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Supernovae and Gamma-Ray Bursts: Relativistic Plasma Physics in the Einstein Centennial

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Study of core collapse supernova with spectropolarimetry has shown that all these events are substantially asymmetric and frequently bi-polar. This argues for a role for rotation, shearing, and strong dynamos leading to jet-like flow to shape and perhaps even power the explosion. Long (several second) cosmic gamma-ray bursts have been directly linked to some core collapse supernovae. Gamma-ray bursts have been established to be caused by narrow jets of energy containing magnetic fields and moving at highly relativistic speeds that first undergo internal shocks to cause the gamma-ray burst, but then collide with the circumburst and interstellar medium to cause the "afterglow" in X-rays, optical, and radio. The most likely explanation of the long gamma-ray bursts is the collapse of a massive, rotating, magnetic star to form a black hole, but rapidly rotating, highly magnetic neutron stars cannot yet be ruled out. Oustanding issues are the physics that converts the implosion of the stellar core into an explosion, the role of dynamos and MHD processes in causing the explosion, the processes by which jets are formed and propagate out of the star, the circumstances under which those jets become highly relativistic, and the origin and evolution of the magnetic field associated with the burst and afterglow.