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Thermodynamics of Flat 4D Einstein-Gauss-Bonnet Black Hole with Rényi Entropy: An RPST-like formalism

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We investigate the thermodynamics of asymptotically flat black holes in four-dimensional Einstein-Gauss-Bonnet (4D-EGB) gravity using Rényi entropy as a non-extensive generalization of the Bekenstein-Hawking entropy. The resulting thermodynamic structure, formulated within a restricted phase space-like (RPST-like) framework, reveals a striking resemblance to the thermodynamics of AdS black holes in the standard RPST formalism. In particular, we identify a thermodynamic duality between the Rényi deformation parameter β and a conjugate response potential ζ , analogous to the central charge and chemical potential in holographic theories. An extensive thermodynamic analysis in both fixed charge- $(\tilde{Q})$ and fixed potential- $(\tilde{\Phi})$ ensembles reveal Van der Waals-like first-order phase transitions which is an unexpected feature for asymptotically flat black holes. Furthermore, through the formalism of geometrothermodynamics (GTD) and thermodynamic topology, It is shown that the Rényi modified flat black hole mimics, in both its thermodynamic topology and geometry, the features of its counterparts in the 4D-EGB AdS black hole under RPST, reinforcing the structural similarity between these seemingly different systems. Our findings point to a deeper correspondence between non-extensive entropy and holographic thermodynamics, suggesting that Rényi entropy may serve as a natural bridge between flat-space black hole thermodynamics and AdS holography.

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