

General Relativistic Simulations of Stellar Collapse and The Formation of Stellar Mass Black Holes

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The cores of massive stars collapse to protoneutron stars, forming, at core bounce, a hydrodynamic shock that initially travels outward in mass and radius, but soon stalls, needing revival by the supernova mechanism. If the latter lacks efficacy, the protoneutron star may reach its maximum mass before an explosion is launched, leading to a second stage of gravitational collapse resulting in the formation of a black hole. Under special, yet to be determined conditions, a black hole – accretion torus system may form in such failing supernovae and act as the engine of a long gamma-ray burst.

I present results from new 1.5D (spherical symmetry plus rotation) and 3D general-relativistic simulations of stellar collapse and postbounce supernova evolution towards black hole formation in massive rotating and nonrotating progenitor stars. I demonstrate that there is no direct black hole formation without protoneutron-star phase in ordinary massive stars and establish the systematics of black hole forming collapse events with progenitor mass, metallicity, rotation, and neutrino heating efficiency based on an extensive set of 1.5D simulations. I go on to present the first 3D simulations of black hole forming core-collapse events that track the evolution from the onset of collapse, through the protoneutron star phase and protoneutron star collapse to multiple tens of milliseconds after the appearance of the black hole horizon.