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Singularity Formation in General Relativity

The celebrated Hawking–Penrose theorems show that, under appropriate assumptions on the matter model, a large, open set of initial data for Einstein's equations lead to geodesically incomplete solutions. However, these theorems are "soft" in that they do not yield any information about the nature of the incompleteness, leaving open the possibilities that **i)** it is tied to the blowup of some invariant quantity (such as curvature) or **ii)** it is due to a more sinister phenomenon, such as incompleteness due to lack of information for how to uniquely continue the solution (this is roughly known as the formation of a Cauchy horizon). In various joint works with I. Rodnianski, we have obtained the first results in more than one spatial dimension that eliminate the ambiguity for an open set of initial data. In this talk, I will discuss our most recent work, in which we developed a new, more robust analytical framework that allows us to treat initial data exhibiting moderate spatial anisotropy, thus going beyond the regime of nearly spatially isotropic initial data that we treated in earlier works. Our approach applies, for example, to open sets of initial data for the Einstein-vacuum equations in high spatial dimensions and to the Einstein-scalar field system in any number of spatial dimensions. From an analytic perspective, the main theorems are stable blowup results for quasilinear systems of elliptic-hyperbolic PDEs. In this talk, I will provide an overview of these results and explain how they are tied to some of the main themes of investigation by the mathematical general relativity community. I will also discuss the role of geometric and gauge considerations in the proofs, as well as intriguing connections to other problems concerning stable singularity formation.