

Nonlinear Waves in Baryonic Gas Clouds under Quantum Dark Matter Effects

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Abstract

Dark matter is known to play a fundamental role in the formation and evolution of cosmic structures; however, its influence on the nonlinear dynamics of interstellar baryonic clouds remains insufficiently explored. In the present work, the instability dynamics of a self-gravitating slab-like interstellar gas cloud composed of baryonic and quantum dark matter fluid components are investigated within a weakly nonlinear framework. The baryonic component is modeled as a classical viscoelastic fluid, while the dark matter component is described as a self-gravitating viscoelastic quantum fluid. By employing the reductive perturbation method, a Korteweg–de Vries (KdV) equation containing multiparametric nonlinear and dispersive coefficients is derived to describe the evolution of baryonic density perturbations. It is found that an increase in baryonic rigidity facilitates the formation of solitary structures at lower dark matter concentrations and leads to a non-monotonic variation in soliton width with changing dark matter abundance. The position corresponding to the maximum soliton broadening is shifted toward lower dark matter concentrations as the baryonic rigidity is increased. In contrast, opposite trends are exhibited by dark matter rigidity and the Bohm quantum potential. For classical isothermal dark matter, the soliton amplitude is found to be nearly independent of dark matter concentration, whereas the inclusion of quantum effects results in a polarity transition between rarefactive and compressive solitary structures. These results suggest that the properties of dark matter can substantially modify the spectrum of weakly nonlinear density eigenmodes that may be excited in realistic composite interstellar gas clouds.

Keywords: Baryonic gas cloud, quantum dark matter, soliton