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Ruling out bosonic repulsive dark matter in thermal equilibrium

Self-interacting dark matter, especially bosonic, has been considered a promising candidate to replace cold dark matter (CDM) as it resolves some of the problems associated with CDM. Here, we rule out the possibility that dark matter is a repulsive boson in thermal equilibrium. We develop the model first proposed by Goodman in 2000 and derive the equation of state at finite temperature. Isothermal spherical halo models indicate a Bose–Einstein condensed core surrounded by a non-degenerate envelope, with an abrupt density drop marking the boundary between the two phases. Comparing this feature with observed rotation curves constrains the interaction strength of our model's dark matter particle, and Bullet Cluster measurements constrain the scattering cross-section. Both ultimately can be cast as constraints on the particle's mass. We find these two constraints cannot be satisfied simultaneously in any realistic halo model –and hence dark matter cannot be a repulsive boson in thermal equilibrium. It is still left open that dark matter may be a repulsive boson provided it is not in thermal equilibrium; this requires that the mass of the particle be significantly less than a millivolt.

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