The Hydromagnetic Interior of a Solar Quiescent Prominence: Two Calculations on the Effects of Power-Law Radiative Loss and Viscosity on a Kippenhahn-Schlüter Slab

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ABSTRACT

This study is a part of an ongoing investigation conducted by BC Low and colleagues to understand the small-scale behaviors of quiescent prominences in recent high-resolution SDO/AIA observations. Two particular calculations will be presented, utilizing the one dimensional Kippenhahn-Schlüter infinite-slab prominence model in a steady state, to simplify the system without losing the nonlinear coupling between force-balance and energy-transport. This slab is supported against gravity by a horizontally-oriented bowed magnetic field, taking the electrical conductivity to be infinite. The first calculation focuses on the thermodynamic balance in a non-resistive and non-viscous plasma subject to radiative loss that is nonlinear in temperature and heating that is directly proportional to the density of the plasma in the presence of magnetic-field aligned thermal conduction. This calculation generalizes the result found in Low et al. (2012, ApJ 755, 34) in which linear-temperature radiation is studied. In both calculations it is found that most circumstances do not produce everywhere continuous solutions. The more common discontinuous or singular solutions describe excessive radiation producing a delta-function mass sheet at the core of the slab. A corresponding delta-function in the electric current density also develops but must dissipate due to the finite electrical conductivity of a realistic prominence plasma. This possible explanation of the observed dynamic interior of prominences is investigated in the second calculation focusing on the effect of viscosity on the resultant resistive flow of the slab across the supporting field. Isothermal condition is assumed to remove the complication of energy-transport in order to isolate the effects of viscosity on the gravitational stratification of the density along the magnetic field. The nonlinear ordinary differential equations of these calculations have interesting mathematical properties studied with a standard Runge-Kutta numerical solver.

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