BLACK HOLES IN $N = 2$ GAUGED SUPERGRAVITY

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Why black hole physics?

- In the early seventies an analogy between the laws of black hole macroscopic dynamics and the laws of thermodynamics was discovered. In particular, the Bekenstein-Hawking entropy of a black hole, $S_{BH} = \frac{A_H}{4}$, behaves in every way like a thermodynamic entropy.
- In order to give a precise statistical mechanical interpretation of black hole entropy, one would like to derive S_{BH} by **counting black hole microstates**. Entropy calculations starting from particular configurations of strings and branes coincide with the BH entropy of certain black holes that are solutions of supergravity theories.

What is supergravity?

A supergravity theory is an interacting field theory with local(gauged) supersymmetry.

- The requiring of locality of SUSY automatically includes gravity.
- For given N and d, we have different supergravities with different field content and properties.
- We are interested in matter-coupled $N=2$, $d=4$ gauged supergravity. Two kinds of multiplets:
  - **supergravity multiplet**: one graviton(s=2) e_μ^a, two gravitini(s=3/2) ψ_μ^A, one vector field A_μ^0,
  - **matter multiplets**:
    - **vector multiplets**, $(A_\mu^\Lambda, z^i, \chi^{A\,i})$ with $i = 1, \cdots, n_V$,
    - **hypermultiplets**, (q^u, ζ^α) with $u = 1, \cdots, 4n_H$ and $\alpha = 1, \cdots, 2n_H$.

Scalar geometries for $N = 2$, $d = 4$ supergravity

- The action is not determined uniquely from the field content but depends on one or more continuous functions in relation to the **scalar geometry**: the scalars are the coordinates of particular target manifolds and the continuous functions encode the geometry of these manifolds. In particular
  - Vector multiplets$\Longrightarrow$ **Special Kähler manifolds**
  - Hypermultiplets $\Longrightarrow$ **Quaternionic manifolds**
- Concerning the Special Kähler manifolds, the isometries are embedded in $\mathrm{Sp}(2n_V + 2, \mathbb{R})$.
- Given the field content, one has to specify a supergravity model giving the scalar manifold in order to fix uniquely the lagrangian.

The gaugings

"Gauged" because some of the isometries of the scalar manifolds are local and the vector fields are the gauge fields corresponding to these local symmetries.

- Two kinds of gaugings are possibile: abelian and non-abelian.
- The presence of local symmetries produces a scalar potential and covariant derivatives.
- We concentrate only on abelian isometries:
  - No hypermultiplets and Fayet-Iliopoulos gauging of a $U(1)$ subgroup of the R-symmetry.
  - Running hypermultiplets and abelian gaugings of the quaternionic isometries.

Black hole solutions and attractor mechanism

A black hole is a classical solution of (super)gravity such that the metric has a singular point and an event horizon exists.

- Of particular interest are the **attractor black holes**:
  - electrically and magnetically charged,
  - the flow of the scalars towards the horizon is described as a dynamical process of extremization of a suitable scalar-dependent function V_{eff}, generally determined by solving the e.o.m. at the horizon,
  - **the Bekenstein-Hawking entropy is given by the critical value** $S_{BH} \sim V_{eff}|_{horizon}$ and it will depend only on the charges and gauging parameters.

How to derive an exact BH solution?

- Make some Ansätze on the fields. For example staticity, spherical/hyperbolic symmetry...
- For some models and gaugings, the equations can be very very hard (especially with hypermultiplets).
- Solve equations of motion. Very difficult: system of second order non-linear equations.
- Solve first-order equations deriving from Killing Spinor equations $\Longrightarrow$ Supersymmetric solutions.
- Solve first-order equations in the Hamilton-Jacobi formalism $\Longrightarrow$ supersymmetric (BPS) and non-supersymmetric (non-BPS) solutions.

Gauged supergravity and Hamilton-Jacobi

- If one imposes the staticity and the spherical/hyperbolic symmetry, the e.o.m. can be derived from a non-singular 1-dimensional effective lagrangian $L_{1d}(q,\dot{q}) = G_{ij}(q)\dot{q}^i\dot{q}^j - V(q)$ (this is definitely non trivial!).
- Pass to the Hamilton-Jacobi formalism, as in classical mechanics. Given the hamiltonian $H(p,q)$ with $p_i = G_{ij}\dot{q}^j$, the dynamics will be determined by the Hamilton-Jacobi equation

$$H(q,\partial W) = G^{ij}\partial_i W \partial_j W + V = 0\,,$$

with $p_i = \partial_i W(q)$. **After finding** $W(q)$, one can write the "first-order flow" equations

$$\dot{q}^i = G^{ij}\partial_j W\,.$$

Some results

- Formulation of the **attractor mechanism for BH in presence of hypermultiplets.** [S. Chimento, D. Klemm, NP, 1503.09055, JHEP]
- First exact **BH solution in presence of hypermultiplets.** 1 vector multiplet and the UHM with scalar geometry $\frac{\mathrm{SU}(1,1)}{\mathrm{U}(1)} \times \frac{\mathrm{SU}(2,1)}{\mathrm{SU}(2)\times\mathrm{U}(1)}$. Near-horizon: $\mathrm{AdS}_2 \times H^2$. Asymptotics: hyperscaling violating. [S. Chimento, D. Klemm, NP, 1503.09055, JHEP]
- Exact BH solution for a **non-homogeneous scalar manifold** with 3 vector multiplets described by the prepotential $F = \frac{X^1 X^2 X^3}{X^0} + A\frac{(X^1)^3}{X^0}$ Near-horizon: $\mathrm{AdS}_2 \times H^2$ or S^2. Asymptotics: AdS_4. [D. Klemm, A. Marrani, NP, C. Santoli, 1507.05553, JHEP]
- Derivation of the **first-order equations for static solutions with spherical/hyperbolic symmetry** of $N = 2$ gauged supergravity coupled to vector- and hypermultiplets. [D. Klemm, NP, M. Rabbiosi, 1602.01334, JHEP]

Conclusions

- We introduced the field content and the scalar geometries defining the matter-coupled $N = 2$, $d = 4$ gauged supergravity.
- We highlighted the concept of gauging of the isometries of the scalar manifolds.
- We considered the black holes as solutions of supergravity models and introduced the attractor mechanism.
- We presented some strategies for finding new BH solutions.
- We presented some new results concerning the coupling of hypermultiplets and non-homogeneous scalar geometries, especially relevant for the $\mathrm{AdS}/\mathrm{CFT}$ correspondence.