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Contributory: From CPL to Canonical Fields: Constraining Quintessence with the Tomographic AP Test

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The nature of dark energy remains one of the central open questions in cosmology. While observational analyses commonly constrain phenomenological equation-of-state parametrizations such as the Chevallier–Polarski–Linder (CPL) model, theoretical interpretations require translating these constraints into physically motivated scalar-field models.

We present a computational framework that directly maps observational likelihoods in the (Ω_m, w_0, w_a) parameter space onto the parameter spaces of canonical quintessence potentials without recomputing the full observational likelihood. The method employs likelihood-guided mapping based on the tomographic Alcock–Paczynski test combined with Type Ia supernova and baryon acoustic oscillation observations. For each potential, we solve the scalar-field background evolution numerically and determine an effective CPL representation over the observed redshift range, allowing observational constraints to be projected efficiently onto the underlying theoretical parameters.

We apply this approach to exponential, pseudo–Nambu–Goldstone boson (PNGB), and inverse power-law (IPL) quintessence models. The resulting constraints reveal that viable scalar-field models occupy only a narrow region of the effective CPL parameter space, considerably smaller than the full phenomenological CPL posterior. This demonstrates how theoretical consistency substantially reduces the allowed dark-energy parameter space and provides a practical route for confronting fundamental dark-energy models with current and future cosmological observations.

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