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Self-similar dynamical evolution of a resistive accreting magnetofluid around a static black hole

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Abstract

In this paper, we apply the Newtonian limit to the general relativistic magnetohydrodynamic (GRMHD) equations that govern the motion of magnetoplasma accreting onto a static black hole. We study the time evolution of a non-viscous, magnetized, thick accretion disk in the presence of the central black hole's dipolar magnetic field. With the presence of finite electrical conductivity in the fluid, the magnetic stress effectively replaces the viscous shear stress in the standard disk model and is responsible for the transfer of angular momentum. All physical quantities of the system are functions of three variables: t, r, and θ. We determine the time dependence of the system's physical functions using the self-similar method. With suitable physical assumptions, we derive the spatial dependence of the functions as accurately as possible through analytical solutions, and, when necessary, through numerical methods. Self-similar solutions indicate that over time, the accretion and rotation of the fluid slow down, the disk becomes less dense, cooler, and less pressurized, and the electrical conductivity of the fluid also decreases. As the electrical conductivity of the fluid increases, the accretion and rotation of the fluid slow down, and the disk becomes denser and cooler, but the mass accretion rate increases. The azimuthal electric current density generated by the motion of the magnetofluid determines the magnetic field structure within the disk and results in a polar component for the disk's magnetic field. Due to the finite electrical conductivity of the fluid, at the boundary surface of the disk, the constant magnetic field lines of the disk connect to the dipolar magnetic field lines of the central black hole. Over time, this configuration remains stable because the time dependence of the magnetic field components of the disk is similar.

Keywords: accretion, accretion disks, black hole, magnetohydrodynamic

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