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Black Hole Dynamics From Atmospheric Science

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Abstract

In this note, we derive (to third order in derivatives of the fluid velocity) a $2+1$ dimensional theory of fluid dynamics that governs the evolution of generic long-wavelength perturbations of a black brane or large black hole in four-dimensional gravity with negative cosmological constant, applying a systematic procedure developed recently by Bhattacharyya, Hubeny, Minwalla, and Rangamani. In the regime of validity of the fluid-dynamical description, the black-brane evolution will generically correspond to a turbulent flow. Turbulence in $2+1$ dimensions has been well studied analytically, numerically, experimentally, and observationally as it provides a first approximation to the large scale dynamics of planetary atmospheres. These studies reveal dramatic differences between fluid flows in $2+1$ and $3+1$ dimensions, suggesting that the dynamics of perturbed four and five dimensional large AdS black holes may be qualitatively different. However, further investigation is required to understand whether these qualitative differences exist in the regime of fluid dynamics relevant to black hole dynamics.