Constraining f (R) gravity and evolving dark energy via large-scale structure and phase-space trajectories

We present a joint observational analysis confronting viable f(R) modified gravity theories, specifically the Hu & Sawicki and Starobinsky models, with background and large-scale structure (LSS) data. Utilizing Monte-Carlo Markov chain (MCMC) sampling across datasets including baryon acoustic oscillations (BAO), type Ia supernovae (SNeIa), cosmic microwave background (CMB) distance priors, and linear growth measurements ($f\sigma_8$, f, σ_8), we place tight constraints on the model parameters governing deviations from General Relativity. Model comparison based on the Akaike Information Criterion indicates that these f(R) extensions are statistically favored over flat ΛCDM ($|\Delta AIC| \geq 3.99$) for the combined data. However, when considering the Bayesian Information Criterion, the evidence for support is significantly reduced. Furthermore, we construct two-dimensional phase-space diagrams in the (μ,γ) and (μ,Σ) planes across several redshifts, establishing a novel diagnostic null-test allowing us to probe for deviations from ΛCDM, corresponding to the fixed point (1,1) in both planes, using LSS observables. Should future weak-lensing and galaxy surveys provide data points with $\mu-1 < 0$ and $\gamma-1 > 1$ or $\Sigma-1 < 0$, then the aforementioned models could be directly ruled out.