions. The canonical generators associated to the asymptotic symmetries are shown to

span a supersymmetric extension of the BMS_3 algebra with an appropriate central charge. The energy is manifestly bounded from below with the ground state given by the null orbifold or Minkowski spacetime for periodic, respectively antiperiodic boundary conditions on the gravitino. These results are related to the corresponding ones in AdS_3 supergravity by a suitable gauge choice that allows to perform the vanishing cosmological constant limit. The analysis is generalized to the case of minimal flat supergravity with additional parity odd terms for which the Poisson algebra of canonical generators form a representation of the super- BMS_3 algebra with an additional central charge.

Finally, the analysis is extended to the case of higher spin gravity without cosmological constant in three dimensions. A consistent set of asymptotic conditions is also proposed, and the asymptotic symmetries are found to be spanned by a higher spin extension of the BMS_3 algebra with a central extension. It is also shown that the main results can be recovered from the ones found for asymptotically AdS_3 spacetimes by virtue of the same gauge choice used in the pure gravity and supergravity case.

This thesis is based on the following publications:

- “*Asymptotically Lifshitz wormholes and black holes for Lovelock gravity in vacuum*”
Javier Matulich and Ricardo Troncoso,
JHEP 1110,118 (2011) [arXiv:1107.5568 [hep-th]]
- “*Asymptotically flat spacetimes in three-dimensional higher spin gravity*”
Hernán A. González, Javier Matulich, Miguel Pino and Ricardo Troncoso,
JHEP 1309, 016 (2013) [arXiv:1307.5651 [hep-th]]
- “*Asymptotic symmetries and dynamics of three-dimensional flat supergravity*”
Glenn Barnich, Laura Donnay, Javier Matulich and Ricardo Troncoso,
JHEP 1408,071 (2014) [arXiv:1407.4275 [hep-th]]