Dark Energy with DEX

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Excellence Cluster
Universe

Dark Energy

simple fluid: $p = w\rho$

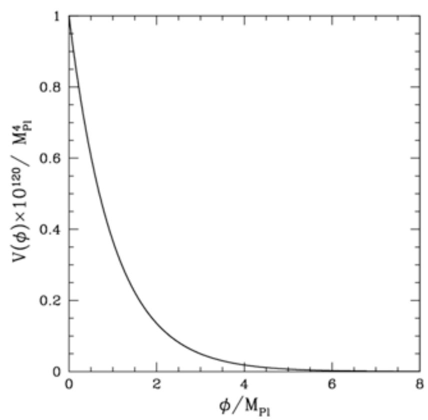
Deceleration parameter (flat Universe, only DE):

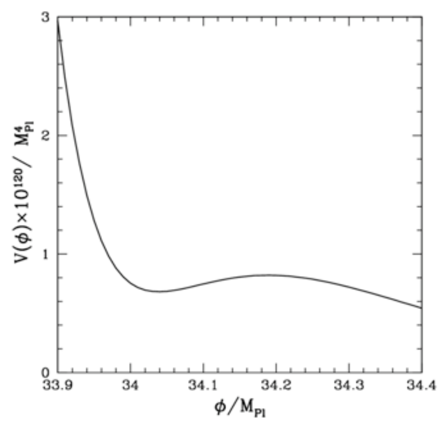
$$q_0 = -\frac{\ddot{a}_0}{H_0^2} = \frac{1+3w}{2}$$

Hence accelerated expansion for $w<-1/3$, i.e. violating strong energy condition !

Cosmological constant: $w=-1$

Quintessence





$$\Omega_\Lambda = 0.7 \quad \rightarrow \rho_\Lambda \approx 10^{-48}\,\mathrm{eV} = 10^{-121}\ M_{\mathrm{pl}}^4$$

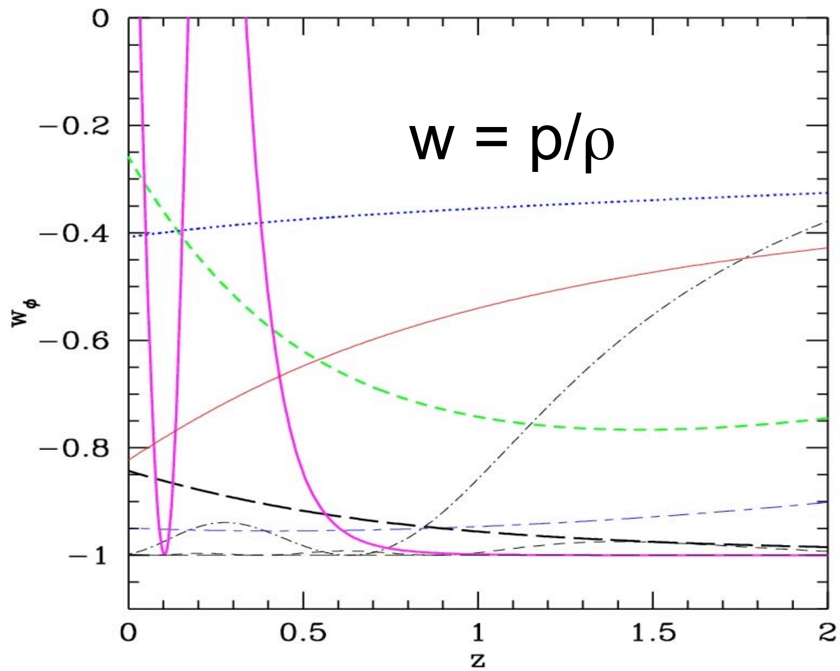
Dynamical dark energy

Equation of state of scalar field:

$$w = \frac{\frac{1}{2}\dot{\phi}^2 - V(\phi)}{\frac{1}{2}\dot{\phi}^2 + V(\phi)}$$

Different Quintessence Models

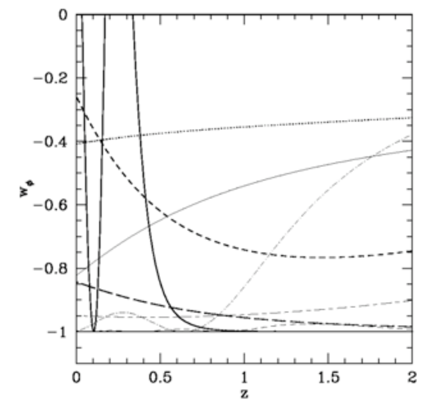
scalar field dark energy models (quintessence)



All models ad hoc

Parameterizations of Dark Energy

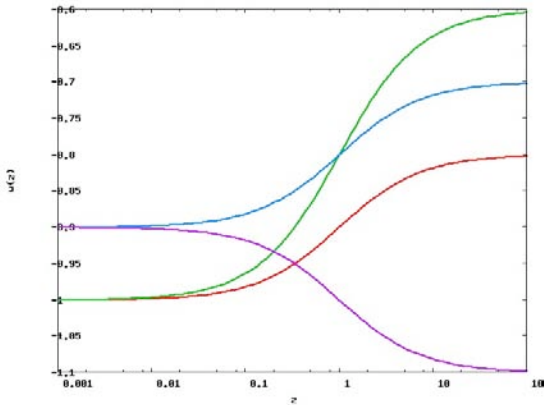
- Background evolution
  - $w = w_0$
  - $w = w_0 + w_1 z$
  - $w = w_0 + \alpha \ln(a)$ (Efstathiou 1999)
  - $w = w_0 + w_a(1-a)$ (Chevalier 2001, Linder 2003)



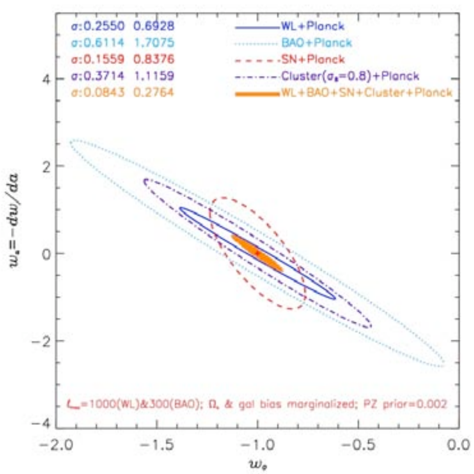
  - binned w(z) ('parameter free')
  - binned $\rho(z)$, H(z)
- Perturbations: c_s^2, γ, ...

Old Figure of Merit

$w(a)=w_0+w_a(1-a)$



w_a



Ma, Weller, Tang

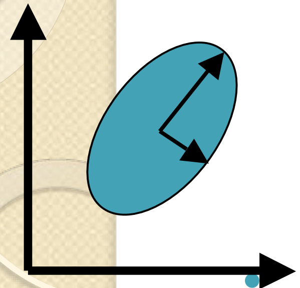
w_0

- Figure of merit: inverse area of 95% contour in w_0-w_a space
- This is some indication but be careful: parameterization imposes certain redshift sensitivity, which does not necessarily reflect particular survey

Better: Binning of w(z)

$$w(z) = \begin{cases} w_i & z \in \left(z_i - \frac{\Delta z}{2}, z_i + \frac{\Delta z}{2}\right] \\ w_h & z > z_{\max} \end{cases}$$

- typically use $\Delta z = 0.05$
- z_{max} given by particular survey
- effectively parameter free and model independent
- DISADVANTAGE: TOO MANY FREE PARAMETERS
- Hence large errorbars; however ...



Principal Component Analysis

- Calculate Fisher matrix for leading order approximation of Likelihood (Gaussian approximation)

$$F_{ij} = \left\langle \frac{\partial^2 \mathcal{L}}{\partial w_i \partial w_j} \right\rangle$$

- Diagonalize Fisher matrix do establish independent modes
- Decompose w(z) in Eigenmodes (decorrelated)

$$\Lambda = WFW^T$$

$$w(z) = w_{fid}(z) + \sum_{j=1}^{N} \alpha_j e_j(z)$$

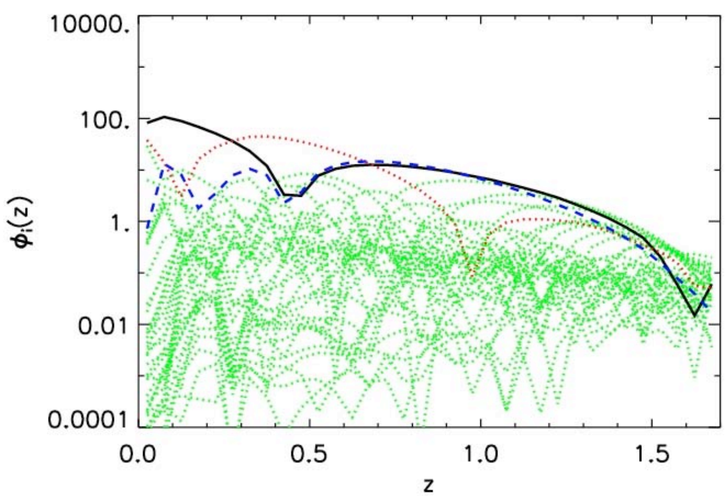
- Inverse of eig[illegible]n Eigenmode ($\Delta\alpha_j = \lambda_j^{-1/2}$), leading Eigenmodes reflect redshift sensitivity of survey/probe

(Huterer and Starkman 2003; Crittenden & Pogosian 2005)

- Going beyond DETF figure of merit and pivot redshift (now proposed)

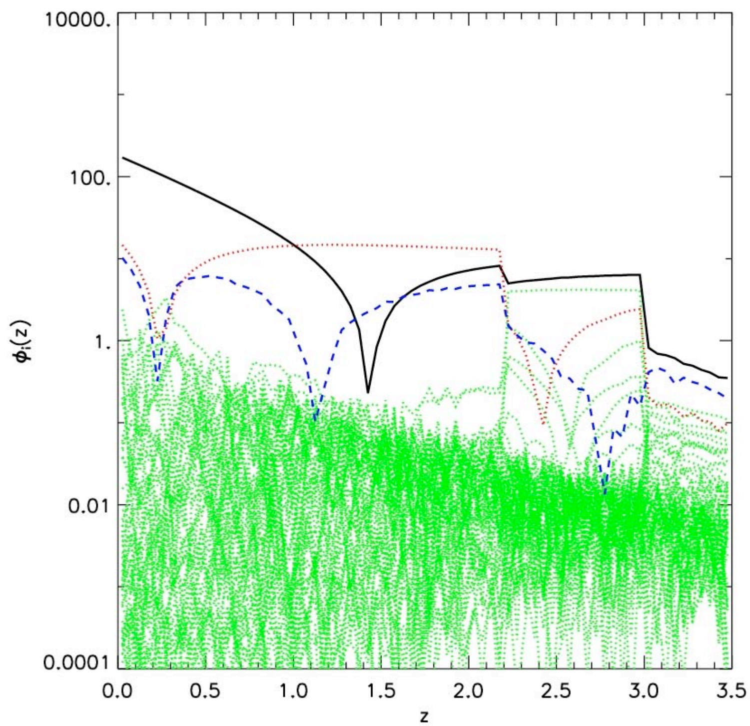
Example: Supernovae Probes

$$ {}_i = N \quad \overline{}_i \mathbf{e}_i(z) $$



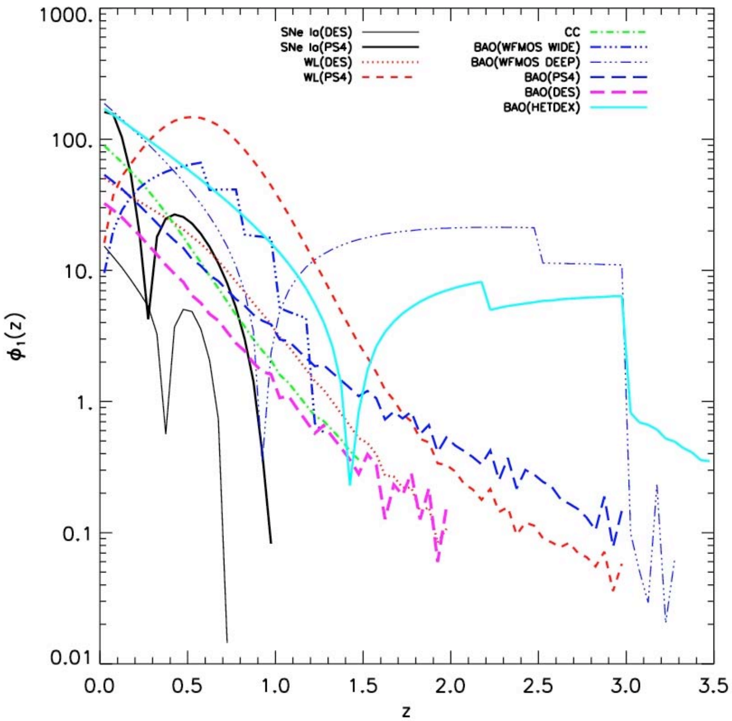
- Measure redshift – distance relation
- SNAP: 2000 SNe
- Use Planck prior and marginalize over other cosmological parameters
- Most weight at z<0.2 (DE domination)
- Modes above third are weakly constraint

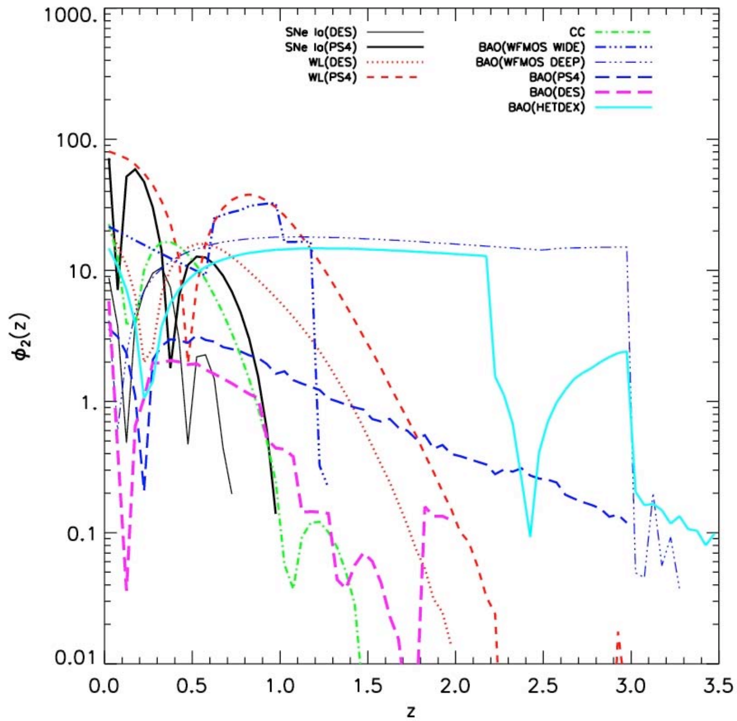
The HETDEX PCAs for BAO



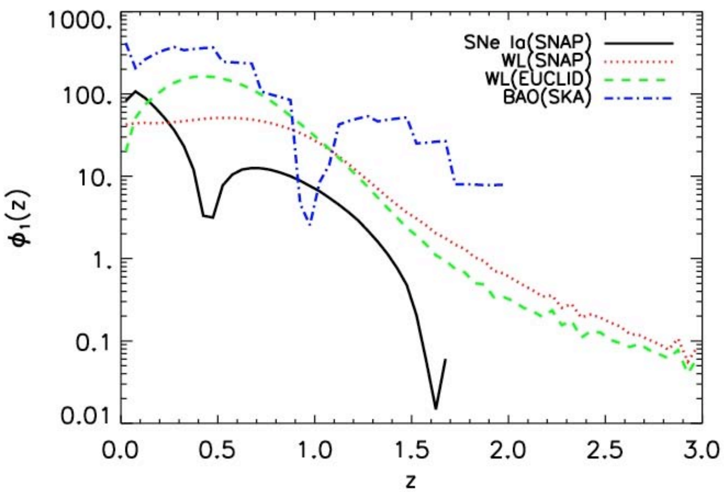
- High redshift range coverage
- reflects distribution of galaxies
- at least two significant modes
- the two first modes are complementary

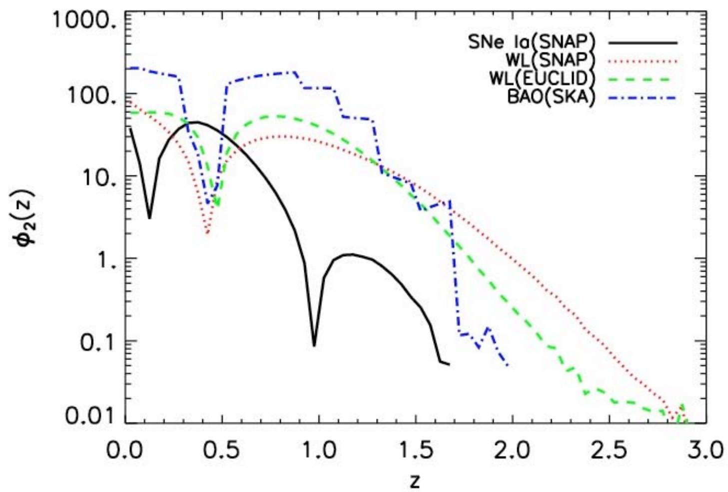
Comparison of Selected Stage III probes





Selected Stage IV probes





Conclusions

- Analysis in spirit of FoMSWG (also different)
- HETDEX provides new window on high redshift constraints on dark energy (e.g. early dark energy etc.)
- In low redshift region almost competitive with PS4 and in high redshift with WFMOS Deep (proposal)
- Number of significant modes (in progress)
- Will only be surpassed at high redshifts from SKA