Testing the stability of fundamental couplings with ESPRESSO

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In Colaboration with:

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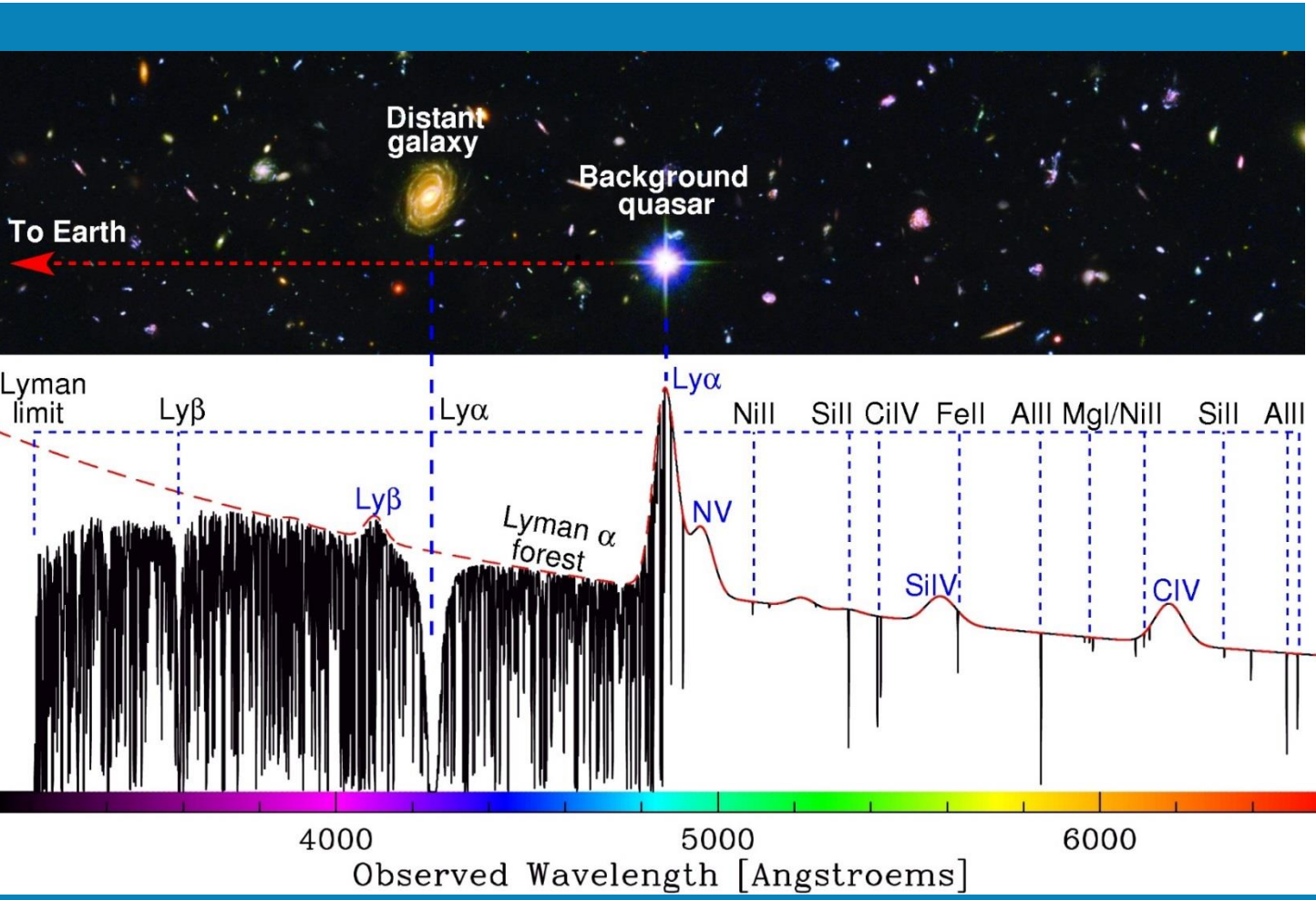
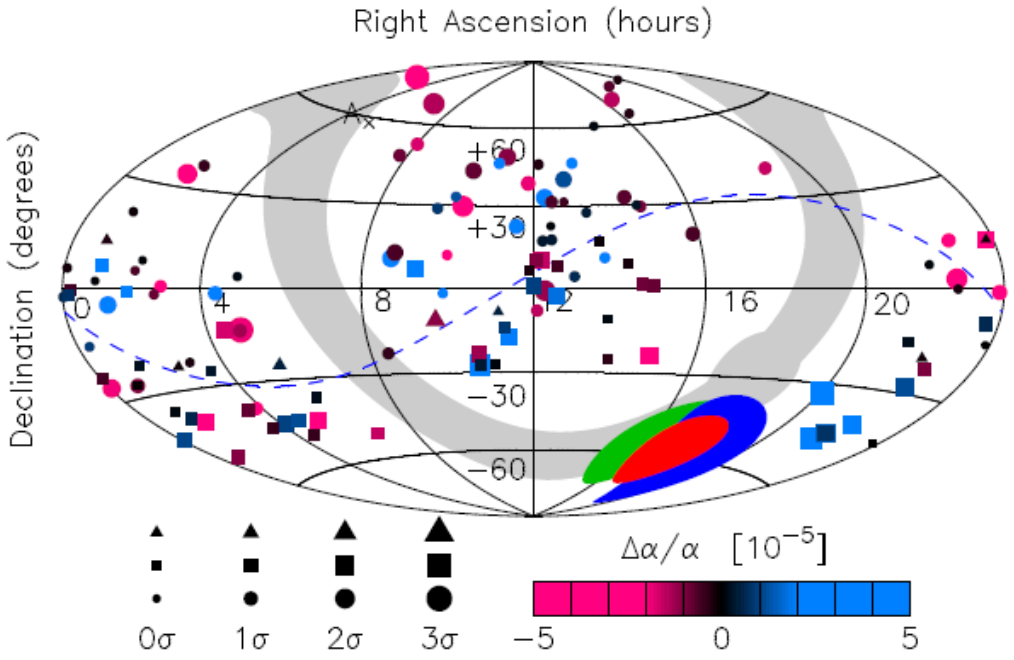
- Paolo Molaro – INAF-OATS

Testing Fine Structure Constant in the Sky





Webb et al. 2011

UVES/VLT and KECK-HIRES archival data

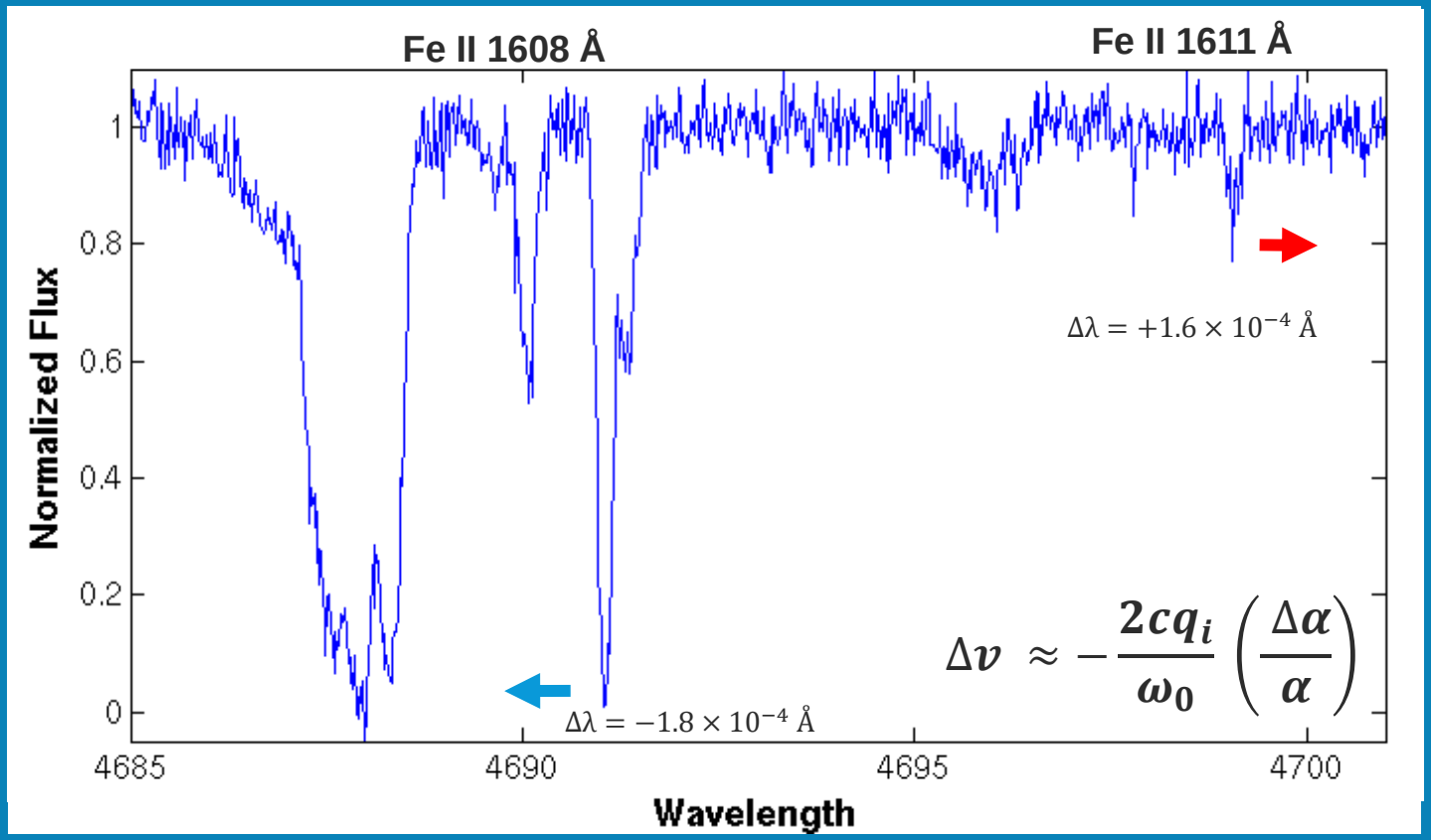
$$\alpha \equiv \frac{e^2}{\hbar c} \sim \frac{1}{137} \qquad \frac{\Delta\alpha}{\alpha} \equiv \frac{\alpha - \alpha_0}{\alpha}$$

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

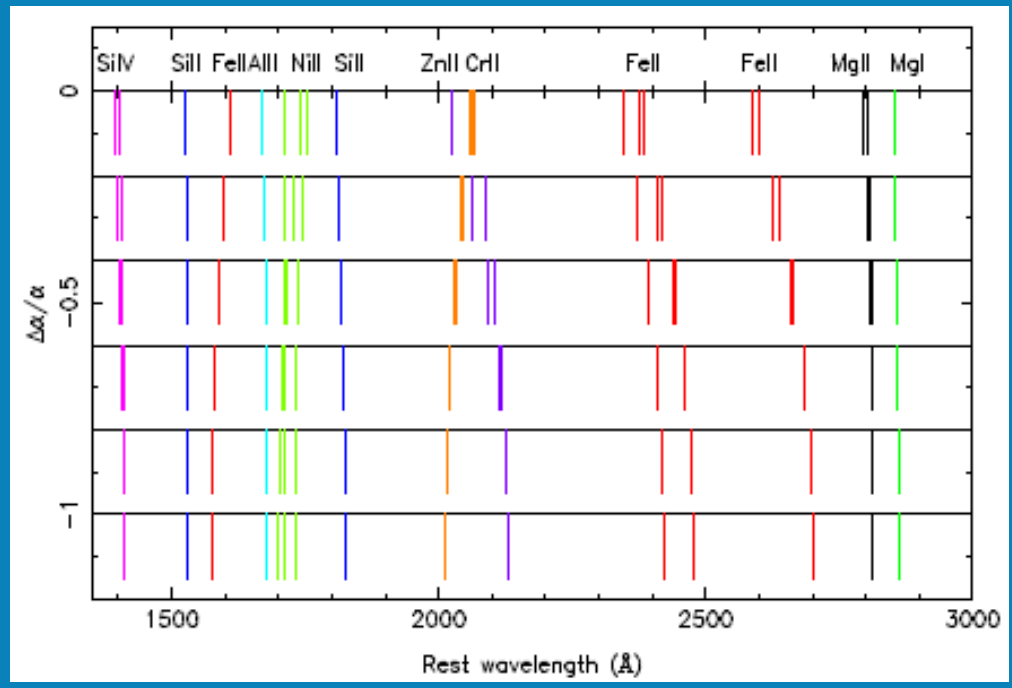
How to Measure α?

Arifitial spectra based on a real system:

$z{\sim}2$ artificial cloud for an $\Delta\alpha/\alpha = 10^{-6}$

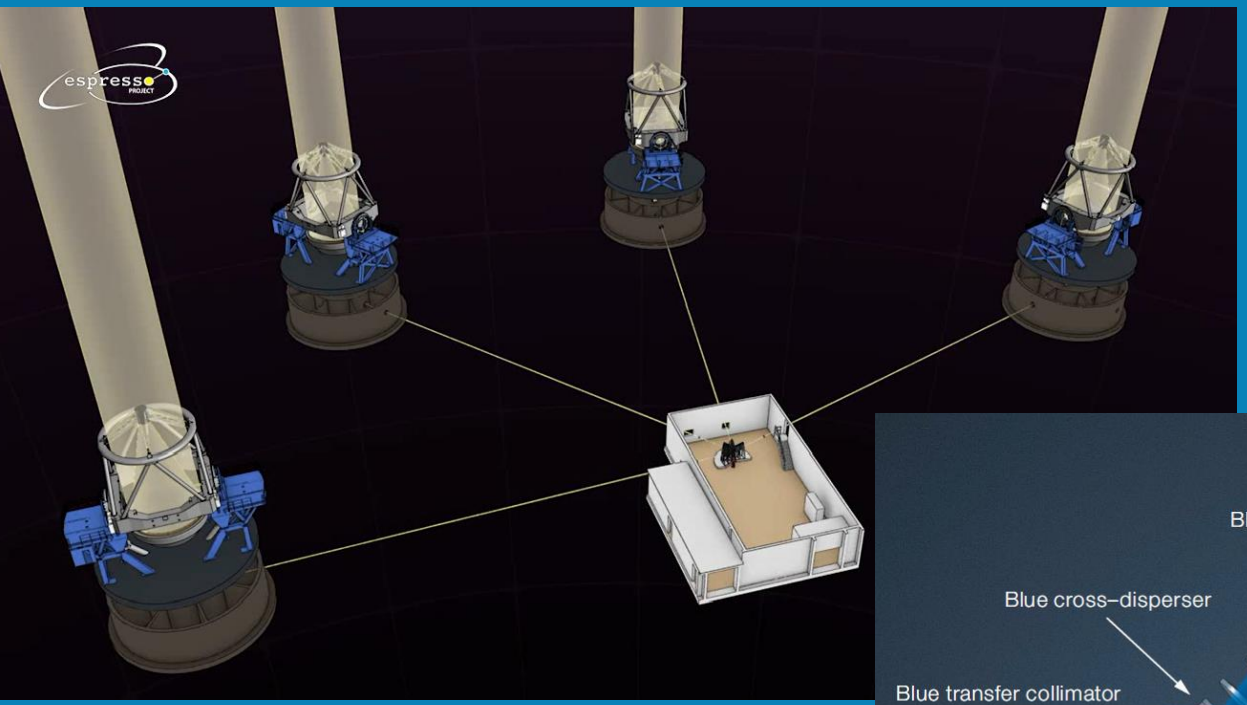


King (PhD thesis) 2011



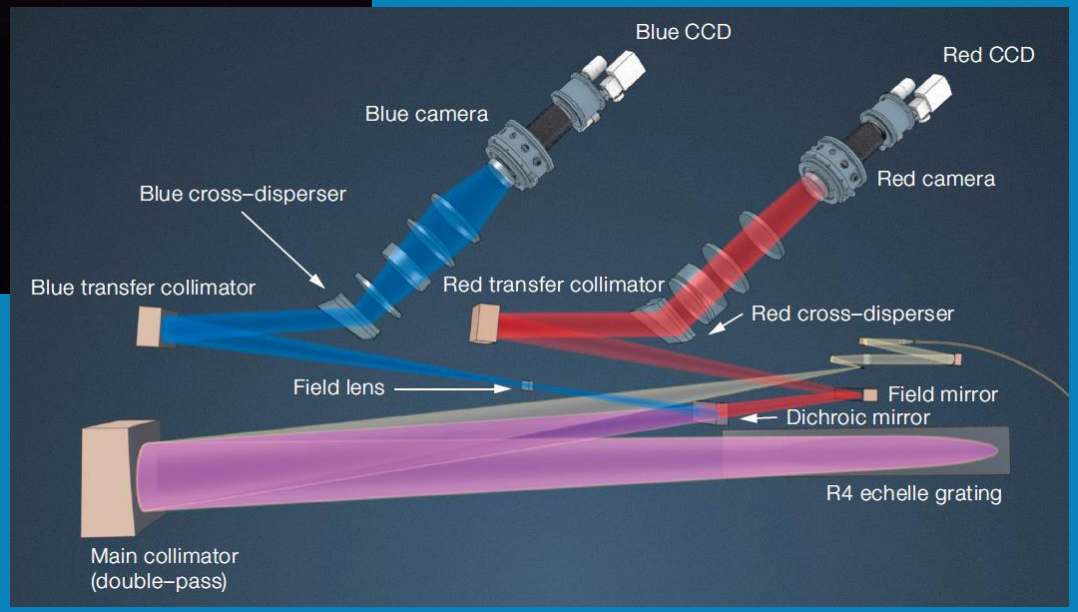
- blue shifters
- redshifters
- anchors

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}

Pepe et al., 2013, The Mensenger 153, 6



High resolution and stability (Laser Frequency Comb)

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

~27 nights to test variation of constants

espresso

GTO Target List and ESPRESSO's Modes

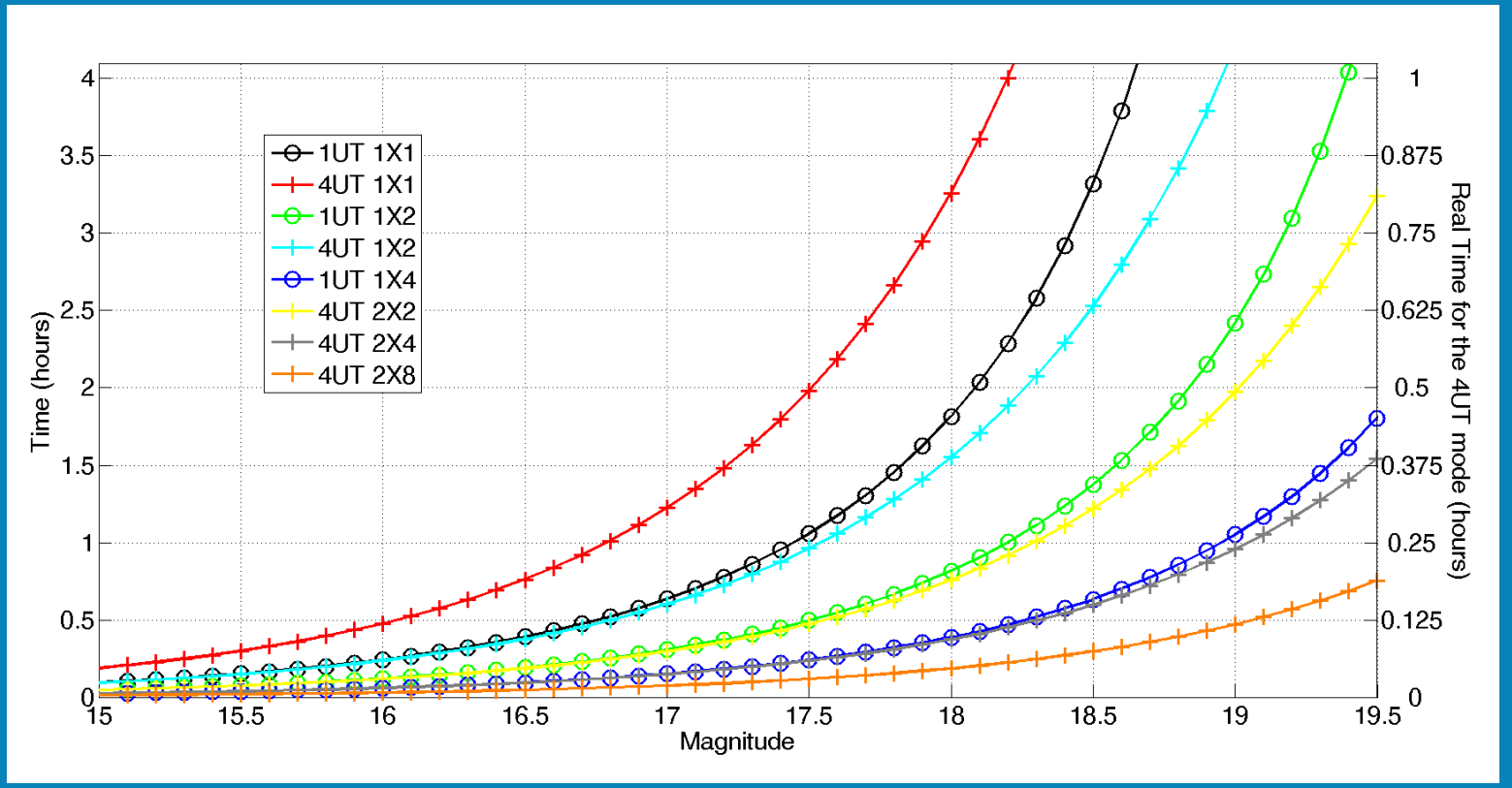
GTO – Garanteed Time of Observation

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*		

Leite et. al. 2016, Phys. Rev. D 94, 123512

$\sigma_{\Delta\alpha/\alpha} = 0.6 \times 10^{-6}$ (per target)

Photon vs Instrumental **Noise**



1 Hour Exposure
Limiting **M= 17.4**

Constrains on Cosmological Models

Dinamic Dark Energy

The scalar field that responsible for dark energy leads to a varying α

$$\frac{\Delta\alpha}{\alpha}(z) = \zeta \int_0^z \sqrt{3\Omega_\phi(z')\left[1 + w_\phi(z')\right]}\,\frac{dz'}{1+z'}$$

$\zeta_{fid} = 0$

Model	ESPRESSO baseline	ESPRESSO ideal	ELT-HIRES
$w_0 = const.$	4.6×10^{-7}	1.5×10^{-7}	7.6×10^{-8}
Dilaton	3.2×10^{-7}	1.1×10^{-7}	5.3×10^{-8}
CPL	3.1×10^{-7}	1.0×10^{-7}	5.1×10^{-8}
η	2.1×10^{-16}	2.3×10^{-17}	5.8×10^{-18}

ESP. Baseline $\sigma_{\Delta\alpha/\alpha} = 0.6 \times 10^{-6}$

ESP. Ideal $\sigma_{\Delta\alpha/\alpha} = 0.2 \times 10^{-6}$

ELT-HIRES $\sigma_{\Delta\alpha/\alpha} = 1.0 \times 10^{-7}$

Phy. Lett. B, 770, 93: C. S. Alves, T. A. Silva, C. J. A. P. Martins, A. C. O. Leite, 2017

Conclusion

- ESPRESSO is comming soon - enabling higher resolution and stability observations
- It will be able to control the known systematics identified on these measurements – Probe or disprove the Dipole
- The target list for ESPRESSO GTO can constrain cosmological models
- Competitive constrains on Eötvös parameter

Thank you for your attention