Searching in the Light for Dark Energy Time Variation

Jason Dick

University of California, Davis

Motivation

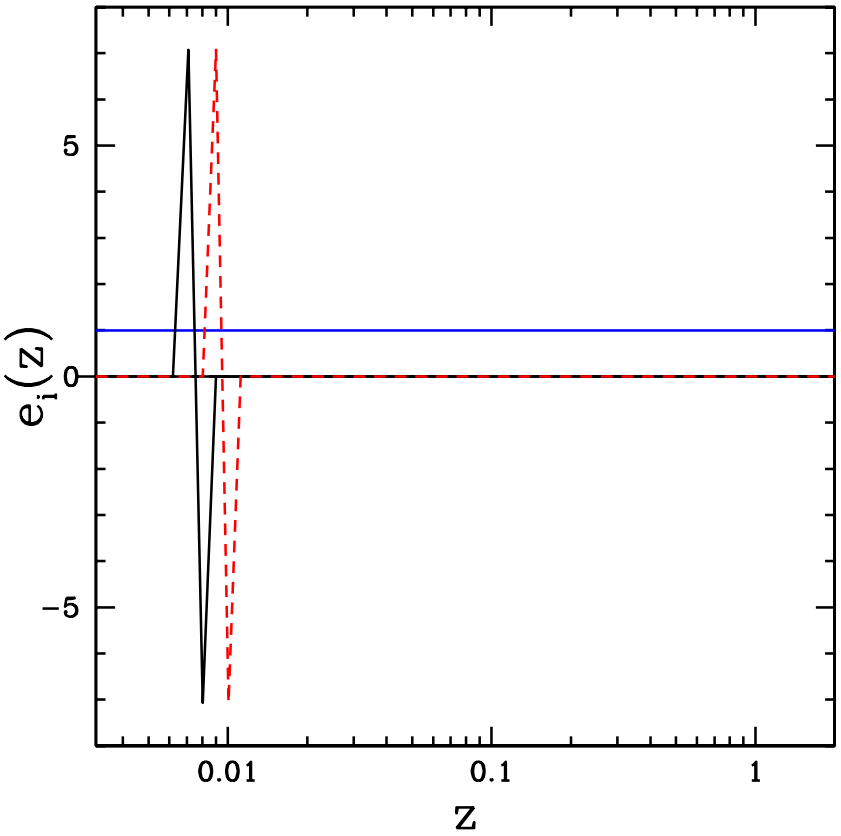
- Is dark energy a cosmological constant?
- Theory gives little insight as to how dark energy varies.
- Theory-independent analysis: let the data decide.
- Our solution: use eigenmodes.

Data

- Supernova data: Riess et. al. (astro-ph/0402512) and Astier et. al. (astro-ph/0510447)
- WMAP constraints: Provided by Mike Chu (taken from his work in astro-ph/0411737)
- BAO constraints: Eisenstein et. al. (astro-ph/0501171)

Parameterization

- Define: $\rho_x(z) = \rho_c a_i e_i(z)$.
- Choose basis: e_0 is constant, others vary



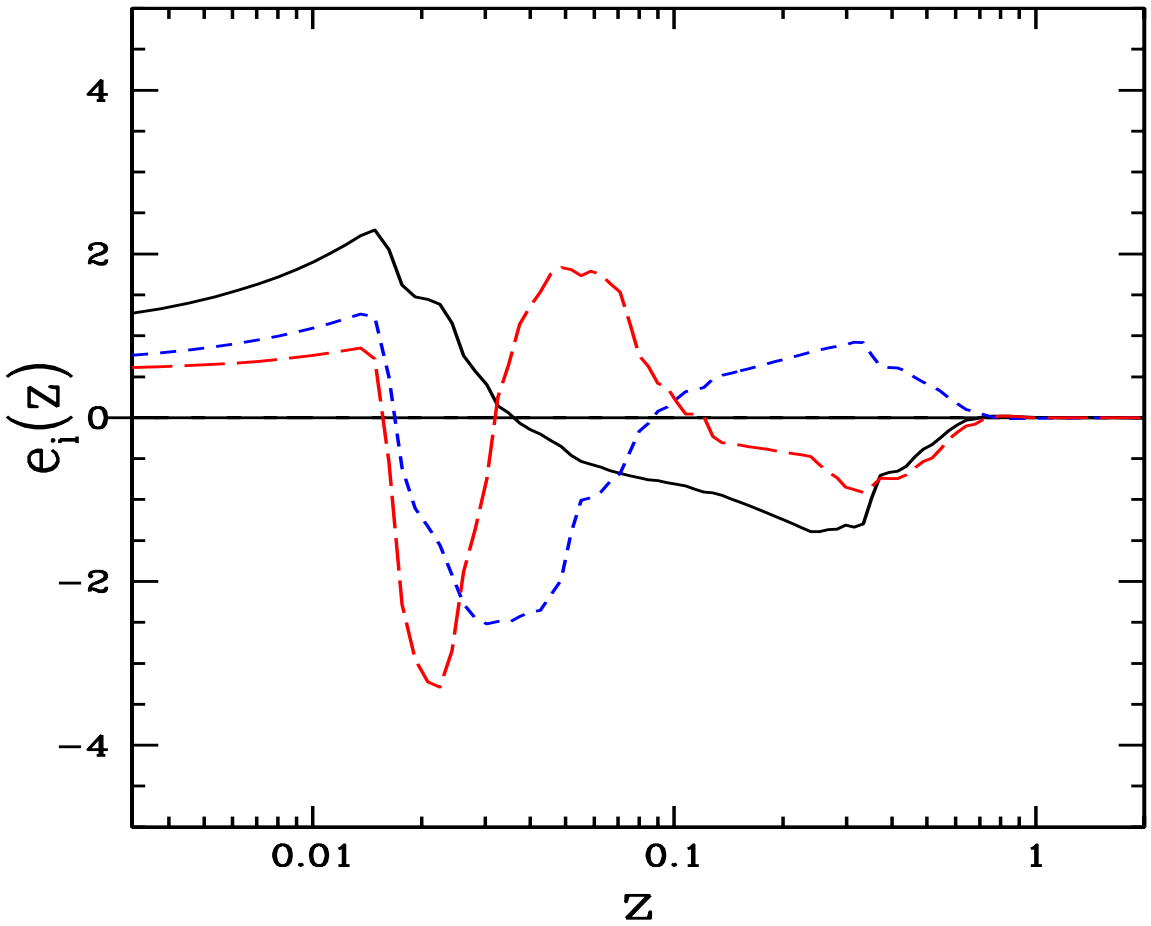
- Constant basis vector (i=0)
- One varying vector
- Another varying vector

Diagonalization

- To describe our cosmology, we now have the parameters: ω_m, Ω_k, a_0, a_1-a_n, and the supernova parameters: M, α, β.
- Take Gaussian approximation to marginalize over all but a_1-a_n.
- Diagonalize to get eigenvectors (a new basis):

Some example eigenmodes

SNLS + BAO + WMAP data

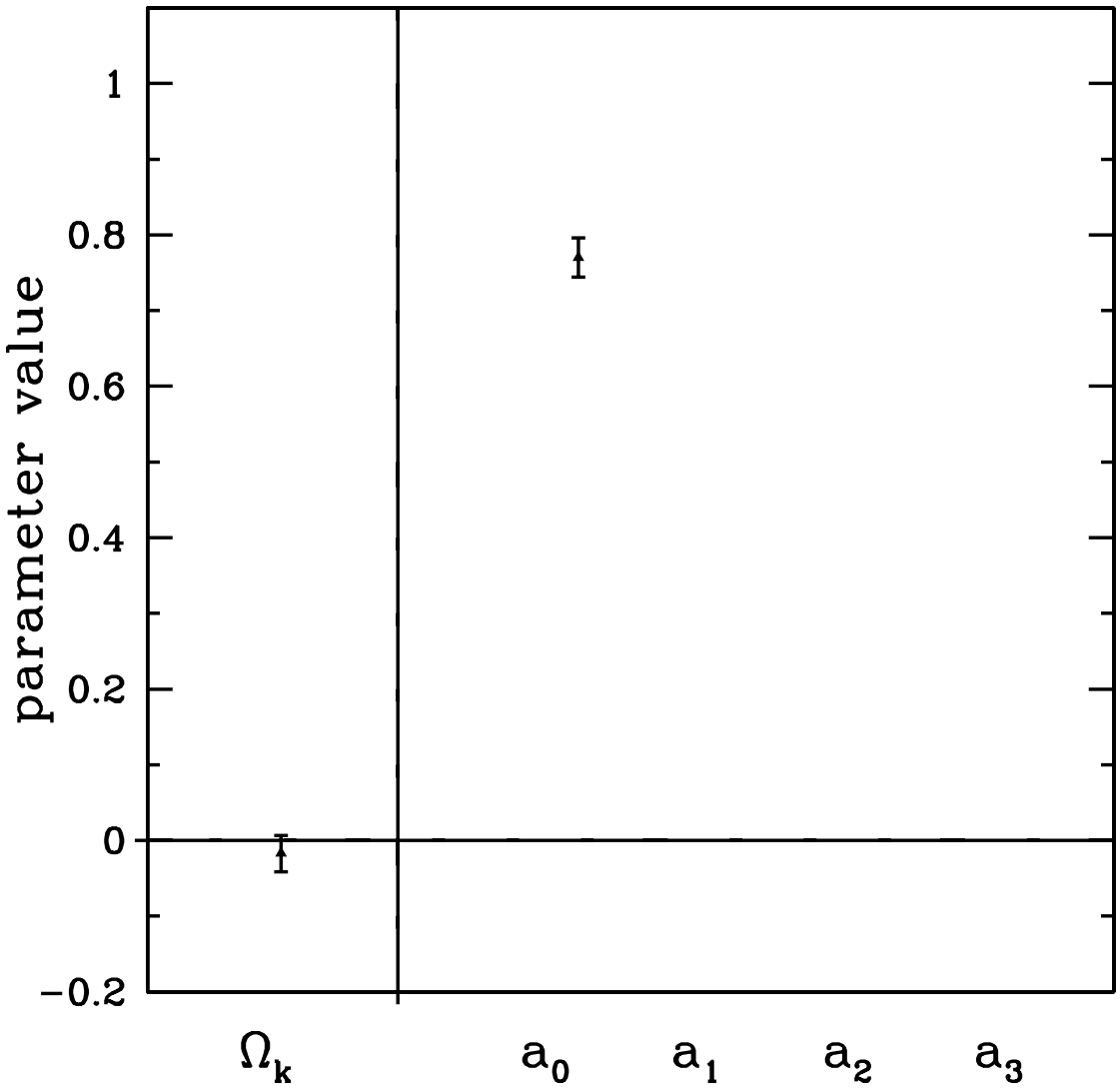


- First varying mode (i=1)
- Second varying mode (i=2)
- Third varying mode (i=3)

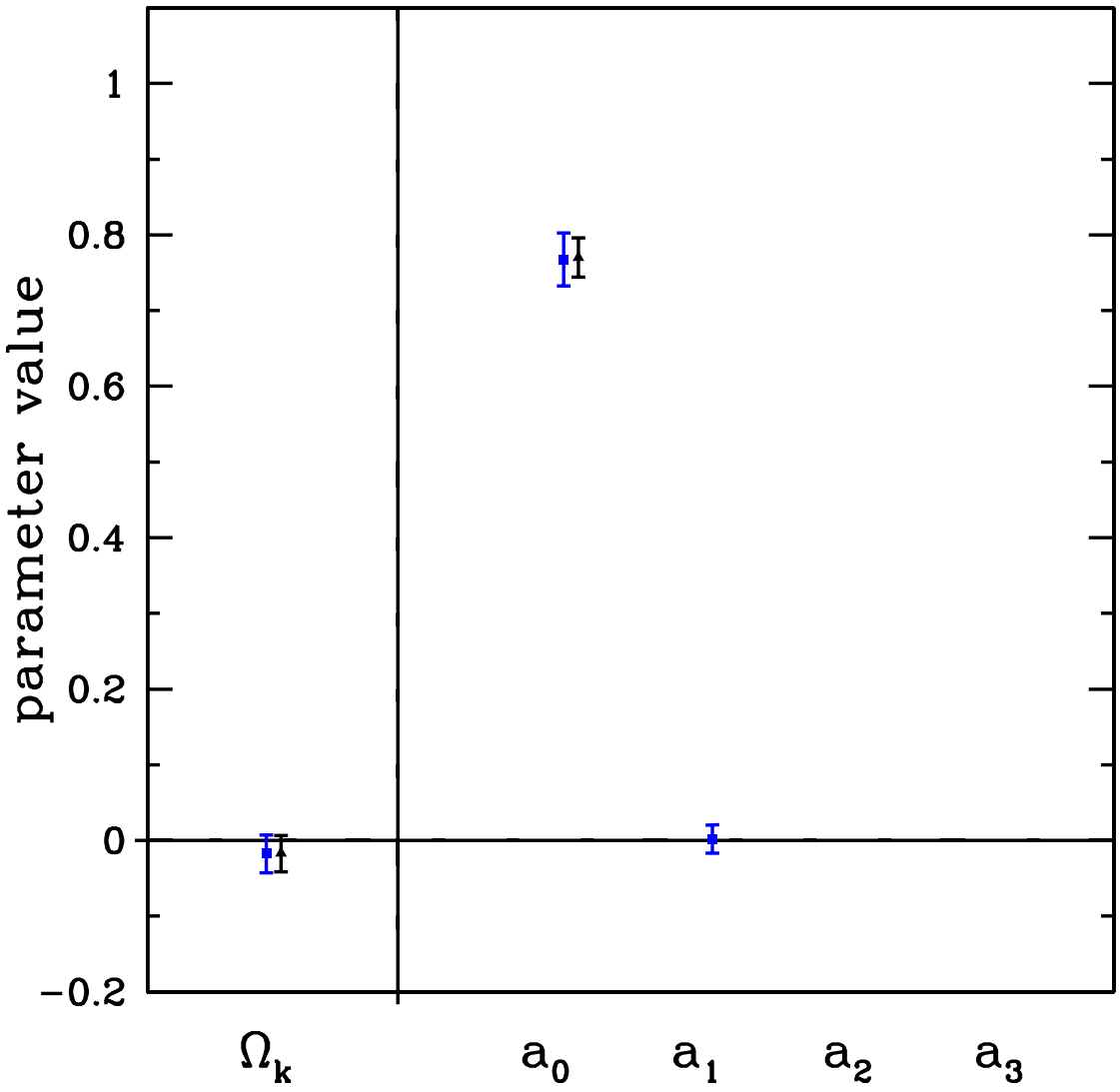
MCMC Analysis

- Frees us from the Gaussian approximation.
- Using MCMC, estimate values and errors of best-measured modes only.
- The errors in each varying mode should be uncorrelated with all other varying modes.

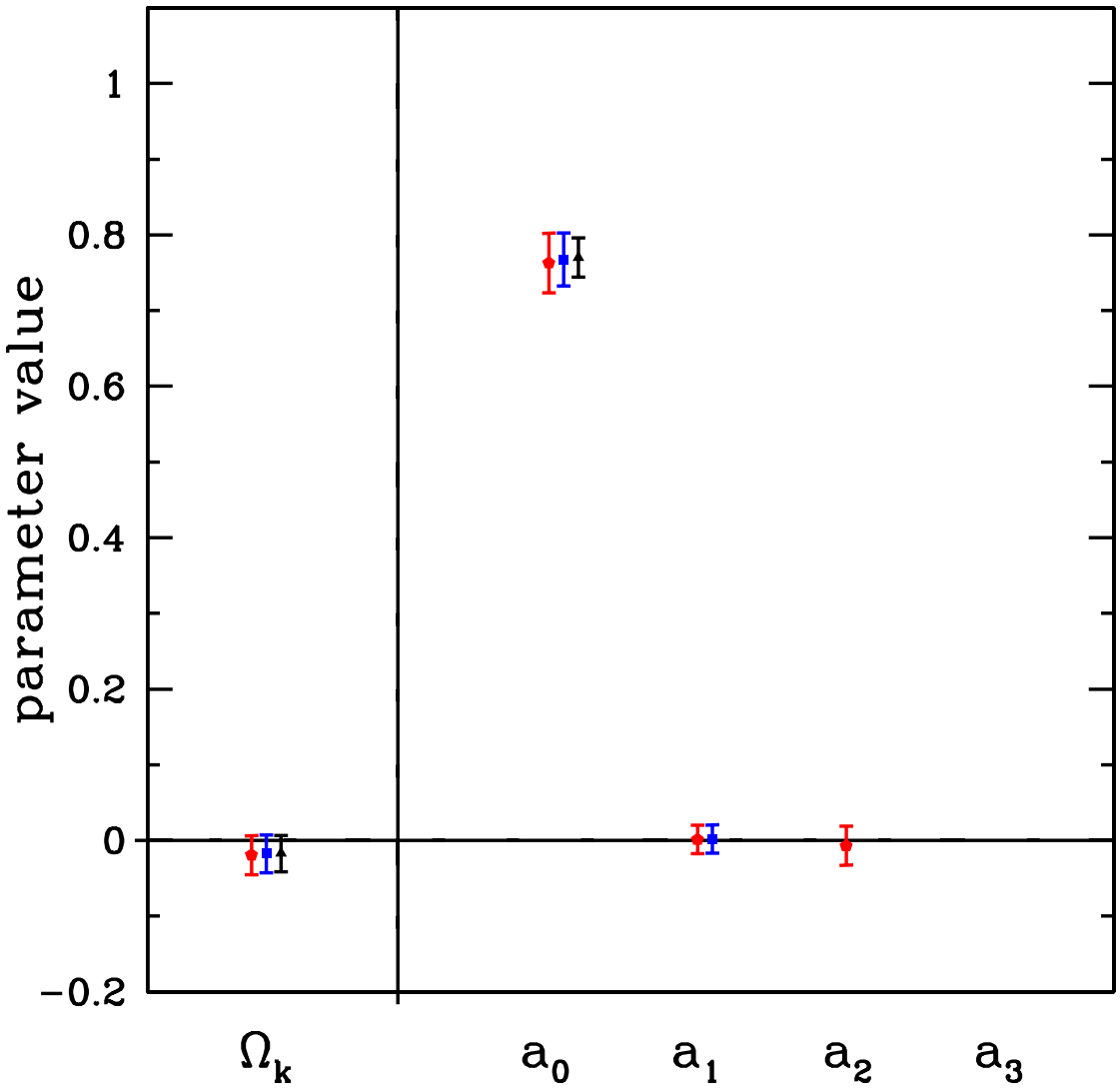
SNLS + WMAP Results



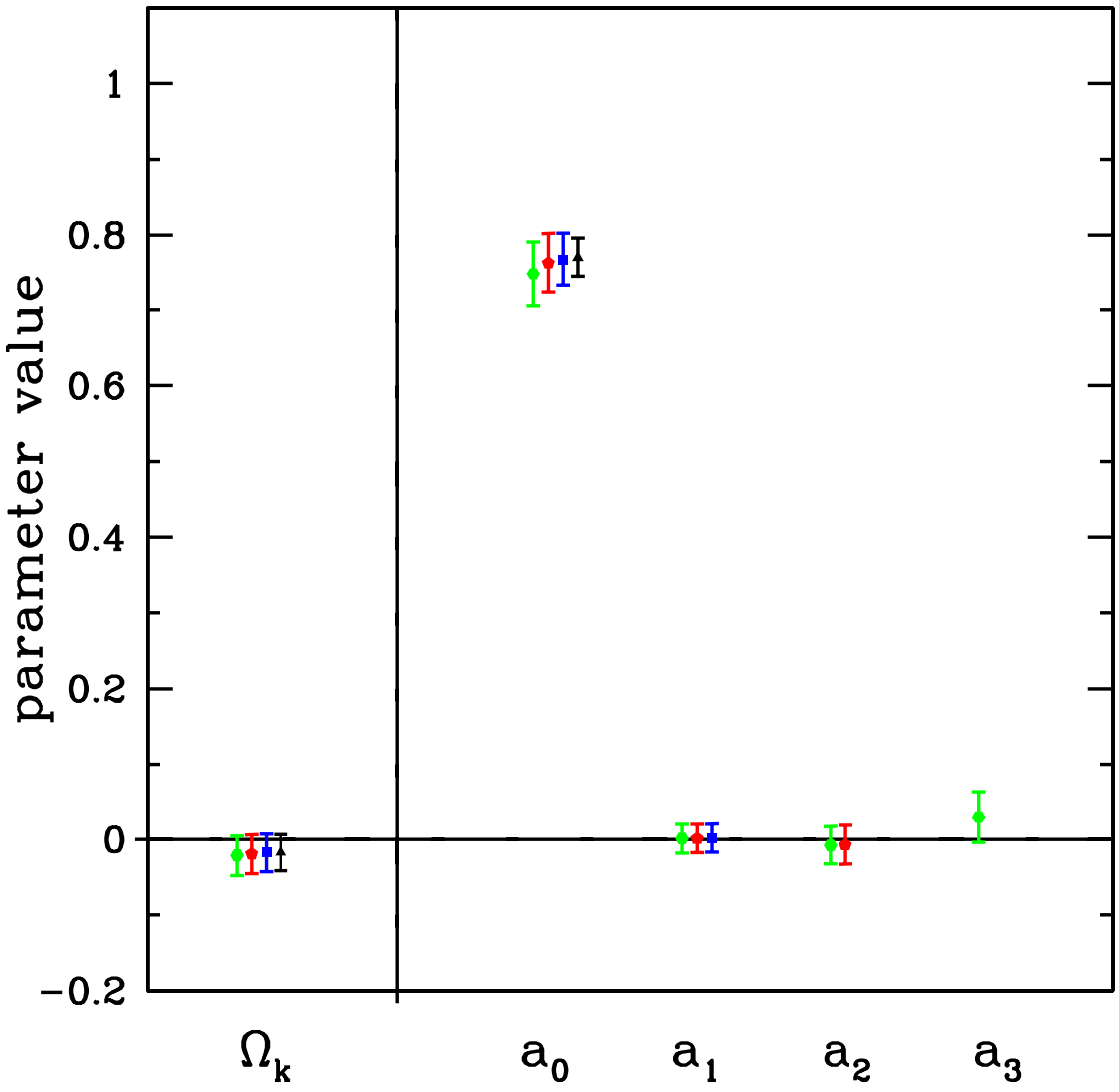
SNLS + WMAP Results



SNLS + WMAP Results



SNLS + WMAP Results



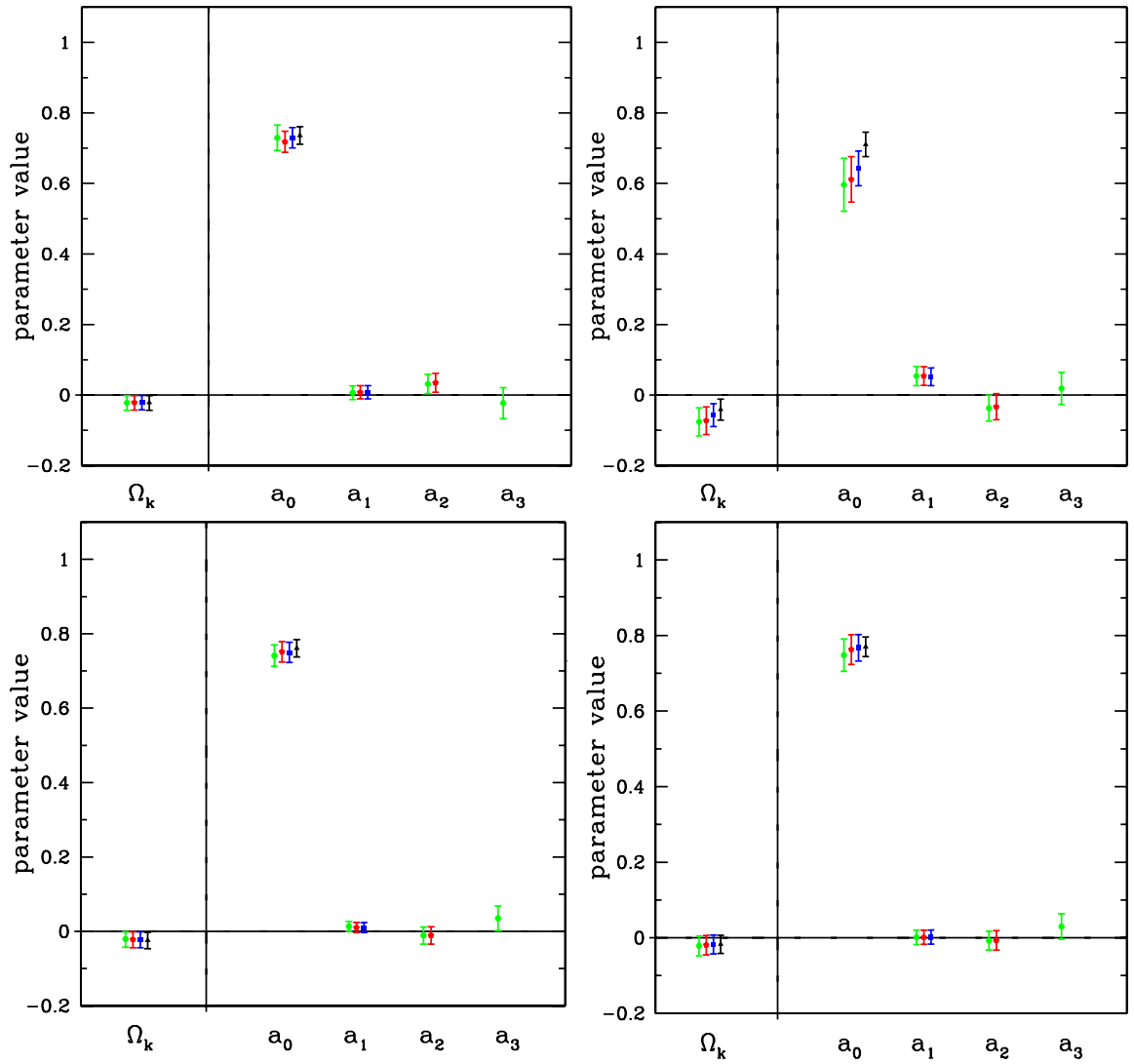
More Results

With BAO

No BAO

Riess Gold

SNLS

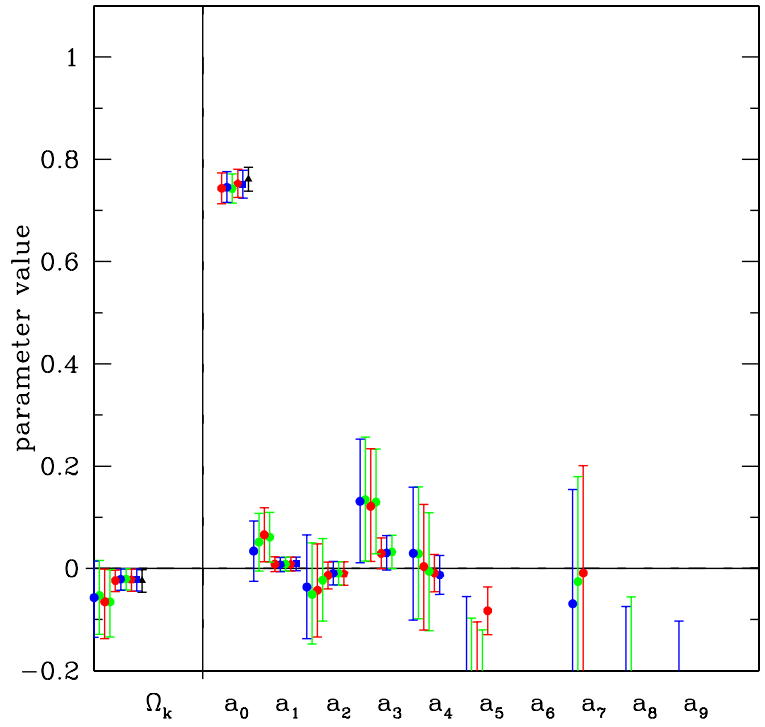


- One DE Param
- Two DE Params
- Three DE Params
- Four DE Params

When Gaussians Go Bad

- Adding more modes: degeneracies appear.
- Here it happens when the MCMC chain includes the 7th dark energy parameter.
- This degeneracy is between a_0 and a_6.

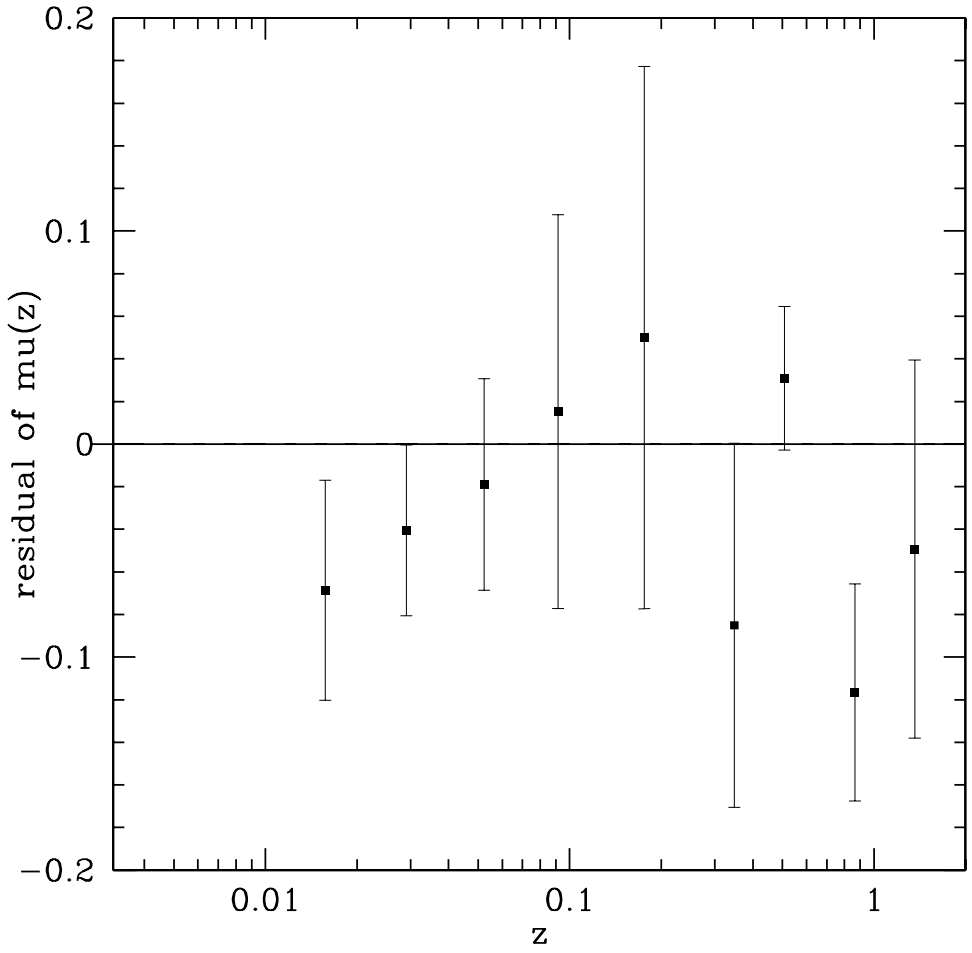
SNLS + BAO + WMAP

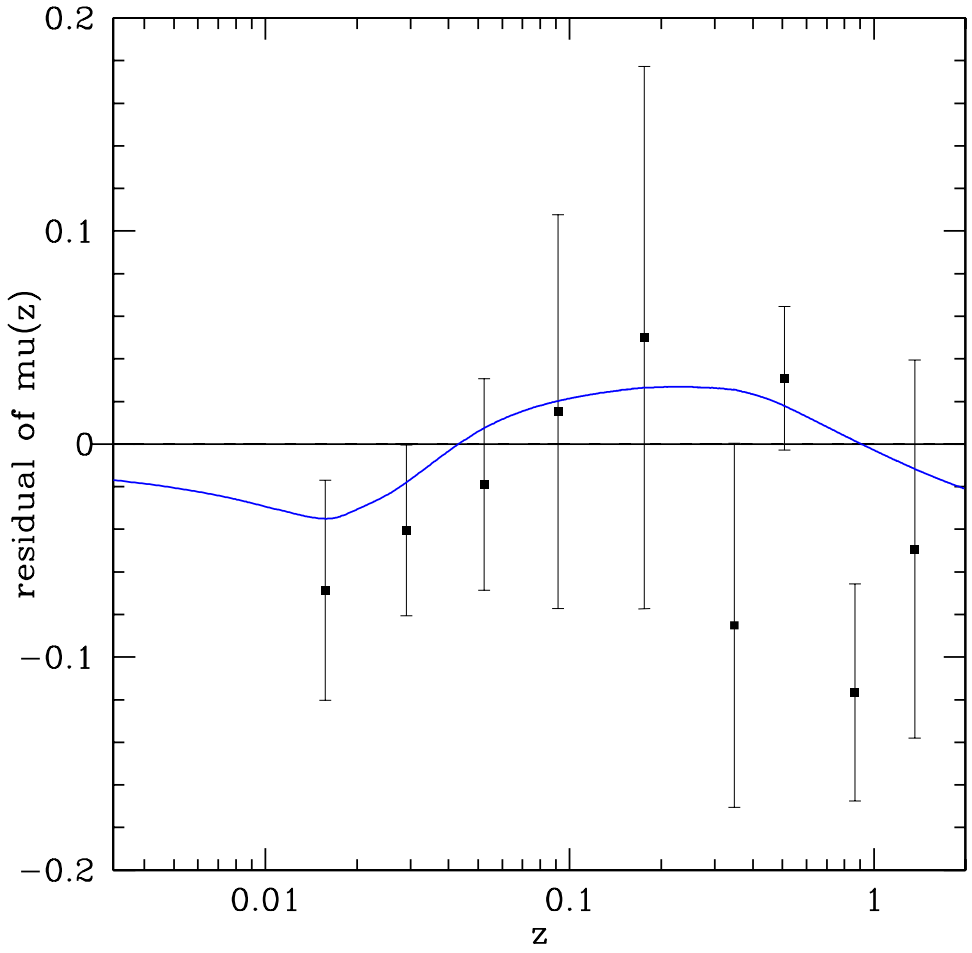


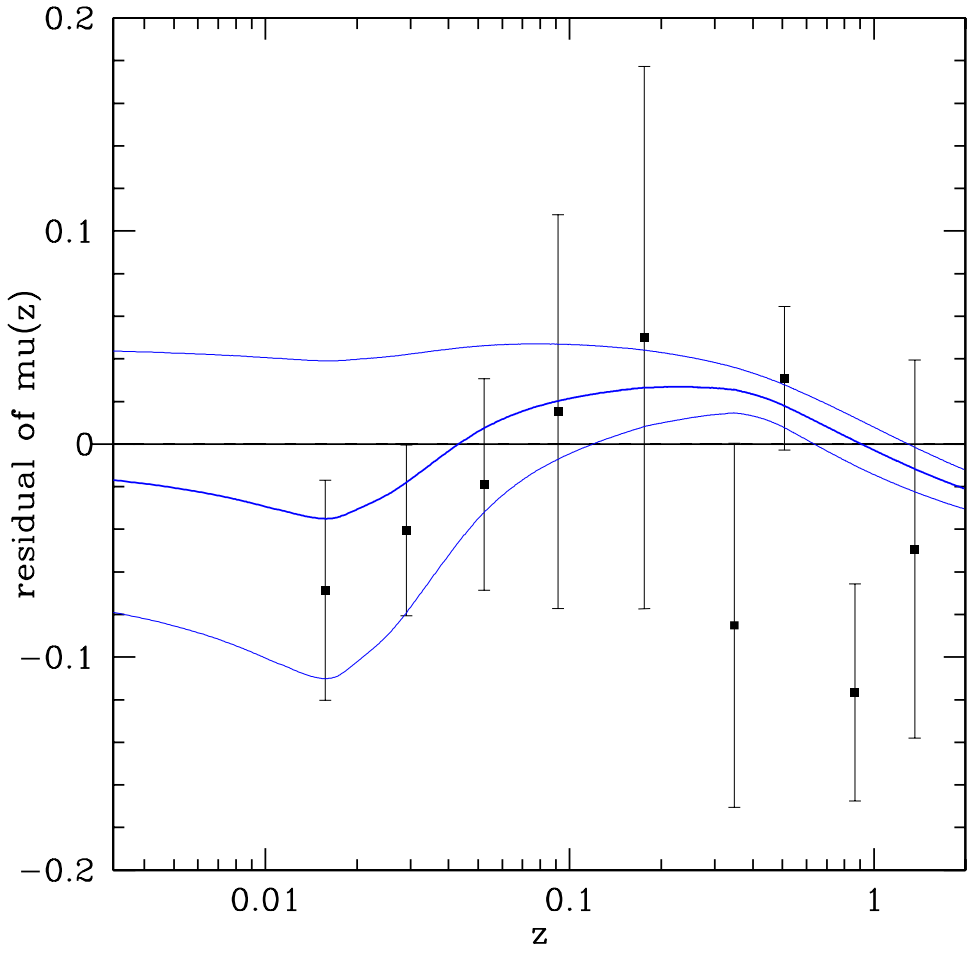
Conclusions

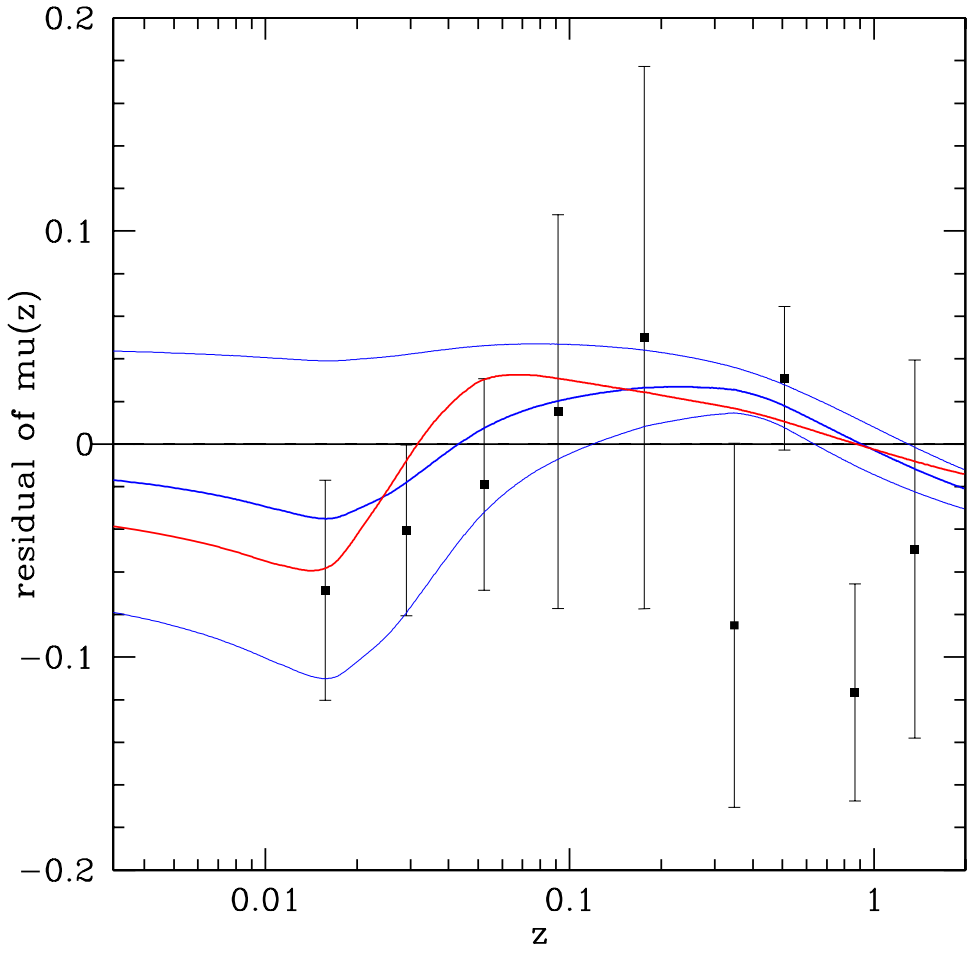
- Good method for detecting deviation from constant without being tied to a particular theory.
- Not tied to the Gaussian approximation.
- As expected, current data is consistent with a cosmological constant and zero curvature.

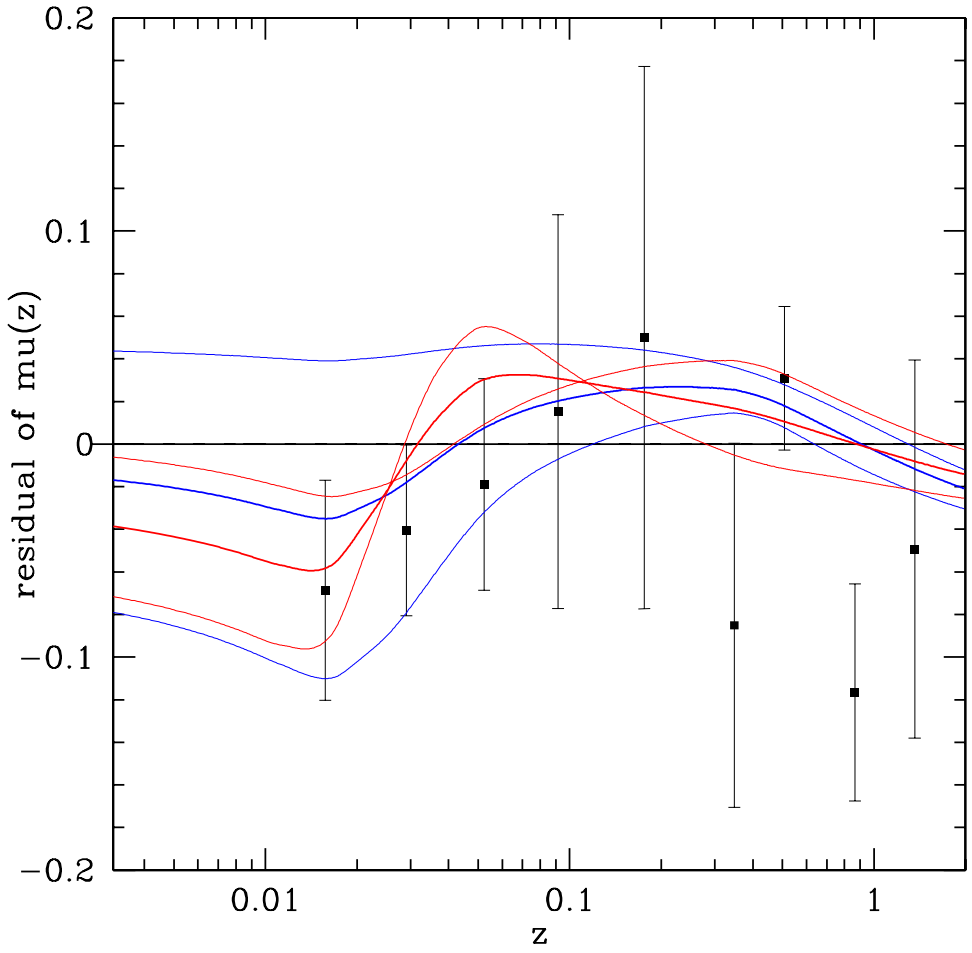
Questions?


0.2
0.1
0
−0.1
−0.2
residual of mu(z)
0.01
0.1
1
z


0.2
0.1
0
−0.1
−0.2
residual of mu(z)
0.01
0.1
1
z


0.2
0.1
0
−0.1
−0.2
residual of mu(z)
0.01
0.1
1
z


0.2
0.1
0
−0.1
−0.2
residual of mu(z)
0.01
0.1
1
z


0.2
0.1
0
−0.1
−0.2
residual of mu(z)
0.01
0.1
1
z