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Analyses of cosmological models with current data

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Abstract. We compare the predictions of different cosmological models with current measurements of the growth of cosmic structures. Using observational data of the growth rate $f(z)$ and the matter fluctuation amplitude $\sigma_8(z)$, we confront the flat ΛCDM model with modified gravity scenarios. Gaussian Process reconstructions are used to describe the data in a model-independent way.

Resumo. Comparamos as previsões de diferentes modelos cosmológicos com dados atuais do crescimento das estruturas cósmicas. Utilizamos medições da taxa de crescimento $f(z)$ e da amplitude das flutuações de matéria $\sigma_8(z)$ para confrontar o modelo ΛCDM plano com modelos de gravidade modificada, usando reconstruções com Processos Gaussianos.

Keywords. observations – theory – large-scale structure of Universe – dark energy – statistical

1. Introduction

Recent analyses of baryon acoustic oscillation (BAO) measurements from DESI, combined with cosmic microwave background (CMB) data (Planck Collaboration et al. 2020; Novaes et al. 2014, 2015) and Type Ia supernovae observations, indicate a reduced preference for the flat ΛCDM model when compared to scenarios with dynamical dark energy, such as the $\omega_0\omega_a$CDM model (DESI Collaboration et al. 2025). These results have motivated extensive investigations of alternative cosmological models and modified gravity theories confronted with current observational data Oliveira et al. (2025a).

In this work, we compare different cosmological models through the evolution of matter perturbations, using observational data of the growth rate $f(z)$ and the amplitude of density fluctuations $\sigma_8(z)$. The joint analysis of these observables allows for a more detailed characterization of cosmic structure formation Franco et al. (2025a).

Within the linear perturbation regime, extensions of the ΛCDM model, such as ωCDM Linder & Cahn (2007), and modified gravity $F(R)$ models, including the Starobinsky Starobinsky (2007) and Hu–Sawicki Hu & Sawicki (2007) classes, predict distinct evolutions for $f(z)$ and $\sigma_8(z)$. We compare these predictions with recent observational measurements Macaulay et al. (2013), investigating possible deviations from the standard cosmological model.

2. Cosmological observables and data

In this section, we present the datasets used in the analysis. We consider observational measurements of the growth rate of cosmic structures, $f(z)$, and of the amplitude of matter density fluctuations, $\sigma_8(z)$, which are observables sensitive to both the expansion history of the Universe and the underlying gravitational theory.

We use 11 measurements of $f(z)$ compiled in Avila et al. (2022b), covering the redshift range $0.013 \le z \le 1.40$, as shown in Table 1. For $\sigma_8(z)$, we employ 14 measurements compiled in Piccirilli et al. (2024), supplemented by a recent low-redshift measurement reported in Franco et al. (2025a), totaling 15 observational points in the range $0.013 \le z \le 3.80$, as detailed in Table 2. These data are used to confront the predictions of the different cosmological models analyzed in this work.

Table 1. Dataset of 11 measurements of $f(z)$ compiled in Avila et al. (2022b).

z	$f(z)$	error
0.013	0.56	0.07
0.15	0.49	0.14
0.18	0.49	0.12
0.22	0.60	0.10
0.35	0.70	0.18
0.38	0.66	0.09
0.41	0.70	0.07
0.55	0.75	0.18
0.60	0.73	0.07
0.77	0.91	0.36
1.40	0.90	0.24

3. Results and discussion

We present non-parametric reconstructions of the growth rate of cosmic structures, $f(z)$, and of the matter clustering amplitude, $\sigma_8(z)$, obtained through Gaussian Processes (GP) applied to current observational data (Oliveira et al. 2024, 2025a,b). These reconstructions are compared with the predictions of modified gravity (MG) models and cosmologies based on General Relativity, allowing us to assess their ability to describe the growth of cosmic structures.

Figure 1 shows the GP reconstruction of $f(z)$ together with the predictions of the Starobinsky, R^2-AB, and Hu–Sawicki models. The reconstruction adequately captures the data trend at low and intermediate redshifts, with most modified gravity models lying within the GP uncertainty band. In particular, the Hu–Sawicki model ($n = 1$) shows excellent agreement with the reconstruction. In contrast, the flat ΛCDM model predicts a systematically higher growth rate, especially at high redshifts.

The behavior of $\sigma_8(z)$, shown in Figure 2, reinforces these conclusions. Modified gravity models are, in general, consistent with the GP reconstruction over the entire redshift range considered. On the other hand, the ΛCDM model exhibits discrepancies

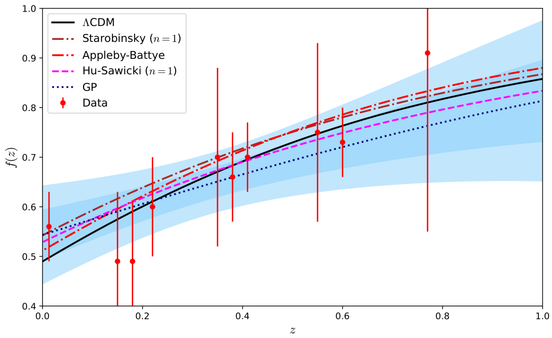

Figure 1. Comparison between the GP reconstruction of $f(z)$ and the predictions of modified gravity models.

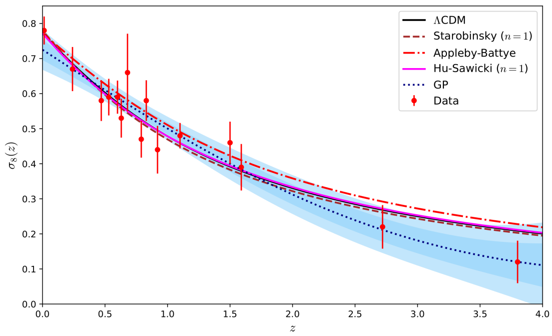

Figure 2. Comparison between the GP reconstruction of $\sigma_8(z)$ and the predictions of modified gravity models.

Table 2. Dataset of 15 measurements of $\sigma_8(z)$ compiled in Piccirilli et al. (2024); Franco et al. (2025a).

z	$\sigma_8(z)$	error
0.013	0.78	0.04
0.24	0.67	0.04
0.47	0.58	0.04
0.53	0.59	0.03
0.60	0.59	0.02
0.63	0.53	0.04
0.69	0.66	0.10
0.80	0.47	0.04
0.83	0.58	0.04
0.92	0.44	0.06
1.10	0.48	0.01
1.50	0.46	0.05
1.59	0.39	0.06
2.72	0.22	0.06
3.80	0.12	0.06

both in amplitude and in the temporal evolution of density fluctuations, suggesting a less compatible description of structure formation when compared to the alternative scenarios analyzed.

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