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Structure and Stability of Dark Energy Stars in Rastall Theory of Gravity

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Abstract. This work explores a novel singularity-free relativistic solution to the Einstein field equations, focusing on dark energy stars within the framework of Rastall gravity. The Low-Mass X-ray Binary (LMXB) 4U 1608-52, characterized by a mass of $1.74 M_{\odot}$ and a radius of 9.3 km (T. Güver et al., *Astrophys. J.* 712, 964 (2010)), is considered as a potential candidate for dark energy star. The analysis begins with the equation of state for dark energy, where its density is linearly related to an isotropic perfect fluid distribution via a coupling parameter α . To address the unknown constants within the model, the induced metric and extrinsic curvature tensors are computed at the stellar surface. A detailed investigation is conducted to examine how the physical properties of the model depend on the Rastall parameter ξ . Notably, the results reveal the possibility of a phase transition from a dark energy-dominated regime to a baryonic matter profile, influenced by both α and ξ . Additionally, the model evaluates the percentage of dark energy present by varying ξ , demonstrating that for a fixed ξ , the dark energy fraction is sensitive to the mass and radius of the star. The model satisfies the energy conditions and causality requirements, affirming its physical viability. Stability analysis further supports the stability of the stellar configuration. The graphical representations of physical parameters, alongside the theoretical results, indicate that the proposed model is non-singular and provides a realistic description of a stable stellar structure composed of both dark energy and baryonic matter.