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Dynamic and Thermodynamic Stability of Black Holes

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I describe recent work with with Stefan Hollands that establishes a new criterion for the dynamical stability of black holes in $D \geq 4$ spacetime dimensions in general relativity with respect to axisymmetric perturbations: Dynamical stability is equivalent to the positivity of the canonical energy, $\mathcal{E}$, on a subspace of linearized solutions that have vanishing linearized ADM mass, momentum, and angular momentum at infinity and satisfy certain gauge conditions at the horizon. We further show that $\mathcal{E}$ is related to the second order variations of mass, angular momentum, and horizon area by $\mathcal{E} = \delta^{\in}\mathcal{M} - \sum_{\rangle} \otimes_{\rangle} \delta^{\in}\mathcal{J}_{\rangle} - (\kappa/\forall\pi)\delta^{\in}\mathcal{A}$, thereby establishing a close connection between dynamical stability and thermodynamic stability. Thermodynamic instability of a family of black holes need not imply dynamical instability because the perturbations towards other members of the family will not, in general, have vanishing linearized ADM mass and/or angular momentum. However, we prove that all black branes corresponding to thermodynmically unstable black holes are dynamically unstable, as conjectured by Gubser and Mitra. We also prove that positivity of $\mathcal{E}$ is equivalent to the satisfaction of a "local Penrose inequality," thus showing that satisfaction of this local Penrose inequality is necessary and sufficient for dynamical stability.