Beyond j=1: Observational Constraints on Almost-ΛCDM Cosmologies

Jess Worsley[1], Saikat Chakraborty[2,3,4], and Peter Dunsby[1,4,5]

[1]Department of Mathematics and Applied Mathematics, University of Cape Town, 7 University Ave N, 7700, South Africa.
[2]Institute of Research and Development, Duy Tan University, Da Nang 550000, Vietnam.
[3]Faculty of Natural Sciences, Duy Tan University, Da Nang 550000, Vietnam.
[4]Center for Space Research, North-West University, Potchefstroom 2520, South Africa
[5]South African Astronomical Observatory, Observatory 7925, Cape Town, South Africa.

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Abstract

The cosmographic condition $j(z) = 1$ provides the kinematical signature of the spatially flat ΛCDM model independently of any specific dark-energy or modified-gravity theory. We investigate the extent to which current observations permit departures from this condition by considering three phenomenological "almost-ΛCDM" cosmographic closures in which the cosmic jerk differs slightly from unity through a small deformation parameter ϵ. The models are constrained using Markov Chain Monte Carlo analyses of recent DESI baryon acoustic oscillation measurements together with compressed Planck cosmic microwave background likelihoods and the Union3, Pantheon+, and DESY5 Type Ia supernova compilations.

Unlike conventional analyses that infer the expansion history after imposing an explicit parameterisation of the dark-energy equation of state, our cosmographic framework reconstructs the expansion history directly from observations, with the effective dark-energy equation of state emerging as a derived quantity rather than an assumed one. We find that all three cosmographic closures are confined by current observations to a remarkably small neighbourhood of the ΛCDM cosmographic fixed point, with the inclusion of Planck data driving the preferred evolution toward $j_0 \simeq 1$ and $w_{\rm DE,0} \simeq -1$. Despite their distinct kinematical constructions, the reconstructed dark-energy evolution consistently exhibits a smooth transition to the phantom regime at early times.

Model comparison using the Akaike and Bayesian information criteria shows that the almost-ΛCDM cosmographic models remain statistically competitive with standard dark-energy parameterisations while relying on fewer assumptions regarding the functional form of $w(z)$. Our analysis demonstrates that current observations constrain the cosmic expansion history more robustly than the detailed evolution of the dark-energy equation of state, which remains sensitive to the reconstruction methodology employed. These results highlight the importance of model-independent cosmographic approaches for interpreting current evidence for dynamical dark energy and provide a natural framework for future studies of cosmological perturbations and structure formation.

Keywords: cosmology: theory — cosmological parameters — dark energy