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The Kähler-Fisher Framework for Fuzzy Dark Matter: Stability, Entropy and Observational Constraints

Abstract

We construct a unified, information-geometric formulation of fuzzy dark matter (FDM) modeled by the Schrödinger-Poisson (SP) system assuming that the dark matter (DM) is composed of ultralight boson. We prove that the Madelung transform is an isometric Kähler morphism between the Fubini-Study (FS) metric on projective Hilbert space and the Sasaki-Fisher-Rao (SFR) metric on the cotangent bundle on the density manifold, with Bohm potential calculated as the first variation of Fisher information. This yields a gravitational entropy functional and quantum Fisher bound on the dark matter particle mass. We use variational and concentration-compactness method to show the existence of soliton. We then derive the viral/Pohozaev identity which expresses an exact balance between Fisher curvature and gravitational Hartree energy at ground states and we prove stability via Lyapunov corecivity. We apply a Gaussian core Schrödinger-Poisson mass estimator to milkyway satellite galaxies Fornax and Leo II and calculate the DM particle mass to be 2.2 *10-22 eV and 1.39 * 10-21 eV, respectively, using stellar kinematical data. It is consistent with observed core sizes yet somewhat lighter than Lyman-alpha lower bounds, highlighting possible roles for multi-state excitations, mixed DM scenarios and entropy/Fisher geometry constraints.