BAO & LSST - From galaxies distributions to the contraints on dark energy

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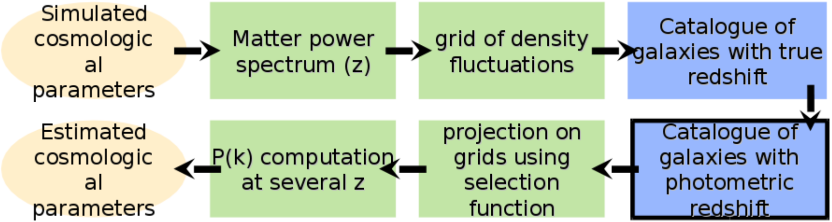
General principle of the simulation

Two aspects :

- Theoretical simulation : computation of the overdensity field grid, of the power spectrum and of the power spectrum without baryons.
- Simulation of the observations :
  1. Generation of a catalogue of galaxies
  2. Projection of this catalogue on grids
  3. Reconstruction of the "observed" power spectra



Principle of the simulation

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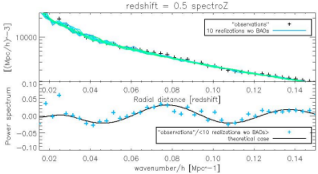
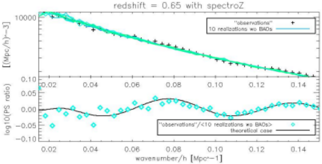
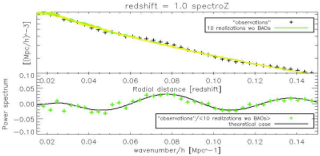
Grids features

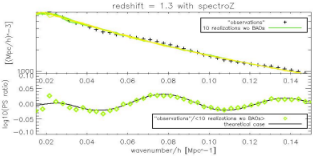
central redshift	redshift range	volume [Gpc^3]	Nb galaxies spectroZ [10^6]	Nb galaxies photoZ [10^6]	Nb galaxies photoZpodds [10^6]
0.5	[0.17-0.90]	13.82	420	413	336
0.65	[0.41-0.93]	19.11	357	358	302
1.0	[0.71-1.35]	46.65	360	361	311
1.3	[0.95-1.72]	76.44	253	254	190
1.5	[1.12-1.98]	94.37	172	171	125

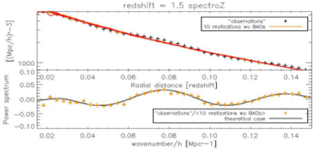
Ref = < 10 spectra without BAOs>





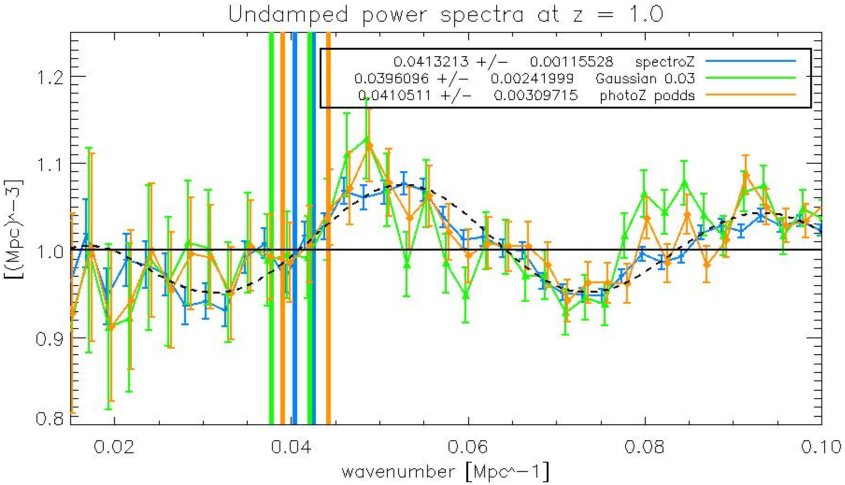






Oscillations = « observations »
/ <10 universes without BAO>
Check spectroZ case: the mean of the spectra
Provides a good estimation of the spectrum
without BAOs.
However, important noise for z=0.5.

Power spectra - PhotoZ case



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Effect of a dynamical dark energy model on the density parameter

Standard Model ΛCDM

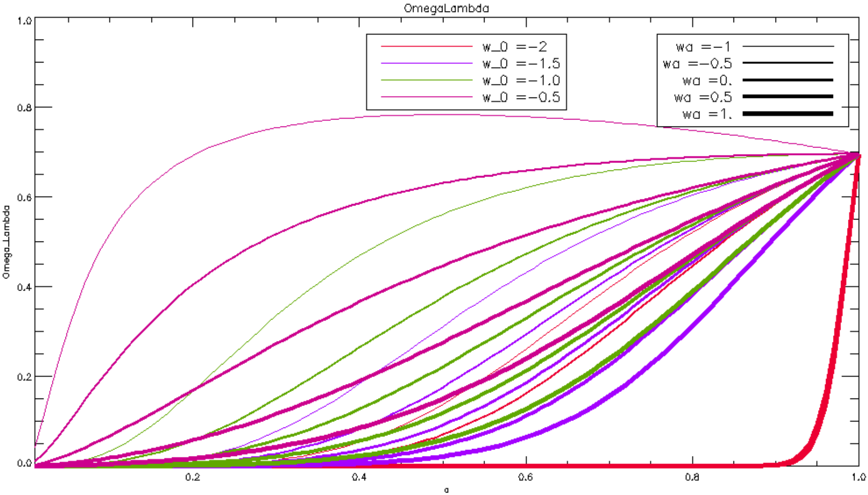
- Λ is a constant and $w_\Lambda = -1$.
- $\Omega_\Lambda = \Omega_{\Lambda,0} f(z)$ avec $f(z) = \exp[3\int_0^z \frac{1+w(z')}{1+z'}\,\mathrm{d}z'] = 1$.
- $\Omega_\Lambda = \Omega_{\Lambda,0}$.

$\Rightarrow$ **Chevallier, Polarski and Linder (CPL) parametrization**

- $w(z) = w_0 + w_a \frac{z}{1+z}$ or $w(a) = w_0 + w_a(1-a)$ with w_0 et w_a two constant parameters.
- $f(z) = (1+z)^{3(1+w_0+w_a)} \exp[-3w_a \frac{z}{1+z}]$
- The reduced dark energy density can so be written as :

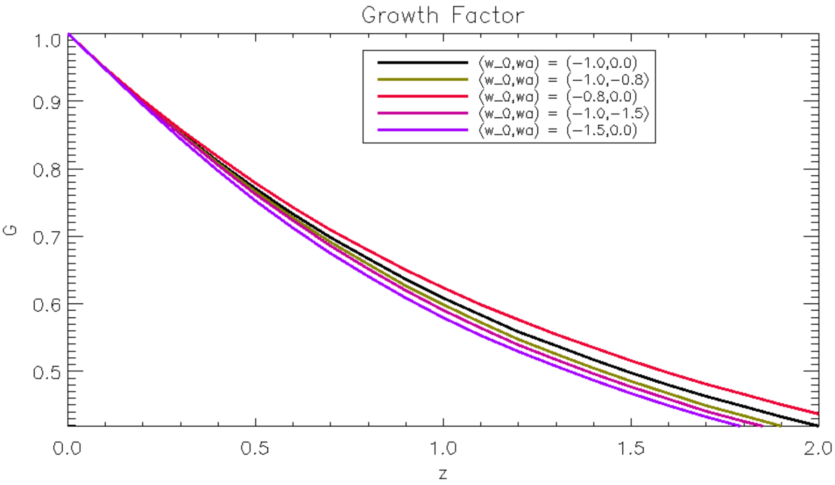
$$\Omega_\Lambda(z) = \Omega_{\Lambda,0}(1+z)^{3(1+w_0+w_a)-3w_a(\frac{z}{1+z})}$$

Effect of a dynamical dark energy model on the density parameter - 2

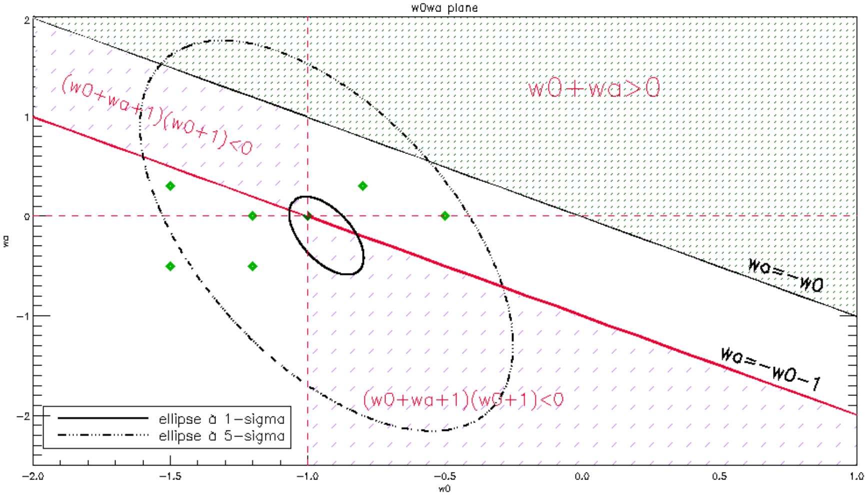


Ω_Λ according to a for different values of $(w_0; w_a)$

Effect of a dynamical dark energy model on the power spectrum



Growth factor for different values of $(w_0; w_a)$



The drawn ellipse comes from Planck data, Planck. Feb 9 2015, Planck Collaboration, "Planck 2015 results. XIII. Cosmological parameters", *Astronomy & Astrophysics*

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Approach

Theoretical simulation

- Hypotheses : Planck data and dark energy parametrized by $(w_0; w_a)$
- Simulation -> theoretical spectrum

Simulation of the observations

From the theoretical power spectra previously computed, the following steps are made

- Generation of a catalogue of galaxies
- Traduction of this catalogue into grids
- Reconstruction of the "observed" power spectra

Approach -2

From these "observed" power spectra, the following fit is applied in order to get k_a.

"Wiggle only" method :

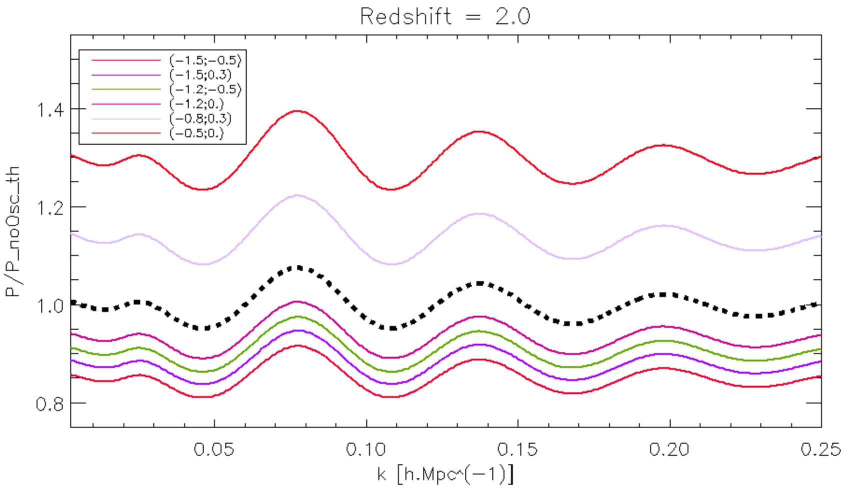
$$P(k) \rightarrow P_{wiggle} = \frac{P(k)}{P_{smooth}(k)} \sim 1 + \mathbf{A}k \exp\left[-\left(\frac{k}{0.1Mpc}\right)^{1.4}\right] \sin\frac{2\pi k}{\mathbf{k_a}}$$

The extracted value from the fit of k_a leads to a value for D_V :

- $k_a^{obs} = k_a^{mod} \frac{D_V}{D_V^{mod}}$
- $D_V(z) = \left[d_A(z, \mathbf{w0}, \mathbf{wa})(1+z)^2 \frac{z}{H(z,\mathbf{w0},\mathbf{wa})}\right]^{1/3}$

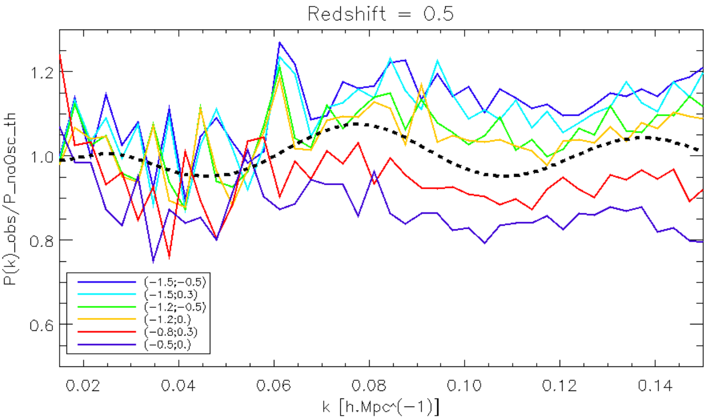
Knowing that D_V depends on $(w_0; w_a)$, its value allows to provide the set of possible combinations for $(w_0; w_a)$ and thus to extract the compatible values.

Simulated theoretical power spectra



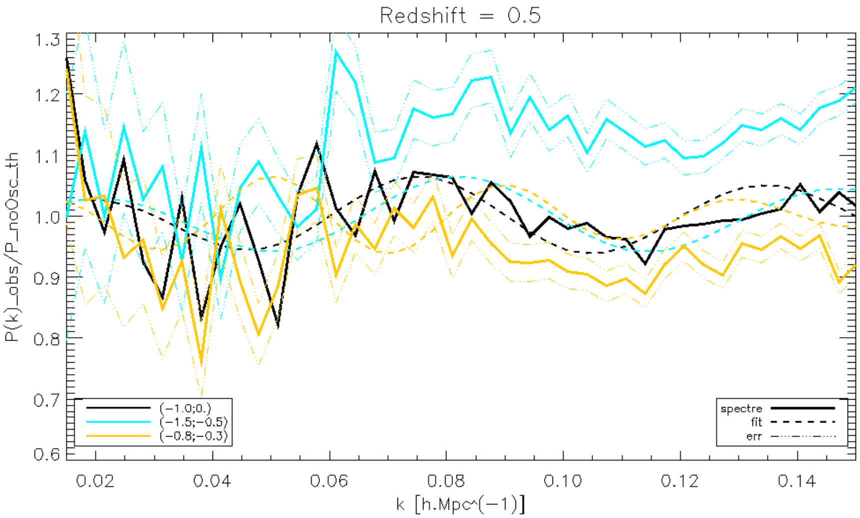
Theoretical case : only the growth factor varies.

Observed power spectra



"Observational" case : cosmology impacts the translation angle → distance, so peak positions are shifted.

Observed power spectra with fits



Fit of k_a

To each value of k_a corresponds a value of D_v which can be computed thanks to the following formula :

$$k_a^{obs} = k_a^{mod} \frac{D_V}{D_V^{mod}}$$

where k_a^{mod} et D_V^{mod} correspond to the values from Planck 2015 measurements (more exactly PLanck 2015+BAO+JLA).

D_V allows to constrain w_0 and w_a because it is linked to these parameters through :

$$D_V(z) = [d_A(z, w_0, w_a)^2 (1+z)^2 \frac{z}{H(z, w_0, w_a)}]^{1/3}$$

with :

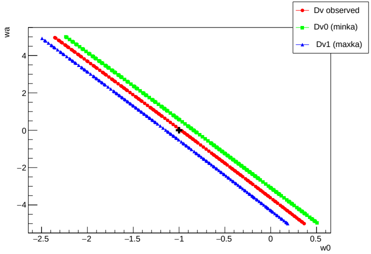
$$d_A(z) = \frac{1}{1+z} \int_0^z H(z')\,\mathrm{d}z'$$

et

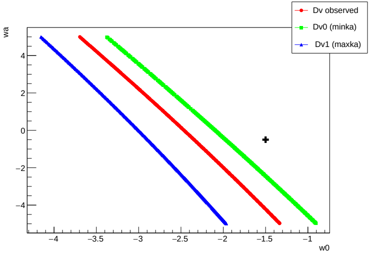
$$H(z) = H_0 \sqrt{\Omega_{m,0}(1+z)^{n_m} + \Omega_{r,0}(1+z)^{n_r} + \Omega_{k,0}(1+z)^{n_k} + \Omega_{\Lambda,0}(1+z)^{n_\Lambda}}$$

where $n_i = 3(1+w_i)$. $w_m = 0$, $w_r = 1/3$, $w_k = -1$ et $w_\Lambda = w_0 + (1-a)w_a$ because I choose the CPL parametrization.

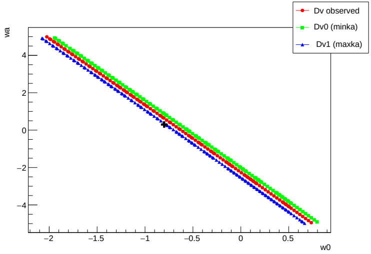
Simple extraction at z=0.5



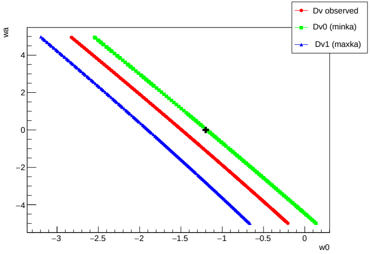
Case (-1 ;0)



Case (-1.5 ;-0.5)

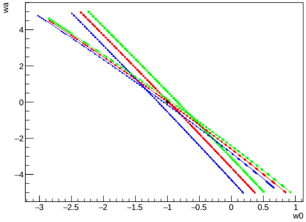


Case (-0.8 ;0.3)

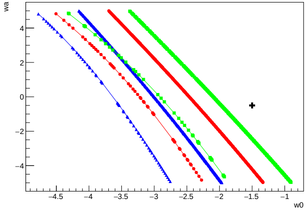


Case (-1.2 ;0.)

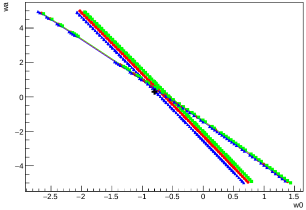
Combined extraction at two redshifts



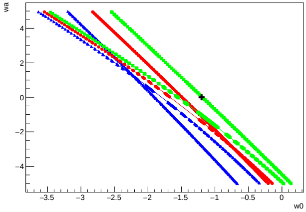
Case (-1 ;0)



Case (-1.5 ;-0.5)



Case (-0.8 ;0.3)



Case (-1.2 ;0.)

Perspectives

Applying this method to power spectra taking errors into account :

- Gaussian errors with $\sigma = 0.03 \times (1 + z)$: in progress
- Photo-Z errors

Content

First steps with CAMEL

Motivations : the simple method presented has some limits :

- the cosmological parameters are assumed to be fixed to the values given by current data.
- only one quantity (D_V) contrains two parameters. Even if the combination of information at different redshifts enables to break the degeneracy, one can reach a better accuracy and reduce the errors by separating the transverse and longitudinal components. This is performed by anisotropic studies.

Improvement - CAMEL :

- CAMEL enables to make a fit with the cosmological parameters being free to vary around some values given by some selected data.
- I have investigated how one can constrain w_0 et w_a by providing the expected value and errors for D_v with LSST.
- The following step would be to work in the frame of an anisotropic analysis and to provide errors on D_a and H in order to constrain the parameters w_0 and w_a with a higher accuracy.

Description of the tested configurations

I added three lines to the list of cosmological parameters in order to take into account the temporal variation of the equation of state parameter.

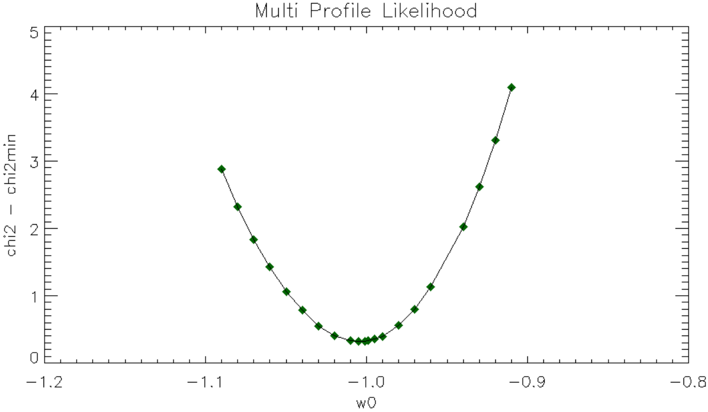
par	Ω_Λ (omega_fld)	cosm	0.7	0.01	0.69	0.71
par	w_0 (w0_fld)	cosm	-1.0	1.0	-2.0	0.
par	w_a (w0_fld)	cosm	0.1	1.0	-0.9	1.1

TABLE : Added input cosmological parameters for CAMEL

3 tested configurations :

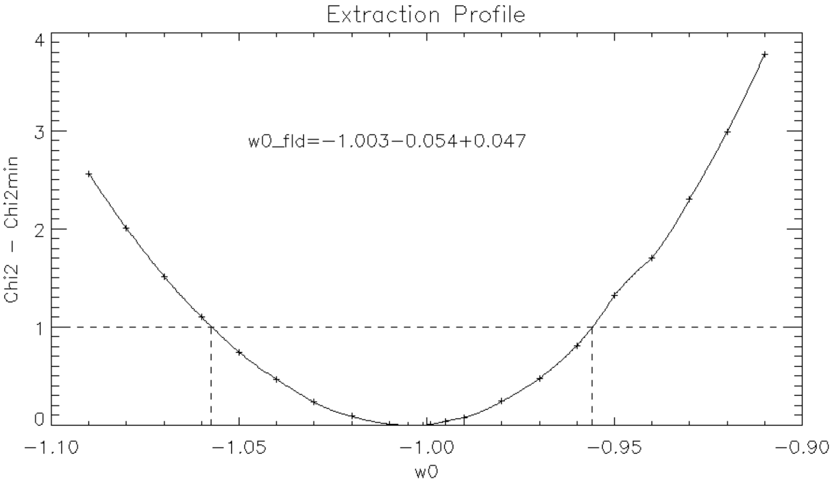
- **BAO1DJLA** contains BAO 1D data from the surveys 6df and BOSS-LOWZ DR11.
- **LSSTSpecJLA** contains "spectroscopic" data from LSST with for value of D_V the one issued from previous simulations in the spectroscopic case (= without error).
- LSSTPhotoJLA contains photometric data from LSST with for value of D_V the one issued from previous simulations in the photometric case, that is to say that the errors have been included so that the redshifts reconstruction is taken into account.

Profile Likelihood - BOSS1D



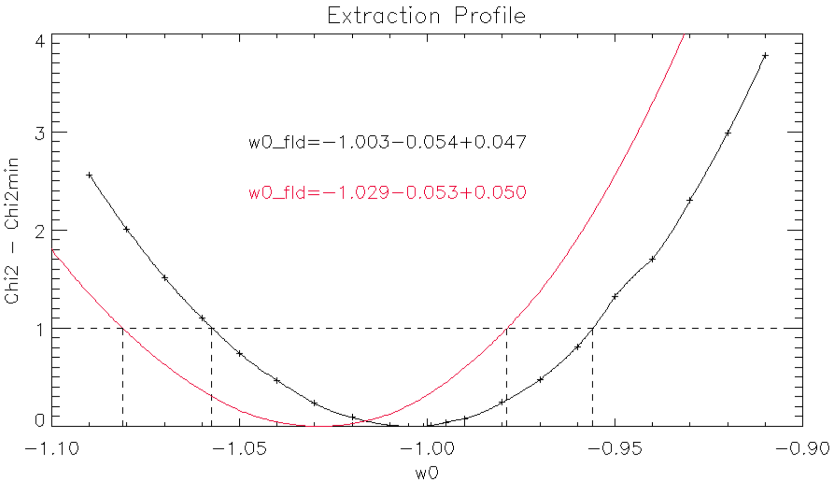
Here, the nuisance parameters are fixed.

Extraction from profile likelihood - BOSS1D



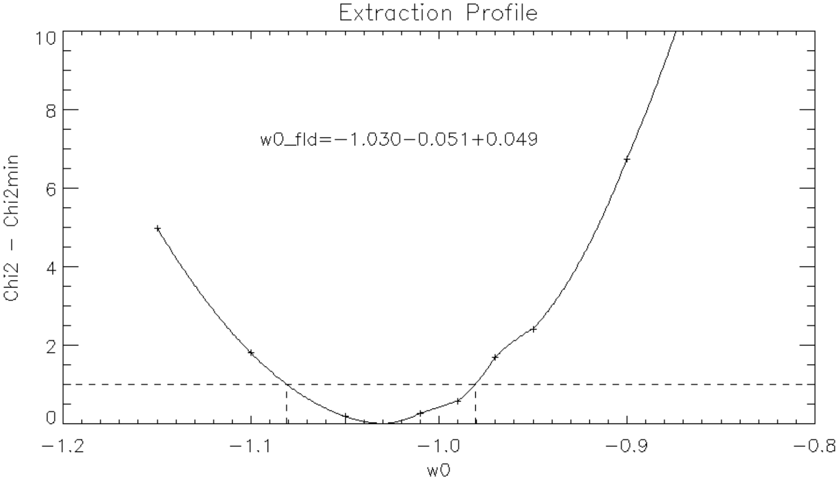
Case BOSS1D with the nuisance parameters being fixed.

Extractions from profile likelihood - BOSS1D



In black : BOSS1D case with the nuisance parameters being fixed. In red : proper BOSS1D case with the nuisance parameters being free to vary.

Extraction from profile likelihood - LSST Spectro



Case LSST Spectro.

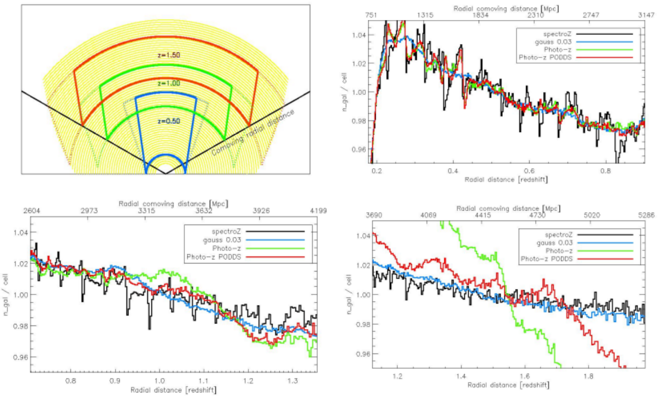
In progress

1. **Likelihood Profiles** :
   - combining the data to see what LSST brings.
   - applying this method to w_a.
2. **Apply the analysis chain to the case** :
   - LSST "photo".

Thanks for your attention !

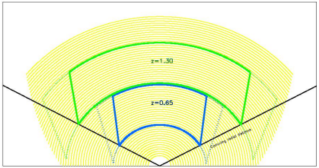
Back-up - Old grids

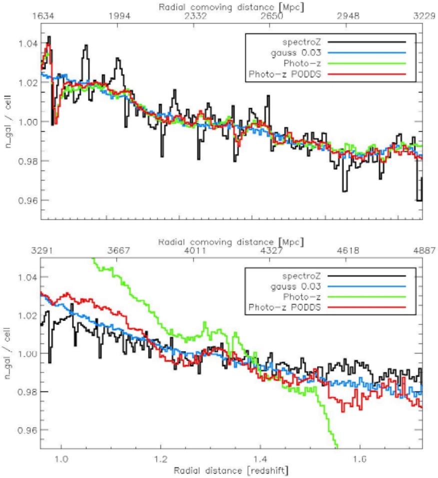
BAO simulations – old grids



z=0.5 et z=1.5: « polluted » area → motivate the use of new grids

New grids





Independant zones very clean
Podds cut : very efficient