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Understanding Interacting Dark Energy from a Dynamical Systems Analysis Approach

Cosmological models in which dark matter and dark energy interact in a non-gravitational manner are known as Interacting Dark Energy (IDE) models and have been proposed to address many long-standing shortcomings and tensions in standard cosmology. Furthermore, recent results from the DESI Collaboration have suggested hints of dynamical dark energy, for which IDE models could provide a viable explanation. The relevance of IDE models underscores the need to understand their parameter space and their potential limitations. In this study, we apply a dynamical systems analysis to a class of IDE models, analysing the critical points and the behaviour of the system at these points. From our analysis, we derive theoretical constraints that avoid common pitfalls such as negative energy densities and future singularities. We also investigate how these models may address the coincidence problem and permit phantom crossing, a phenomenon also hinted at by the recent DESI results. In general, we find a clear preference for interaction models where energy flows from dark energy to dark matter. Lastly, we emphasize the importance of considering theoretical constraints on cosmological systems alongside observational data.

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