Research Abstract

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My current research focuses on the collapse and explosion of massive rotating stars. I am interested in those very massive stars ($M \gtrsim 20 M_\odot$) in which the cores collapse to black holes because the "delayed" neutrino-absorption mechanism fails either partially or completely. My thesis research has shown that such stars, "collapsars," are capable of producing extremely energetic accretion-powered explosions which can be the source of classical gamma-ray bursts (GRBs) and asymmetric hyper-energetic supernovae. In rapidly rotating stars, an accretion disk forms as the star collapses into a black hole created by the implosion of its core. Rapid accretion of stellar matter into the hole at a rate of $10^{-4} - 10^{-1} M_\odot\,\mathrm{s}^{-1}$ can power a variety of stellar explosions. In the case of prompt black hole formation in hydrogen-stripped stars, classical GRBs of the long duration variety ($\mathrm{T}_{90} \gtrsim 5\,\mathrm{s}$) can be produced with sufficient energy to explain the most energetic GRBs detected so far (see "Collapsars - Gamma-Ray Bursts and Explosions in "Failed Supernovae"," MacFadyen & Woosley, ApJ 524, 262-289 (1999)). Longer GRBs and soft x-ray transients are possible when part of the star falls back onto the central proto-neutron star after a weak supernova. The observational signatures of these explosions are diverse and depend on the beaming of the explosion, the amount of radioactive ^{56}Ni produced and mixed into the stellar envelope, the angular momentum of the progenitor star and its radius at core collapse. Recent observational evidence, both the close association of well-localized GRBs with star forming regions and possible direct links between GRBs and supernovae, supports the collapsar model for long-duration GRBs. My research utilizes multi-dimensional hydrodynamical simulations to explore stellar collapse and explosion by various mechanisms – jets, powered either by a MHD mechanism or neutrino annihilation; accretion disk wind, powered by viscous heating; and explosive nuclear energy release. I am currently exploring the case of collapsars occurring in stars which have not been completely stripped of hydrogen and the ensuing jet-driven explosion of the supergiant envelope. I am also studying the nucleosynthesis and explosive nuclear burning in rotating massive stars and stellar explosions due to winds driven from viscous accretion disks.