Numerical solutions of Neutrino-Dominated Accretion Flows with a Non-Zero Torque Boundary Condition and its applications in Gamma-ray Bursts

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Abstract

A stellar mass black hole (BH) surrounded by a neutrino-dominated accretion flow (NDAF) is widely considered as the central engine of gamma-ray bursts (GRBs). Previous studies on NDAF have been based on the assumption of "no torque" boundary condition, which is however invalid when the disk is magnetized. Recent general relativistic magnetohydrodynamic (GRMHD) simulations on magnetized disk show there is a significant magnetic stress at the inner edge. In this paper, we revise the NDAF model by introducing non-zero boundary stresses and general relativistic corrections. We present a numerical solution for such non-zero torque NDAF model. Their properties are significantly changed due to this non-zero boundary torque. As a consequence, we find that: (1) non-zero torque NDAF can account for those bright and powerful GRBs, which are hard to interpret with previous NDAF; (2) the variability of the prompt emission and the steep decay phase in the early X-ray afterglow are explained by the viscous instability in NDAF; (3) the strength of the gravitational waves radiated by a possible processing accretion disk is slightly enhanced due to the change of the material distribution caused by the existence of the magnetic torque.