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Near horizon data and physical charges of extremal AdS black holes

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Abstract

We compute the physical charges and discuss the properties of a large class of five-dimensional extremal AdS black holes by using the near horizon data. Our examples include baryonic and electromagnetic black branes, as well as supersymmetric spinning black holes. In the presence of the gauge Chern–Simons term, the five-dimensional physical charges are the Page charges. We carry out the near horizon analysis and compute the four-dimensional charges of the corresponding black holes by using the entropy function formalism and show that they match the Page charges.

Keywords: AdS black holes; Entropy function; Page charges

1. Introduction

Black hole physics is a very active area of ongoing research. A statistical understanding of black hole entropy is one of the most important and long standing questions in theoretical physics.

In the last years, important progress in understanding the attractor mechanism and entropy of extremal (non-BPS) black holes was based on the entropy function formalism [1–4]. An important advantage of this method is that one needs just the near horizon geometry to characterize the

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black hole. In particular, one can compute the entropy and the conserved charges by using just the near horizon geometry [4,5].

In [5] it was explicitly shown how to construct the conserved charges of black holes/rings by using just the near horizon data. For example, it is by now well known that the dipole charge appears in the first law of black ring thermodynamics, even if it is not conserved [6]. Therefore, the entropy of the black rings can also depend on the dipole charges, not only on the usual conserved charges.

In general, when there are degrees of freedom living outside the horizon, they contribute to the asymptotic charges and so the asymptotic charges and the charges computed from the near horizon data may not be the same.[1] One expects that the macroscopic entropy is completely determined by the near horizon geometry. However, a counterexample is the 4D–5D lift of BMPV black hole [8]. That is, the 4D and 5D black holes have the same near horizon geometry, but different microscopic spectra. If true, that would imply that different microscopic entropies will correspond to the same near horizon geometry. In fact, this discrepancy [9,10] was solved in [11] by removing the ‘hair’, which contributes to the degeneracies. This further suggests that the physical charges can be obtained, in fact, from the near horizon data only.

Also, in the presence of the gauge Chern–Simons term, there are subtleties in the definition of the charges. Since the Maxwell charge is carried by the gauge fields themselves, it is diffused throughout the bulk and so it is not localized. This clearly resembles the previous discussion, and one expects a ‘hair’ contribution to the asymptotic charges. The physical charges in this case are the so-called ‘Page charges’ (see [12] for a nice brief review).

A similar analysis can be used for asymptotically AdS black holes. However, the interpretation of the attractor mechanism is quite different than in flat space. That is, the moduli flow is in fact an RG flow towards the IR attractor horizon once the theory is embedded in string theory (more precisely in type IIB) [13]. Interestingly enough, the near horizon data can be also used to compute the shear viscosity coefficient, not just the entropy [14–17].[2]

Given these motivations, it is clearly useful to understand the robustness of the near horizon analysis for the AdS black holes. In this paper we generalize the work of [5] to AdS black holes. Though, an important difference is that we use the entropy function formalism to obtain the four-dimensional physical charges and compare them with the charges of [5]. We would like to emphasize that our analysis is built on the previous (but less general) work on asymptotically flat and AdS extremal black holes [5,19–21]. However, the near horizon geometry ansatz we consider is more general due to the existence of a magnetic Kaluza–Klein (KK) part. We work out in detail several examples, which are relevant in the context of AdS/CFT duality.

The paper is organized as follows: in Section 2 we present a concrete analysis of the entropy function formalism for a generic near horizon geometry ansatz when the gauge Chern–Simons term is present. We also show that the four-dimensional charges obtained from the entropy function after KK reduction match the five-dimensional Page charges. In Section 3 we apply the general results of Section 2 for some concrete examples. Finally, we conclude with a discussion of our results. In Appendix A we present details of the KK reduction of the Chern–Simons term. Appendix B contains an analysis of toroidal spinning black branes.

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[1] A discussion on asymptotic charges and the charges computed at the horizon for the black ring can be found in [7].

[2] For other transport coefficients there is, in general, a non-trivial flow and the near horizon data is not enough [18].