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Gravitational Collapse, Black Holes and Space-time Singularities in Einstein Gravity

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The final fate of massive collapsing matter clouds has been a fundamental topic in black hole physics and gravitation theory for past many decades. We discuss the current developments here. The general theory of relativity predicts a necessary occurrence of space-time singularity in such a scenario when a massive star collapses under its own gravity on exhausting its internal nuclear fuel. Such a singularity, which is a super-ultra dense region, may or may not be covered within a horizon of gravity. It is in fact the formation and behavior of the apparent horizon that decides whether the space-time singularity is enveloped in a black hole, or it may be visible for far away observers in the Universe. The formation of event and apparent horizons in gravitational collapse is very much a subject of very active current investigations. We point out that the apparent horizon and trapped surfaces formation is determined in terms of initial data for collapse and the allowed evolutions by Einstein equations, emphasizing the computational aspects and techniques involved, both numerical and analytical. The black hole and naked singularities in collapse involve key open issues such as genericity and stability related to these outcomes and other aspects in terms of their applications in relativistic astrophysics. We discuss some of these, including implications for quantum gravity, and other recent developments in this talk.