Warsaw Lectures on black holes and their microstates in string theory

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These are series of four lectures given at the Advanced school on quantum spacetime, University of Warsaw in September 2024. Website: `https://quantum-spacetime.fuw.edu.pl/`

The following is the proposed goal and plan of the lectures.

Goal of lectures

1. Give the broad idea of black holes (BH) and their microstates in string theory.
2. Describe supersymmetric (susy) states in string theory, and the susy indices relavant for BH microstate counting.
3. Discuss supersymmetric, extremal BHs in gravity and string theory.
4. Describe idea of Quantum BH entropy as functional integral over AdS_2, and how one obtains dimension of Hilbert space of susy BHs from gravity as successive approximations.
5. Show that there are large quantum corrections in BHs very close to extremality. Revisit idea of extremal BHs, describe relation to Schwarzian theory.

Plan of lectures/list of topics

Lecture 1

- Puzzle of BH entropy
- Idea of BH microstates in string theory
- Correspondence principle
- Supersymmetry and Witten index

Lecture 2

- BPS states and helicity supertrace
- Charged and extremal BHs
- Supersymmetric BHs in minimal supergravity

Lecture 3

- Supersymmetric BHs in string theory
- Quantum entropy
- Best understood example in string theory

Lecture 4

- Question of decoupling of the BHs, zero modes in AdS_2
- Regulating the zero modes with temperature, and emergence of Schwarzian theory
- Results for Schwarzian and super-Schwarzian path integral
- Interpretation for near-extremal BHs and susy BHs

Possibly useful references and resources

- The LONTI lectures on "Introduction to black hole micro state counting" https://www.youtube.com/playlist?list=PLlva4MroG-KEKFatOXq8zCteMw1Z5XAF7 by S.M. covers what we covered here in Lectures 1 and 2 at a slower pace.
- The lecture of A. Dabholkar at PITP 2018 https://static.ias.edu/pitp/2018/node/1796.html gives a nice overview of the program of quantum entropy.
- The book on Supergravity by Freedman and Van Proeyen is a great introduction to the ideas and techniques in supergravity. https://www.cambridge.org/core/books/supergravity/B7EEC3E37A39AB6E6625850857B96AA7 In particular, there is a whole chapter dedicated to BPS solutions, the near-horizon AdS_2 geometry, and the attractor mechanism.
- The application of localization to supergravity can be found in lectures by S.M. in the following school. https://indico.ictp.it/event/8560/other-view?view=ictptimetable. The school also has other useful introductory lectures on localization and its applications.
- The full calculation of the Hilbert space dimension through localization can be found in https://arxiv.org/abs/2209.13602. It may be useful to see the development of these ideas in https://arxiv.org/abs/1012.0265, https://arxiv.org/abs/1111.1161, https://arxiv.org/abs/1404.0033.
- The decoupling of 4d extremal BHs in gravity and string theory is discussed in https://arxiv.org/abs/2209.13608 and references in that paper. See, in particular, https://arxiv.org/abs/2003.02860, https://arxiv.org/abs/2011.01953, for the calculations of the density of states for near extremal and near-BPS black holes.