Interacting vacuum dark energy

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Introduction

Observational evidence implies that the Universe is expanding at an accelerating rate [1, 2].

The standard model of cosmology, ΛCDM, attributes this acceleration to a cosmological constant but a number of problems with this model motivate alternative theories [3].

One such alternative is the interacting vacuum scenario, in which the vacuum energy is dynamical and interacts with dark matter [4, 5].

Theory

In the interacting vacuum scenario, the interaction is introduced at the level of the continuity equations:

$$\dot{\rho}_c + 3H\rho_c = -Q$$

$$\dot{V} = Q$$

$$Q = -q_V HV$$

An advantage of considering an interaction of this form is that an analytical solution to the continuity equations can be found.

We want to investigate whether this interacting vacuum scenario is favoured by cosmological datasets and if so, what values of the interaction strength, q_V, are most likely given the data.

Method

We consider three different methods for reconstructing the interaction: using the analytical solution, using a numerical solution and using Gaussian processes.

Gaussian processes reconstruct a function by summing up Gaussian distributions [6]. This introduces an additional free parameter: the correlation length between the Gaussians.

We can then use the numerical Boltzmann solver CAMB [7] along with the Markov Chain Monte Carlo code CosmoMC [8] to constrain our model parameters using observational data, for example, Planck CMB data, JLA supernovae and KiDS weak lensing data.

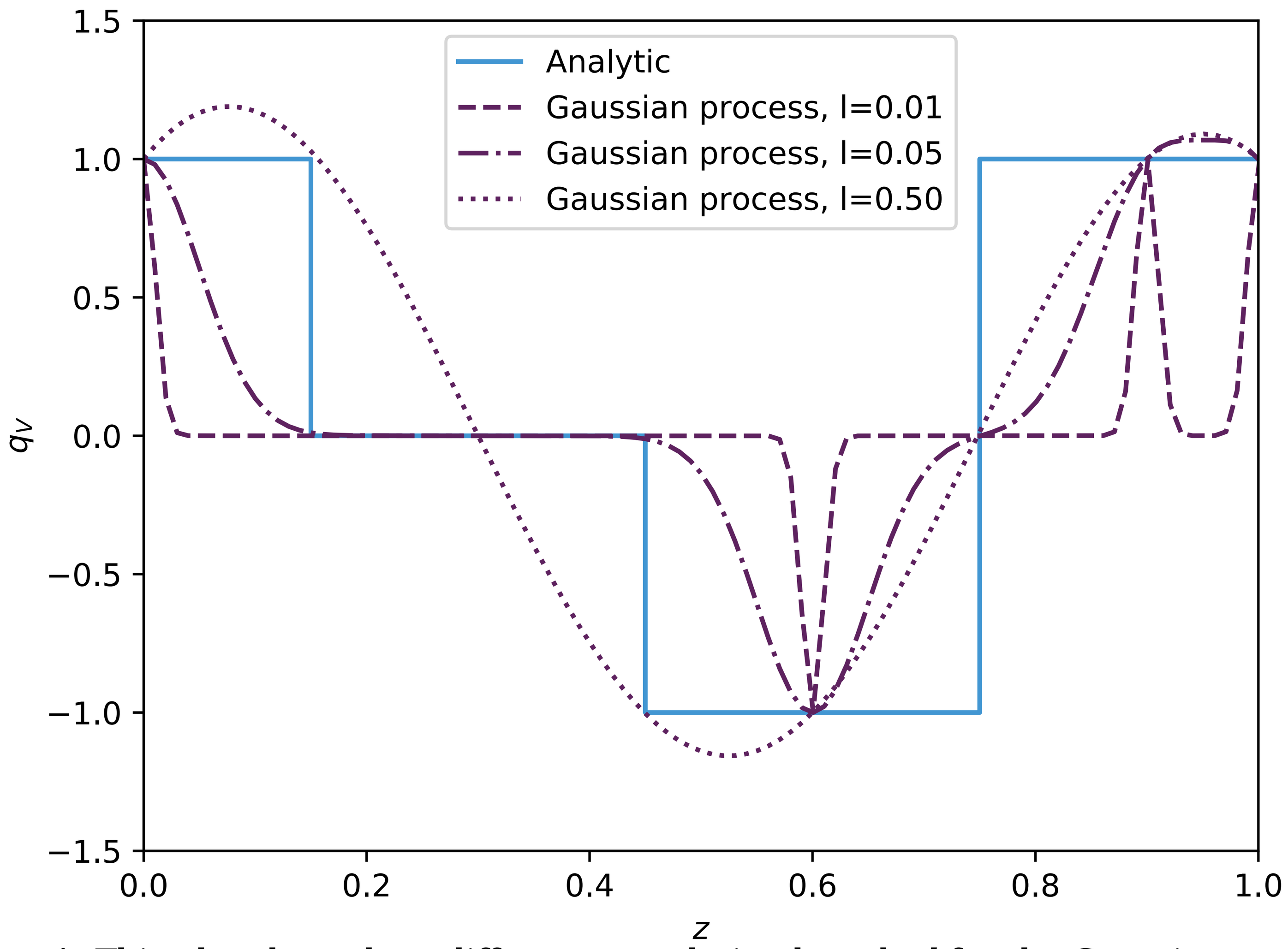

Figure 1: This plot shows how different correlation lengths l for the Gaussian process compare to the analytic solution for an arbitrary interaction and binning.

Results

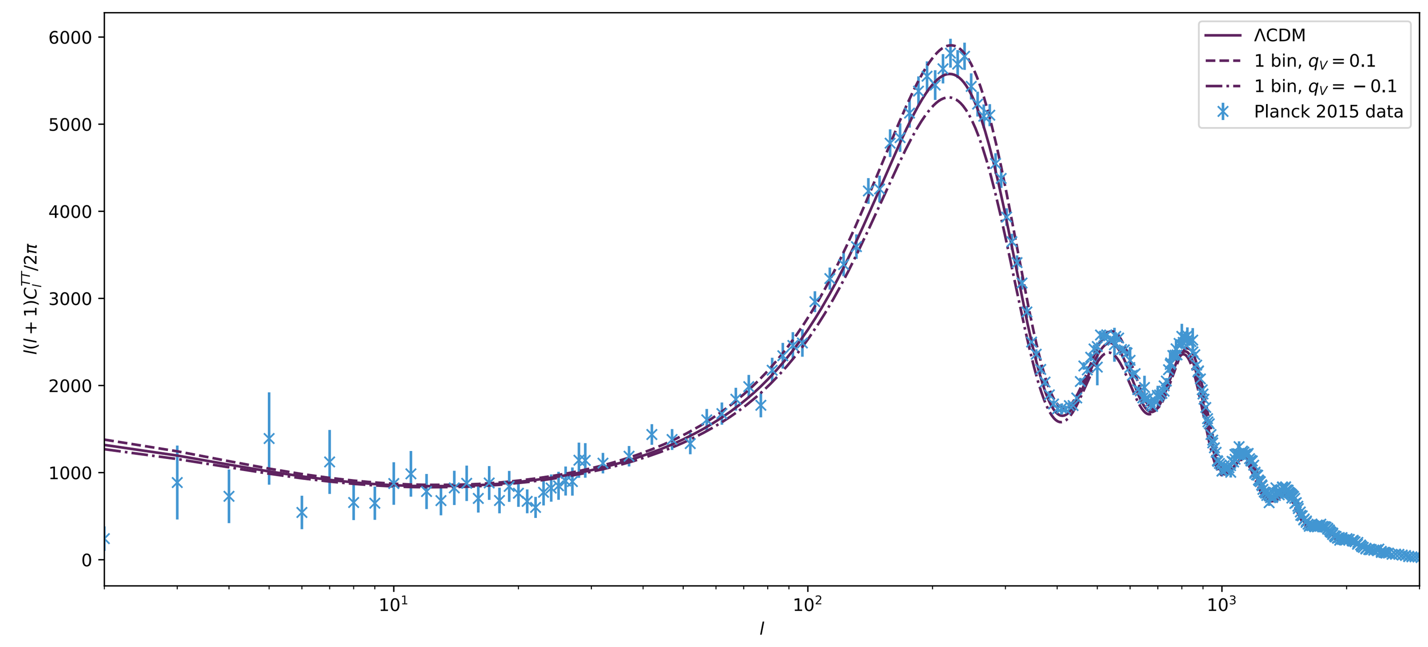

Figure 2: This plot shows the effect that a small negative or positive interaction has on the CMB TT power spectrum, in comparison to the ΛCDM case. The data points are from Planck 2015.

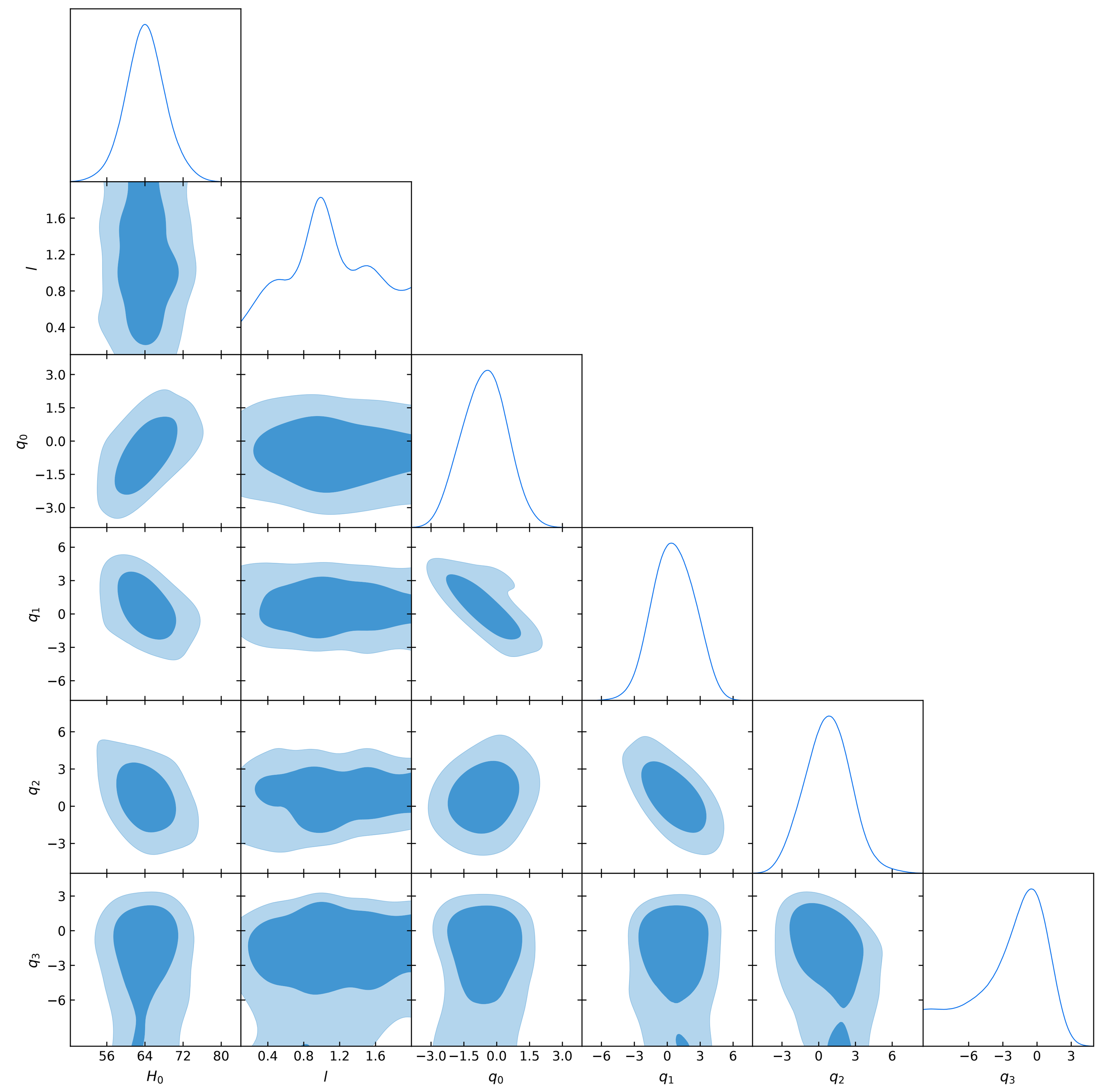

Figure 3: This contour plot shows some preliminary results from an MCMC run using Planck 2015 data with the Gaussian process approach and four redshift bins.

Future work

The next step in this project is to continue running the MCMC code with different datasets so that we have constraints on both the background and perturbations in our interacting scenario.

We then plan to make a comparison between the reconstruction methods used. It will be useful to understand how well the Gaussian process approach performs.

The end goal of the project is then to compare our interacting vacuum scenario with ΛCDM and see if we can draw any conclusions about which model best fits cosmological datasets.

References

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[7] https://camb.info/

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