Evidence for the existence of a novel class of supersymmetric black holes with AdS$_5\times$S^5 asymptotics

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We construct a new class of charged, rotating hairy black holes in a consistent truncation of $\mathcal{N} = 8$ supergravity, which retains one charged scalar field and a U(1) gauge field. These hairy solutions can be uplifted to solutions of type IIB supergravity with AdS$_5\times$S^5 asymptotics. We find rotating hairy black holes with finite entropy arbitrarily close to the supersymmetric bound - the resulting supersymmetric solution is a one-parameter extension of the Gutowski-Reall solution [1]. These solutions have finite curvature invariants (including at extremality), but in the extremal limit exhibit diverging tidal forces in the near horizon region. Nevertheless, we argue that these limiting supersymmetric black holes can be consistently studied within the supergravity approximation.