Searching in the Light for Dark Energy Time Variation

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

![Graph showing varying basis vectors]

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

• To describe our cosmology, we now have the parameters: $\omega_m$, $\Omega_k$, $a_0$, $a_1$-$a_n$, and the supernova parameters: $M$, $\alpha$, $\beta$.

• 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

- Parameter values:
  - $\Omega_k$
  - $a_0$, $a_1$, $a_2$, $a_3$
SNLS + WMAP Results
SNLS + WMAP Results
More Results

With BAO

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

No BAO

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

Riess Gold

SNLS
When Gaussians Go Bad

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

\[ \text{SNLS + BAO + WMAP} \]
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?