Dark Energy Constraints from the ESPRESSO Fundamental Physics GTO

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FUNDAÇÃO CALOUSTE GULBENKIAN

Echelle SPectrograph for Rocky Exoplanet- and Stable Spectroscopic Observations

Parameter/Mode	singleHR (1 UT)	multiMR (up to 4 UTs)	singleUHR (1 UT)
Wavelength range	380–780 nm	380–780 nm	380–780 nm
Resolving power	134 000	59 000	225 000
Aperture on sky	1.0 arcsec	4 × 1.0 arcsec	0.5 arcsec
Spectral sampling (average)	4.5 pixels	5.5 pixels (binned × 2)	2.5 pixels
Spatial sampling per slice	9.0 (4.5) pixels	5.5 pixels (binned × 4)	5.0 pixels
Simultaneous reference	Yes (no sky)	Yes (no sky)	Yes (no sky)
Sky subtraction	Yes (no simul. ref.)	Yes (no simul. ref.)	Yes (no simul. ref.)
Total efficiency	11 %	11 %	5 %
Instrumental RV precision	< 10 cm s^{-1}	~ 1 m s^{-1}	< 10 cm s^{-1}

F. Pepe et al., 2013, The Messenger, 153, 6

80% Rocky Planets, 10% Varying Constants, 10% to be decided: ToO + Exquisite Science

First Light: End of this year!

α measurements from absorption systems in Quasar Spectra

Quasar Absortion Spectrum: Powerfull Science Labs

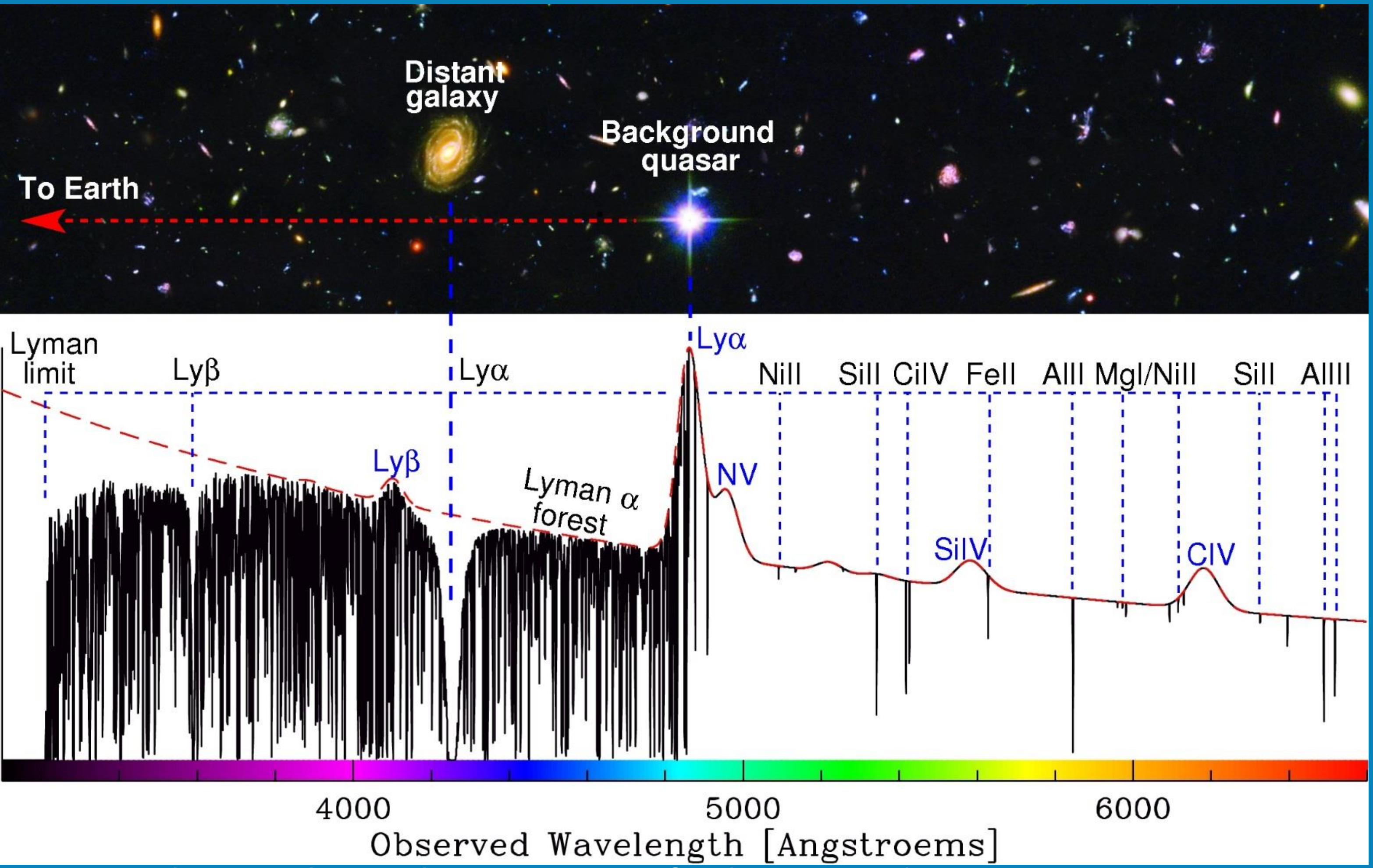
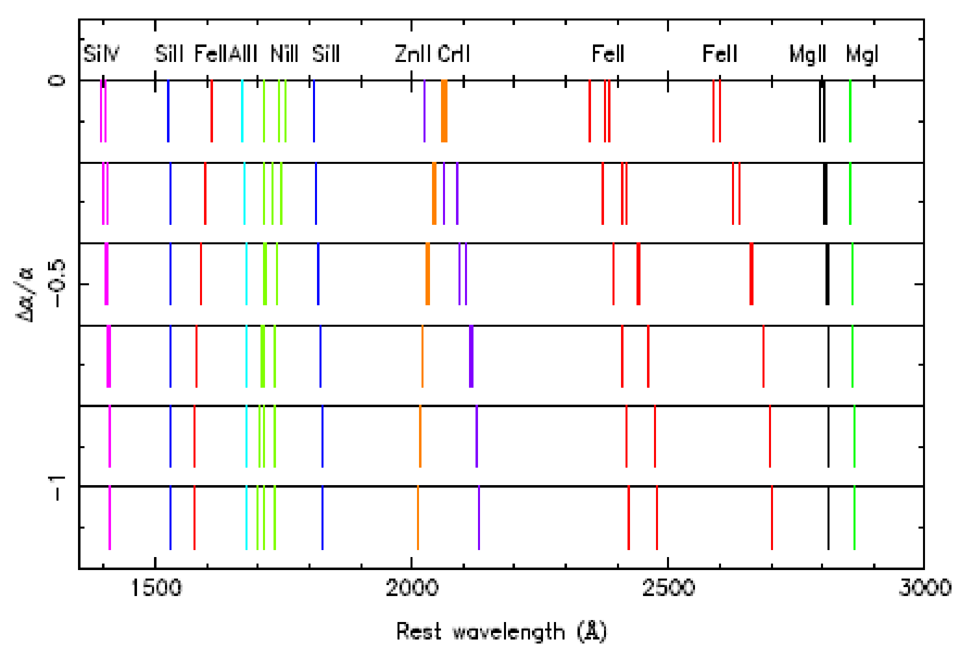


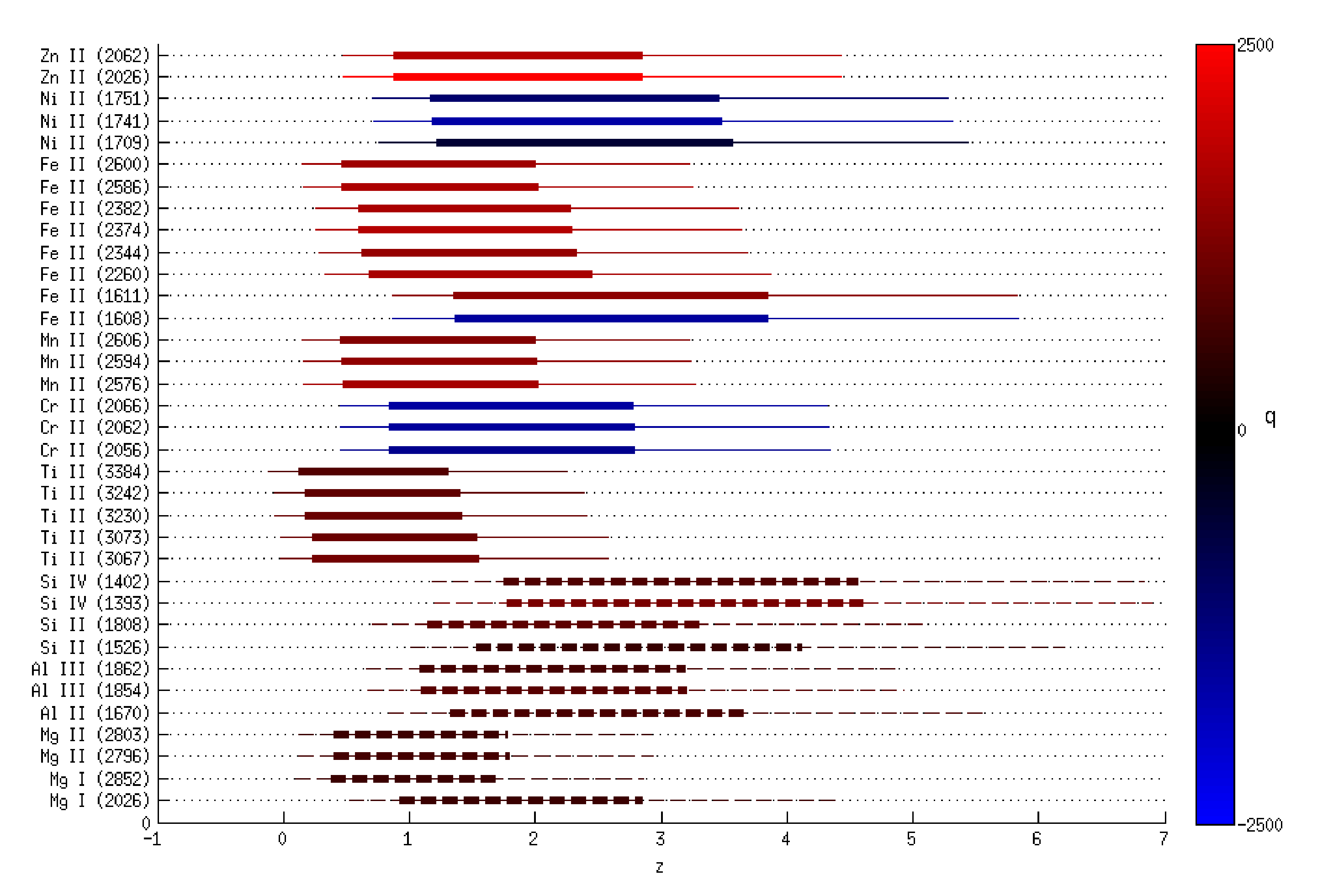
Image: Michael Murphy, Swinburne University of Technology, Melbourne, Australia

King (PhD thesis) 2011



- μ - H_2, HD, CO molecules
- $T_{CMB}(z)$ - CO, CN

Target Selection for ESPRESSO



Wavelength range: 380 – 780 nm

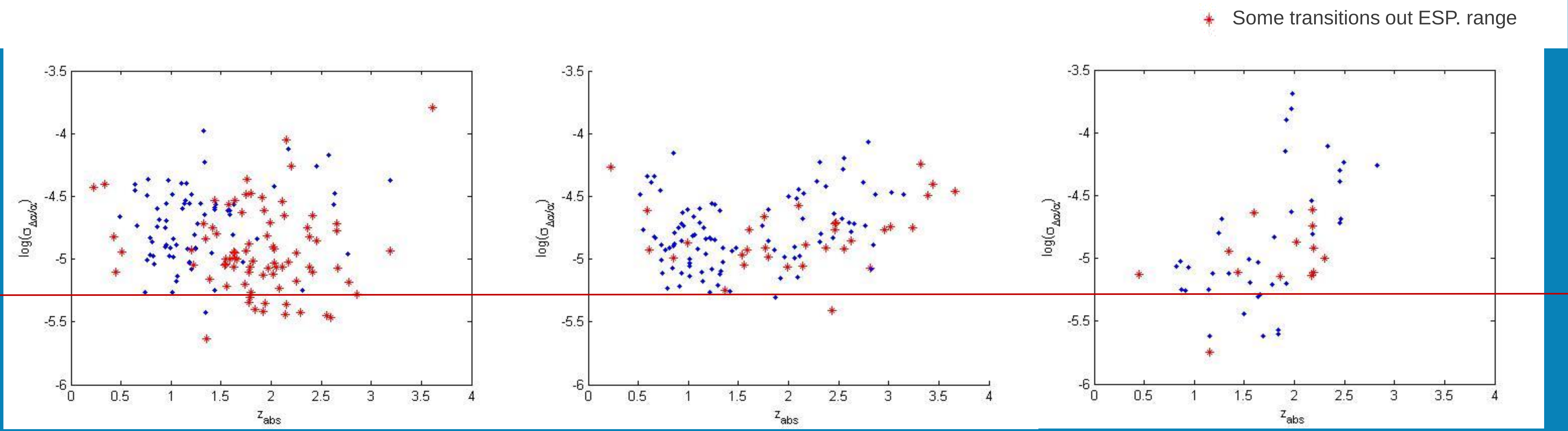
Priority Sistems:

- Uncertainty lower than 10ppm
- Measurements with anchors and sensitivity transitions (Δq)
- Brighteness
- Sky position
- Simplicity of the spectra

14 QSO targets have been identified as priority for the Garanteed Time of Observation

ESPRESSO wavelength range targets z∼2

From the Whole Sample to the Best Targets



UVES/VLT

King's Ph.D. Thesis (2012)

KECK-HIRES

Murphy's Ph.D. Thesis (2002)

Dedicated Measurements

Chand et al. (2004) correction from Murphy et al. (2008)
Chand et al. (2006),
Bonifacio et al. (2014),
Levshakov et al. (2007),
Molaro et al. (2008),
Evans et al. (2014)

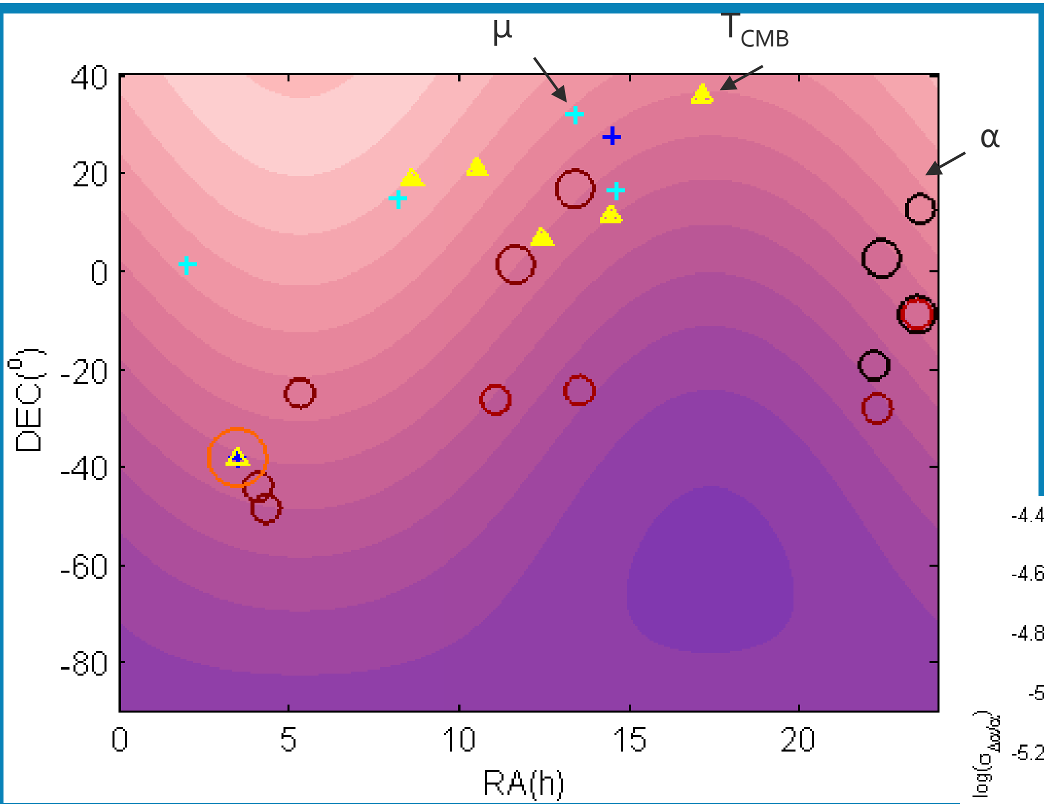
Criteria of selection:

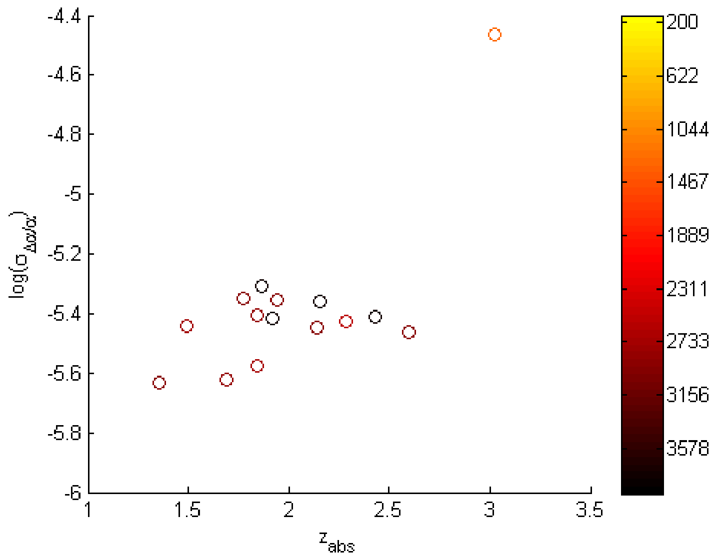
- **Dec<30°**
- $\boldsymbol{\sigma < 5ppm}$
- $\boldsymbol{\Delta q \geq 2000}$

UVES - Ultraviolet and Visual Echelle Spectrograph
HIRES - High Resolution Echelle Spectrometer

Target List – ESPRESSO's GTO

Name	z_{abs}	M	$\frac{\Delta\alpha}{\alpha}$ (10^{-6})	$\sigma_{\frac{\Delta\alpha}{\alpha}}(10^{-6})$	μ	T
J034943-381031	3.02	17.3	-27.9	34.2	x	x
J040718-441013	2.59	17.3	5.7	3.4*	x'	
J043037-485523	1.35	16.5	-4.0	2.3*		
J053007-250329	2.14	18.8	6.7	3.5*	x'	
J110325-264515	1.84	15.9	6.1	3.9*		
J110325-264515	1.84	15.9	5.6	2.6		
J115944+011206	1.94	17.5	5.1	4.4*		
J133335+164903	1.77	16.7	8.4	4.4		
HE1347-2457	1.43	16.3	-21.3	3.6		
J220852-194359	1.92	17.0	8.5	3.8		
HE2217-2818	1.69	16.0	1.3	2.4		
Q2230+0232	1.86	18.0	-9.9	4.9		
J233446-090812	2.15	18.0	5.2	4.3*		
J233446-090812	2.28	18.0	7.5	3.7*		
Q2343+1232	2.43	17.5	-12.2	3.8*		





Fine Structure Constant and Dark Energy

Coupling between the scalar field and the electromagnetism

$$\mathcal{L}_{\phi F} = -\frac{1}{4} B_F(\phi)\, F_{\mu\nu}F^{\mu\nu}$$

Gauge kinetic function is linear

$$B_F(\phi) = 1 - \zeta k\,(\phi - \phi_0)$$

$$\frac{\Delta\alpha}{\alpha} \equiv \frac{\alpha - \alpha_0}{\alpha} = \zeta\, k(\phi - \phi_0)$$

For a flat Friedmann-Lemaître-Robertson-Walker Universe with a canonical scalar field

$$\dot{\phi}^2 = \left(1 + \omega(z)\right)\rho_\phi$$

$$\phi(z) - \phi_0 = \frac{\sqrt{3}}{k}\int_0^z \sqrt{1 + w(z)}\left(1 + \frac{\rho_m}{\rho_\phi}\right)^{-1/2} \frac{dz}{1+z}$$

Principal Component Analyses to Constraining Dark Energy

Principal Component Analysis (PCA)
Observable → Likelihood → Fisher matrix → reconstruction of w(z)

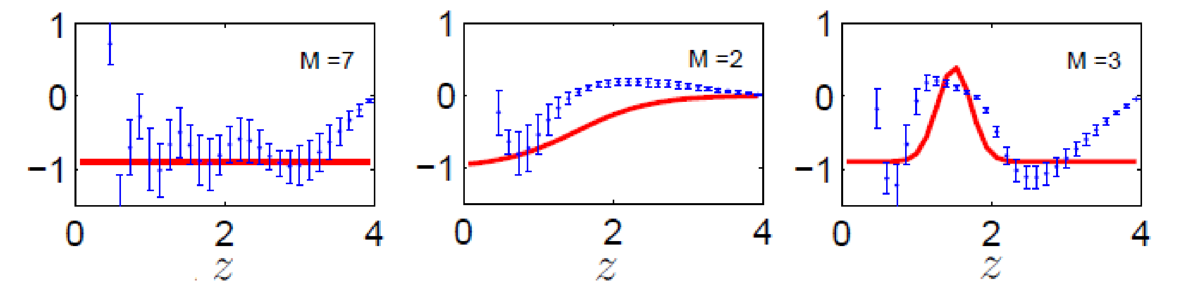
- Type Ia Supernova data
- Spectroscopic α measurements

In previous work - Amendola et al. 2012; Leite et al. 2014; Leite & Martins 2015;

- Dark energy constraints improve when we combine the Supernova datasets with α measurements
- ESPRESSO and ELT α measurements allow to reconstruct the equation of state to higher redshift
- Larger redshift coverage is generally better than a bigger number of measurements
- Future Supernovas Surveys will improve the constrains as well.

- Fiducial forms

$$w(z) = -0.9$$
$$w_F(z) = -0.5 + 0.5\tanh(z - 1.5)$$
$$w_F(z) = -0.9 + 1.3\exp(-(z-1.5)^2/0.1)$$



ESPRESSO 14 targets for GTO

Name	z_{abs}	M
J034943-381031	3.02	17.3
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J043037-485523	1.35	16.5
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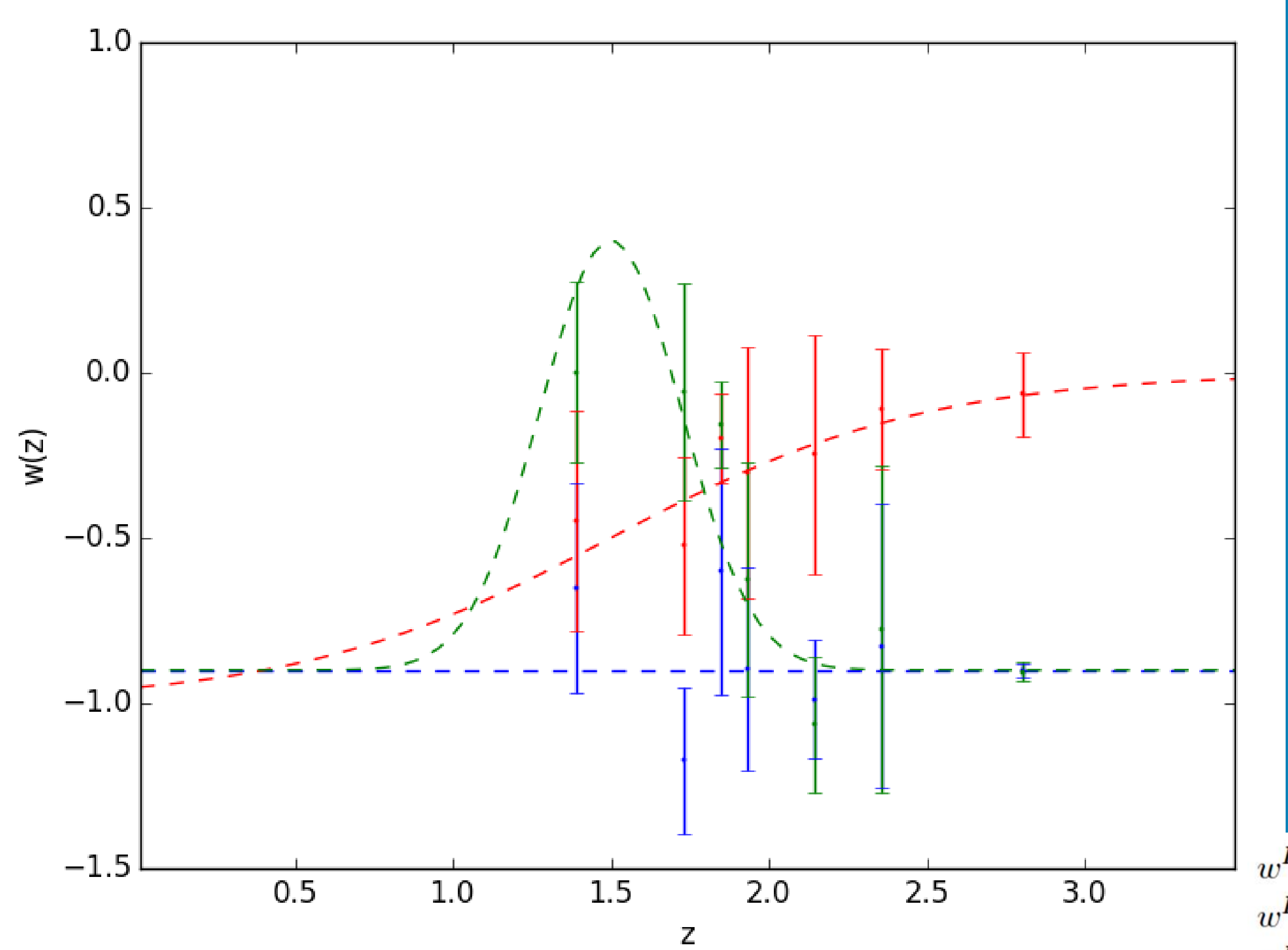


Baseline - $\sigma_{\Delta\alpha/\alpha} = 6 \times 10^{-7}$

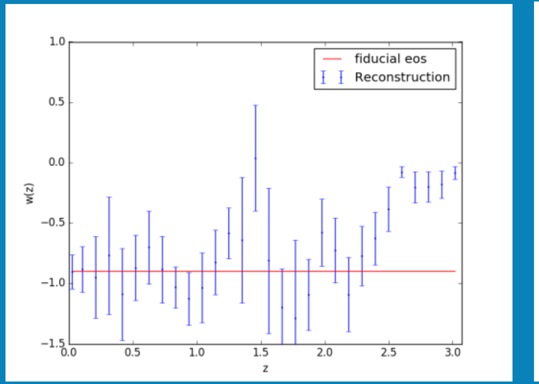
Ideal - $\sigma_{\Delta\alpha/\alpha} = 2\times10^{-7}$

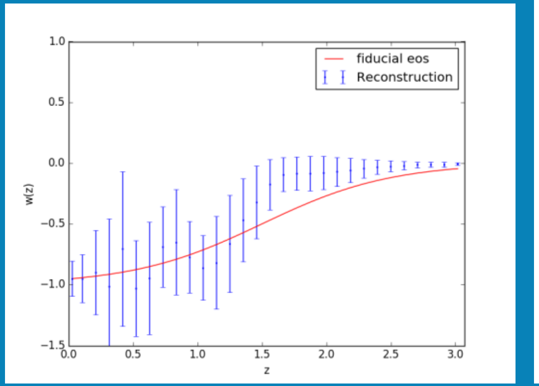
$$
\begin{aligned}
w^F(z) &= -0.9, \\
w^F(z) &= -0.5 + 0.5\tanh(z - 1.5), \\
w^F(z) &= -0.9 + 1.3\exp\left(-(z-1.5)^2/0.1\right)
\end{aligned}
$$

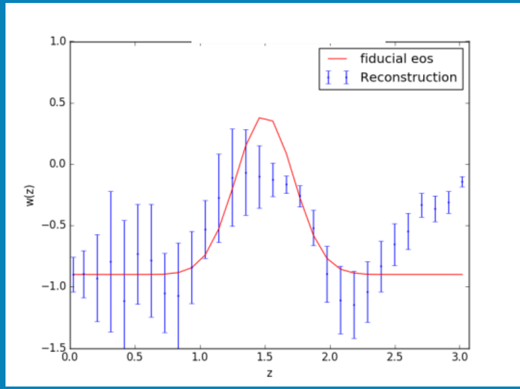
Future Sna Ia Surveys + GTO ESPRESSO

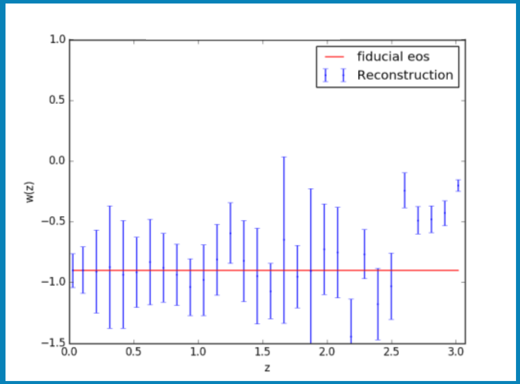
- **LOW (SNAP)** - 3000 SN - z: 0 - 1.7
- **MID (EUCLID)** - 1700 SN - z: 0.75 - 1.5

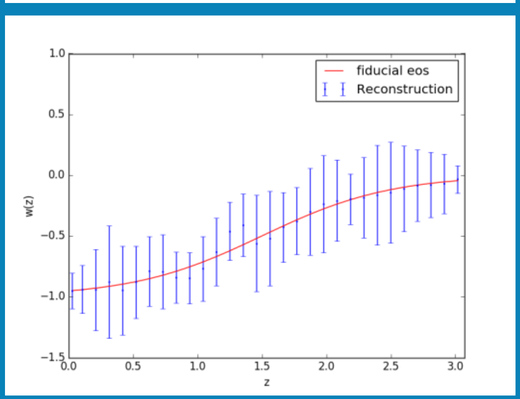
$\sigma_m = 0.11$

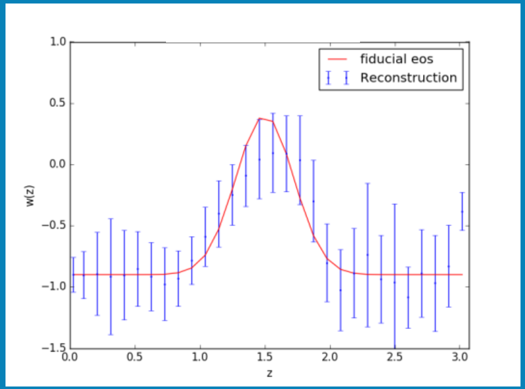












Number of modes under 0.3

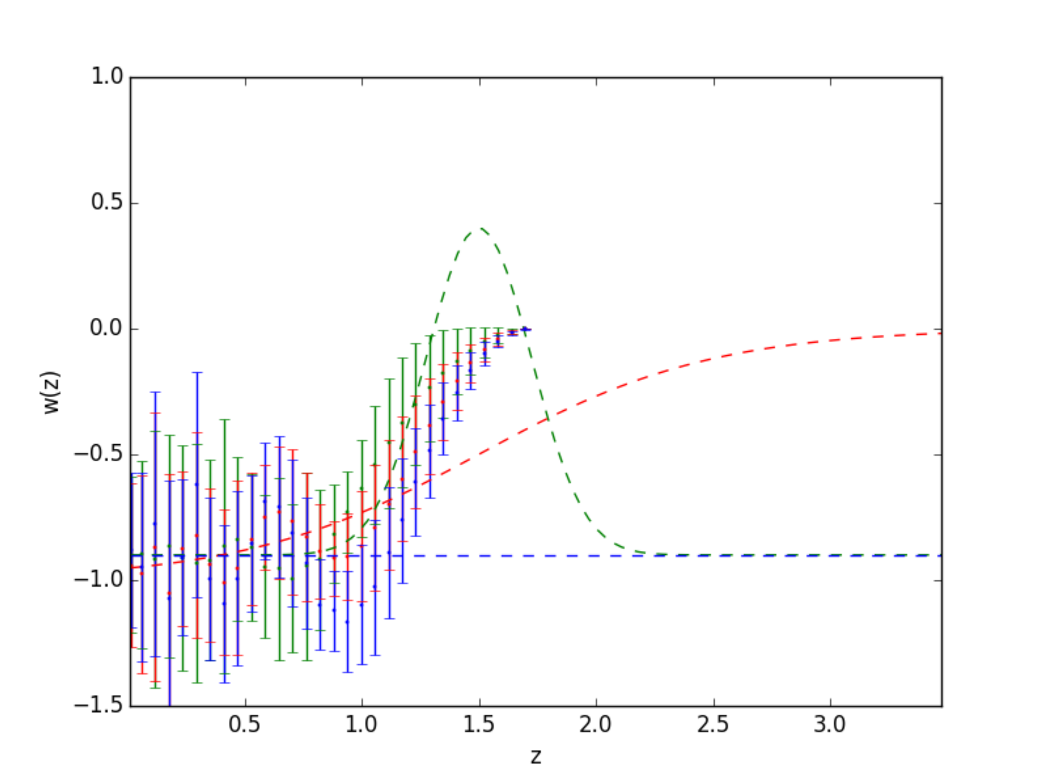
- **Baseline** uncertanty for GTO measurements

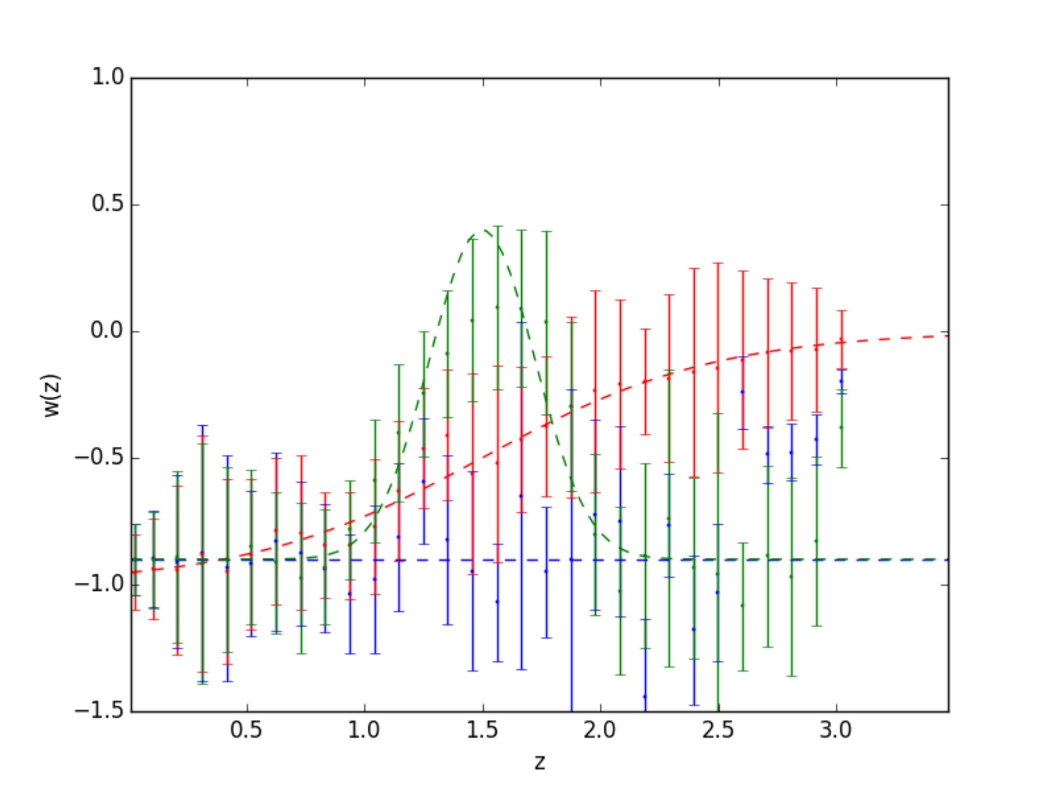
	constant	step	bump
GTO	1	-	1
GTO + SNAP	4	4	4
GTO + SNAP + Euclid	4	4	5

- **Ideal** uncertanty for GTO measurements

	constant	step	bump
GTO	3	1	2
GTO + SNAP	9	4	5
GTO + SNAP + Euclid	9	4	6

Future Sna Ia Surveys + GTO ESPRESSO





Conclusions and Future Work

- A list of targets was put together for the ESPRESSO GTO's needs
- Selection of target(s) for the UHR mode and testing the gains for the GTO (simulations)
- Sn Ia surveys are limited (for now) to $z \sim 1.7$
- The higher redshift coverage of α measurements will bring additional constraints for Dark Energy
- The target list for ESPRESSO GTO can start to distinguish between models
- ESPRESSO GTO + SN Ia will be able to parametrize w and put competitive constraints on Dark Energy

Thank you for your attention