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Magnetohydrodynamics of Gamma-Ray Burst Jets

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Magnetic fields are believed to play a dominant role in driving and collimating astrophysical jets, including the relativistic outflows that emanate from the vicinity of the supermassive black holes in active galactic nuclei and the ultrarelativistic jets, evidently associated with solar-mass black holes or rapidly rotating neutron stars, that are inferred to give rise to gamma-ray bursts (GRBs). Recent numerical simulations using special-relativistic, axisymmetric, ideal MHD have demonstrated the viability of this mechanism and revealed the detailed structure of relativistic plasma outflows of this type. The main results of these simulations are presented and analyzed, and their qualitative properties are explained with the help of steady-state, radially self-similar, semianalytic solutions and asymptotic analytic scalings. The distinctions between relativistic and nonrelativistic outflows and between MHD and purely hydrodynamic acceleration are highlighted, and the possible effect of initial thermal driving in GRB sources is discussed. Remaining open questions related to the general modeling of such outflows and to the specific application to GRB jets are pointed out.