VILA DO CONDE,
PORTUGAL,
29-31 MARCH, 2016

11th Iberian Cosmology Meeting

IBERICOS 2016

SOC **ANA ACHÚCARRO** (LEIDEN/BILBAO), **FERNANDO ATRIO-BARANDELA** (SALAMANCA), **MAR BASTERO-GIL** (GRANADA), **JUAN GARCIA--BELLIDO** (MADRID), **RUTH LAZKOZ** (BILBAO), **CARLOS MARTINS** (PORTO), **JOSÉ PEDRO MIMOSO** (LISBON), **DAVID MOTA** (OSLO)

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SERIES OF MEETINGS WHICH AIM TO ENCOURAGE INTERACTIONS AND COLLABORATIONS BETWEEN RESEARCHERS WORKING IN COSMOLOGY AND RELATED AREAS IN PORTUGAL AND SPAIN.

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Measuring BAO at redshift $z \sim 10$

Fernando Atrio-Barandela.
Departamento de Física Fundamental.
Universidad de Salamanca.
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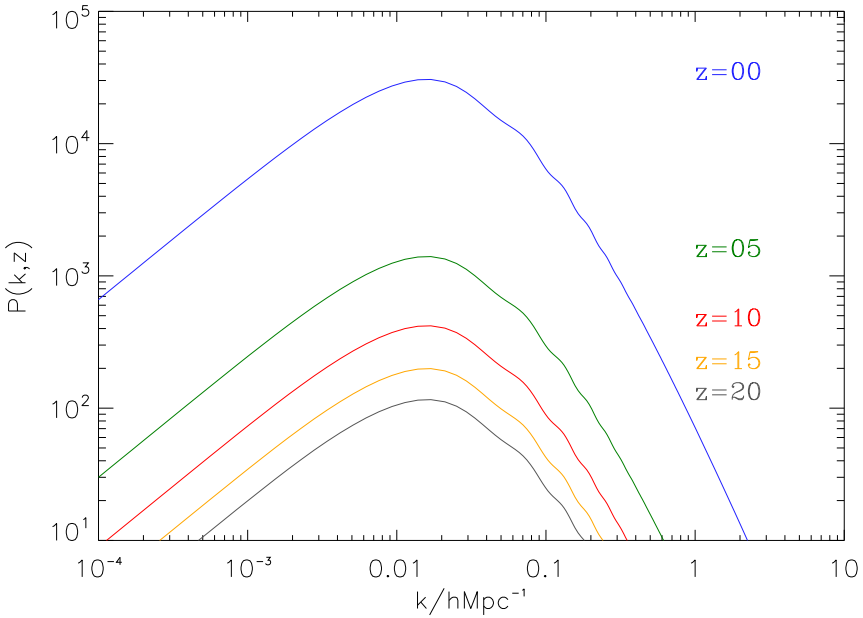
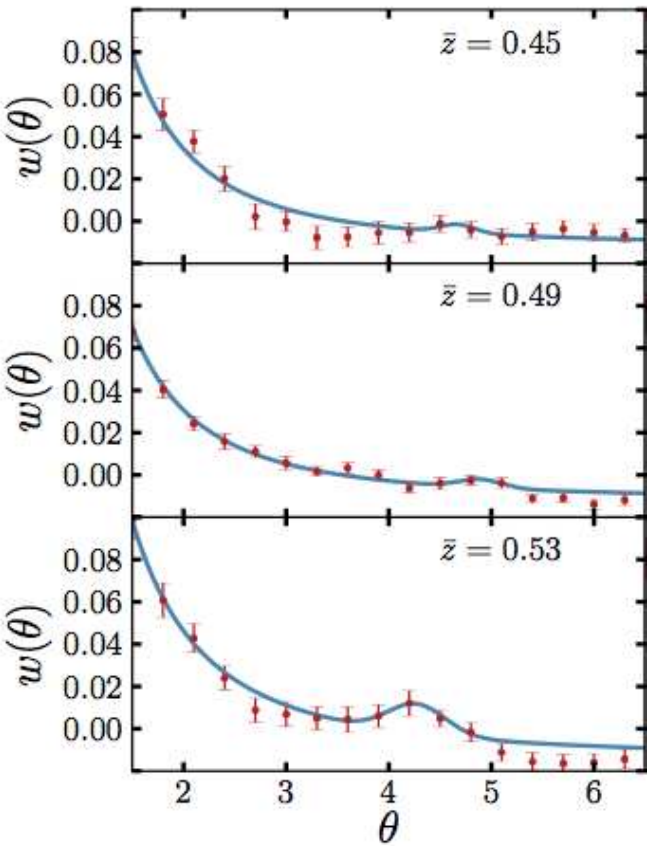
Atrio-Barandela & Kashlinsky (2014) ApJL, 797, L26

Kashlinsky, Arendt, Atrio-Barandela & Helgason (2015) ApJL, 813, L12

What are Baryon Accoustic Ocillations (BAOs)?





Above: Matter power spectrum at different redshifts.
Right: 2-point angular correlation fucntion from SDSS DR10 (from Carvalho et al 2015).

The Idea.

• Hypothesis: The light emitted by the first sources at the end of the dark ages ($z \sim 10$) will be distributed in halos that will reflect the underlying inhomogeneities of the matter density field.

• Idea: Identifying the fluctuations of this first light will give us a probe of the matter power spectrum at the redshift of reionization ($z \sim 10$).

• Goal: BAOs will provide a standard rule to measure angular diameter distances to the epoch of reionization.

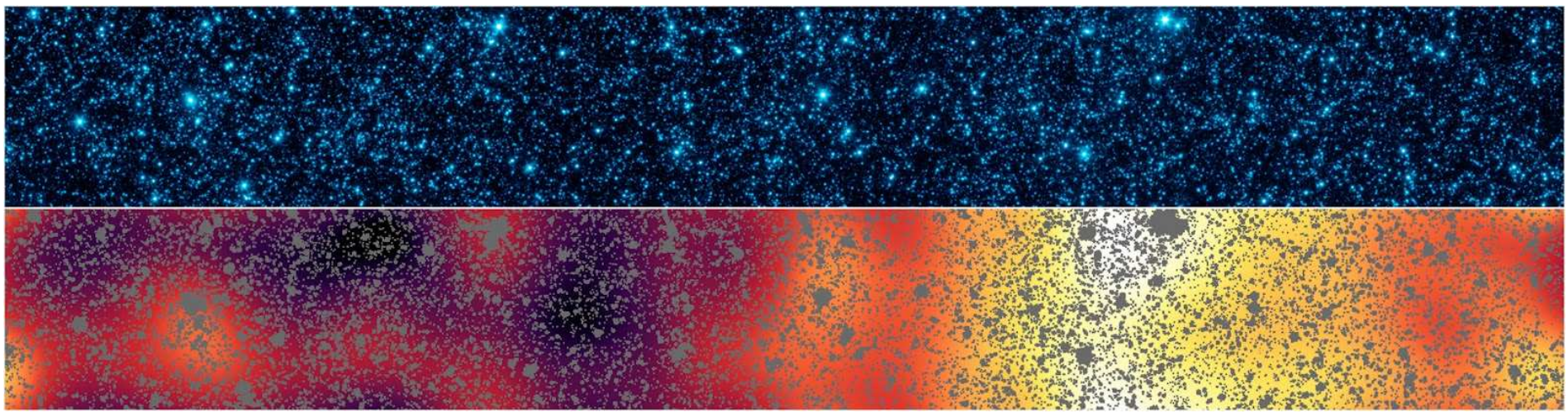
Where is the light of the first sources?

• The spectral energy distribution of sources at high z exhibits a cutoff at energies above the Lyman limit. In the presence of significant amounts of neutral hydrogen (H I) such cutoff would lie at the Ly-α transition at 10.2 eV (0.122 μm), while if the surrounding hydrogen were ionized the cutoff would be the Ly-continuum of 13.6eV (0.0912 μm).

Photon energy	1+z	μm
Ly-continuum (13.6eV)	10	0.9
	15	1.4
Ly-α (10.2eV)	10	1.2
	15	1.8

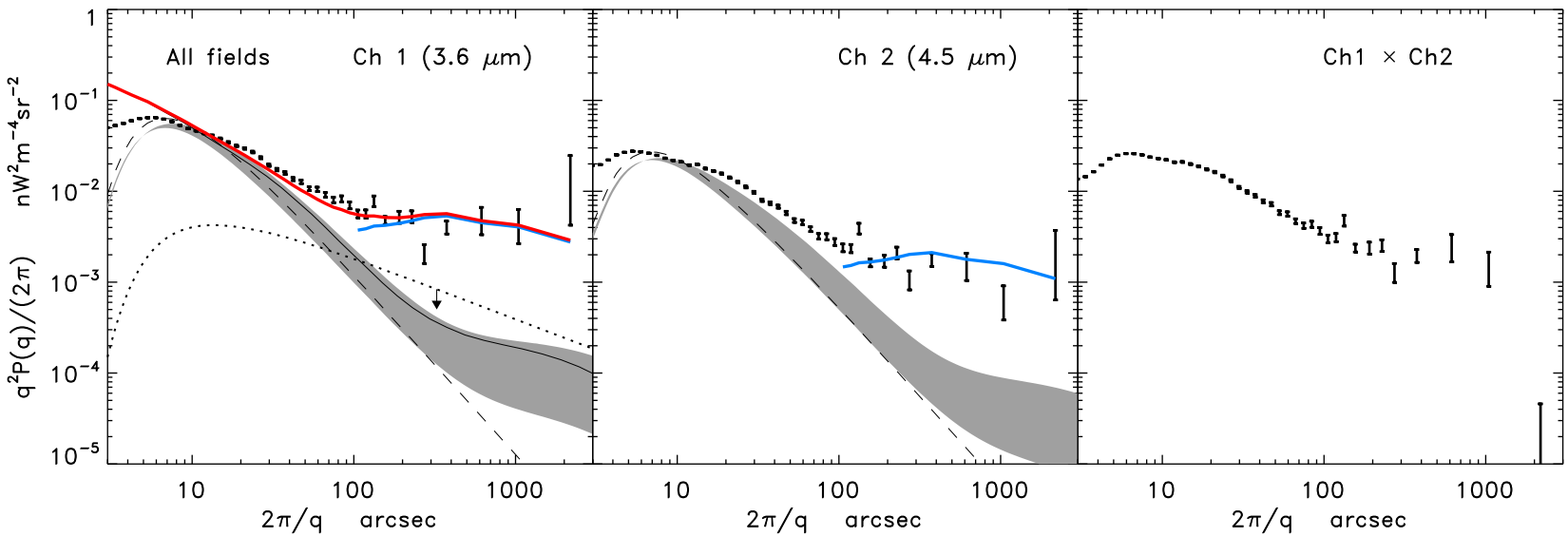
The light emitted by the first sources would fall in the Near Infrared (NIR)

Cosmic Infrared Background Fluctuations.



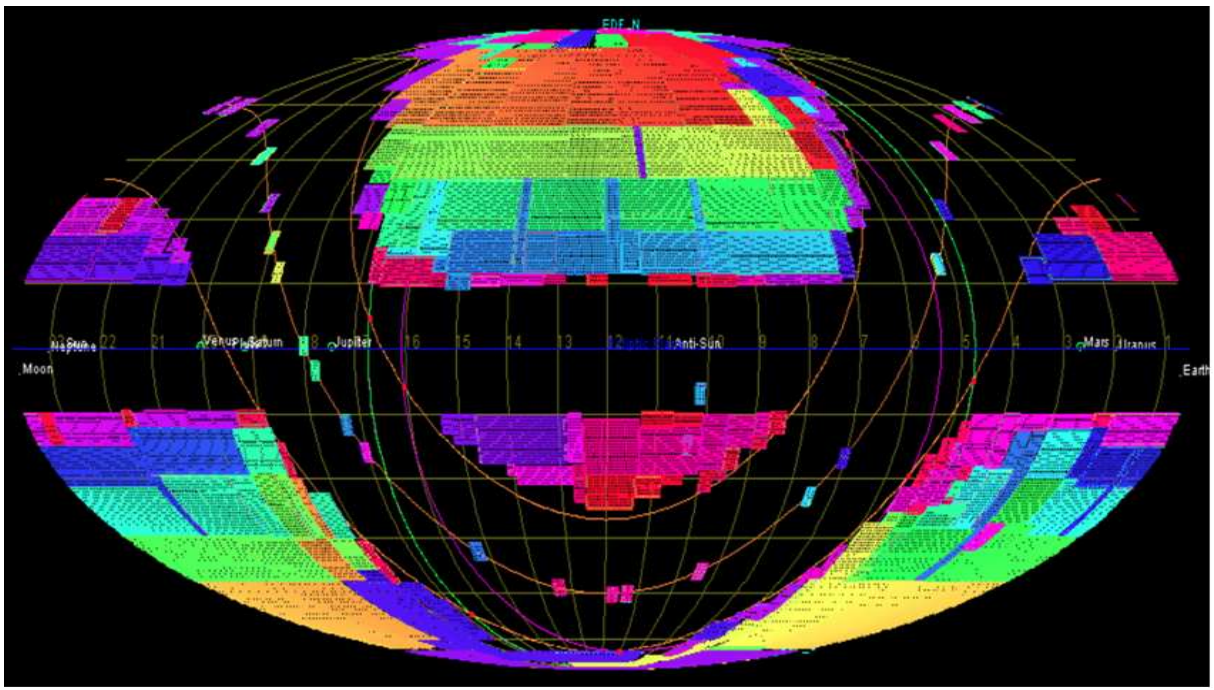
Top: Spitzer field at 3.6μm. Bottom: residual large scale background fluctuations after subtracting all known sources (Kashlinsky et al 2012).

Testing the High-z Origin of the CIB: Data.



Spitzer Field-averaged CIB fluctuations at 3.6μm (left), 4.5μm (middle) and cross power (right). Black line: remaining known galaxies; shaded area: CIB fluctuations from the remaining known galaxies; dashed line: shot-noise contribution; blue line: high-z ΛCDM contribution; red line: sum of Shot-Noise, known galaxies and high-z galaxy population from ΛCDM (from Kashlinsky et al 2012).

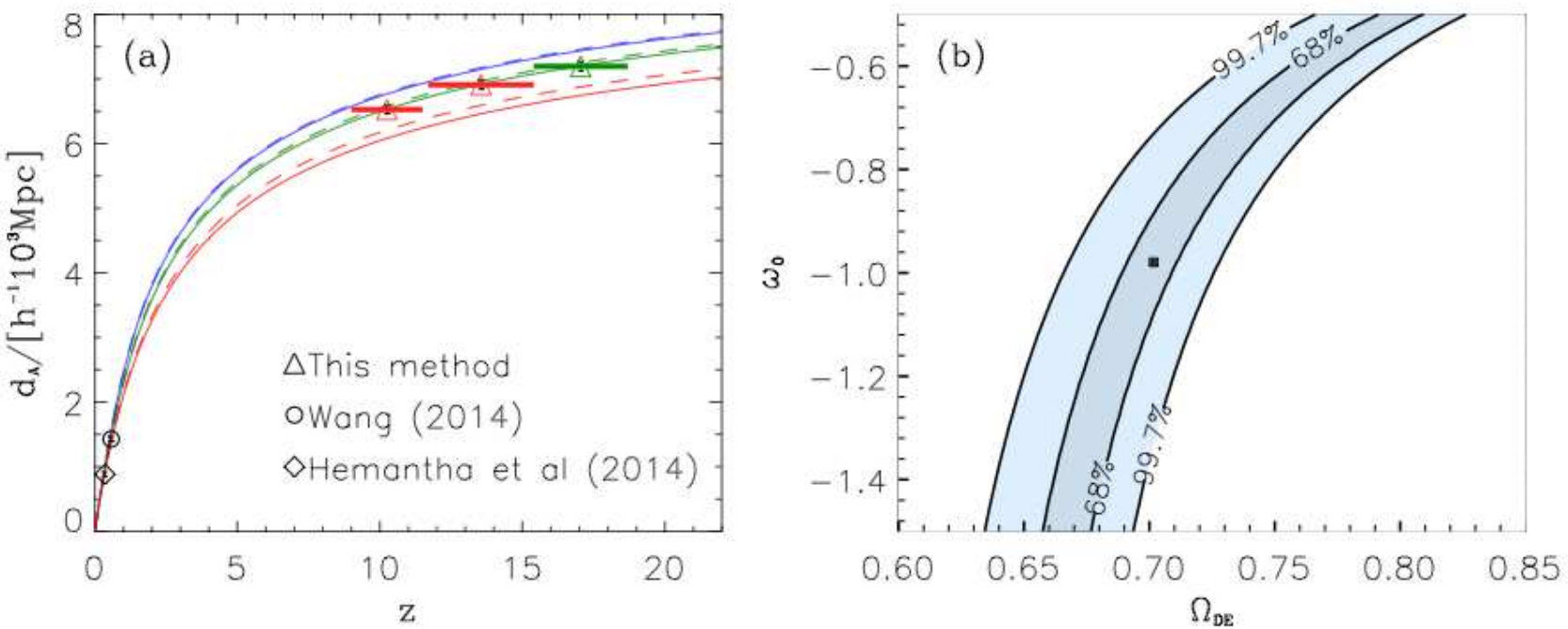
Euclid data.



$\sim 15,000 \text{deg}^2$ covered by the Euclid mission after 6 years of integration in ecliptic coordinates.

• The Euclid NISP (Near Infrared Spectrograph and Photometer) instrument will observe in three filters: Y(0.92-1.146μm), J(1.146-1.372μm) and H(1.372-2.0μm)

Results I.



Expected results from and constrains on the Chevalier-Polarski-Linder EoS parametrization $w_{DE}(z) = w_0 + w_a z/(1+z)$.

Reionization and TSZ anisotropies.

• The first stars will heat up the Interstellar Medium and produce Thermal Sunyaev-Zeldovich anisotropies, with an amplitude:

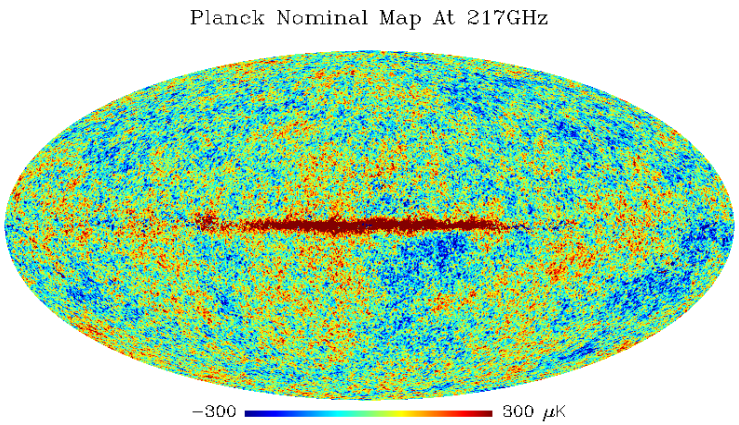
$$\Delta T_{\rm TSZ} \simeq \frac{4}{\pi} G(\nu) \left(\frac{k_B T_e}{m_e c^2}\right) \left(\frac{\sigma_T}{d_A^2}\right) \left(\frac{M_{\rm ion}}{\mu m_H}\right) n_{sources} T_{\rm CMB}$$

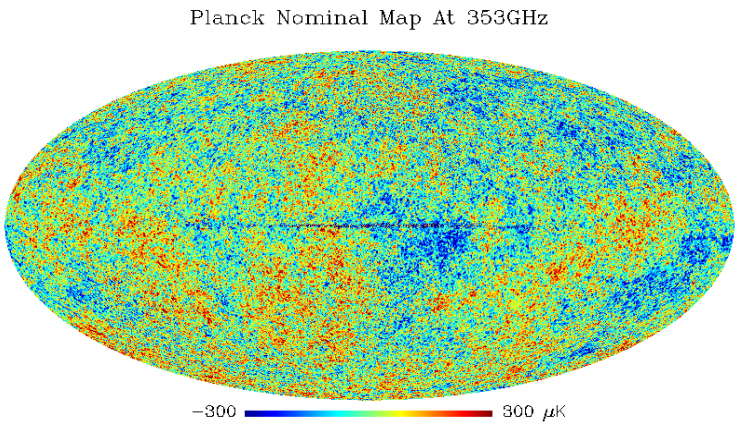
$$\simeq 200 G(\nu) \left(\frac{0.5{\rm Gpc}}{d_A}\right)^2 \left(\frac{M_{POP-III}}{10^2 \mu M_\odot}\right) \left(\frac{\tau}{0.044}\right) \left(\frac{T_e}{10^4 K}\right) \left(\frac{n}{10^{11} sr^{-1}}\right) \ {\rm nK}$$

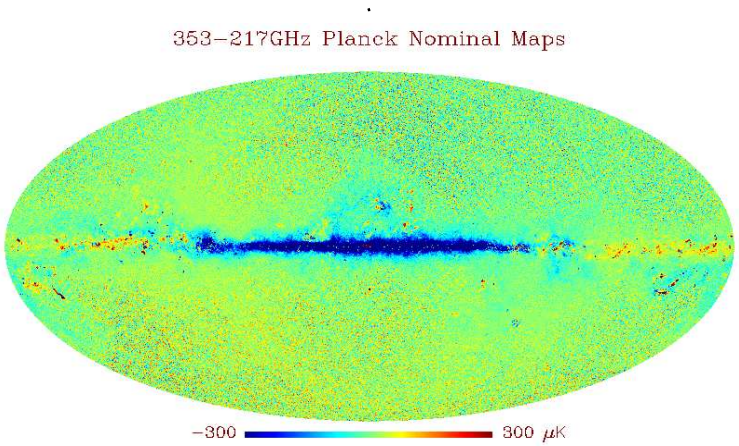
$\mu \equiv$ mean gas molecular weight and $\boxed{\tau = 0.044}$.

The angular diameter distance can be extracted from Cross-Correlating CMB and CIB maps.

CMB data.

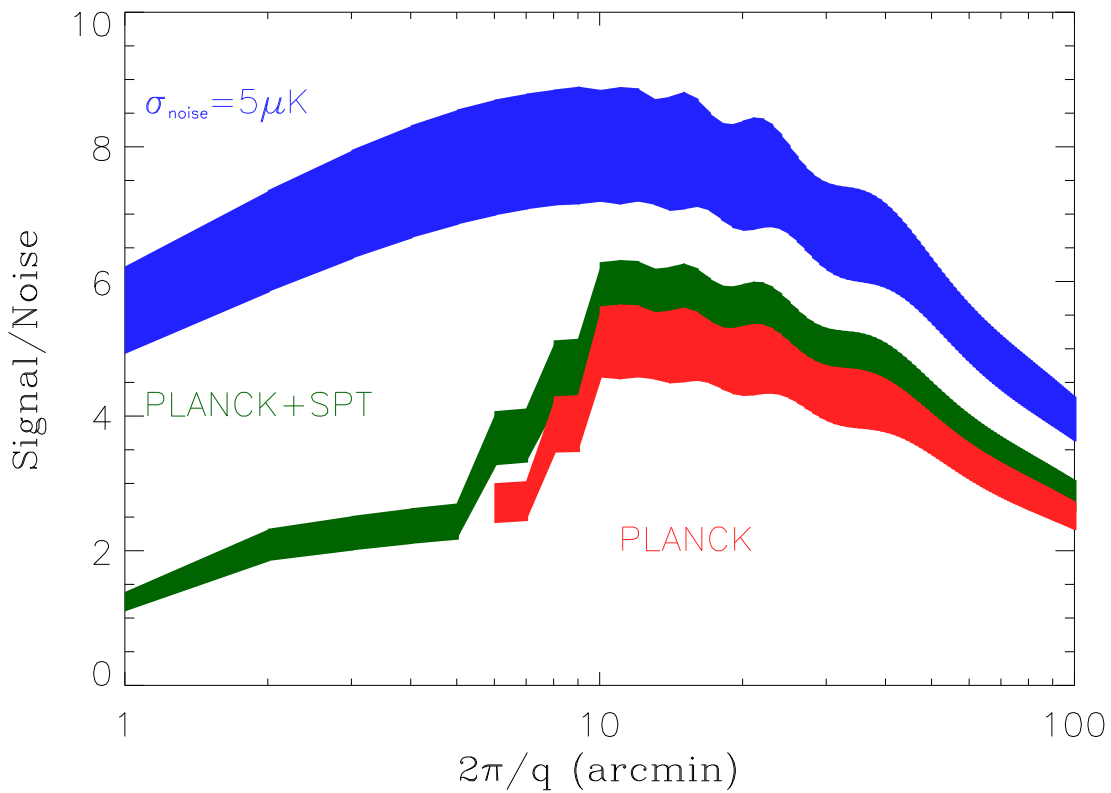






The 217GHz channel is needed to subtract the intrinsic CMB contribution

Results II.



Shaded areas: uncertainties due to model parameters.

The cross-correlation of CMB and CIB maps provides an "indirect" measurement of the angular diameter distance.

Caveats.

• CIB fluctuations require removing sources to very deep levels. JWST time will be required.

• CIB-CMB cross-correlation is model dependent.

• We measure power spectra, not correlation functions that give angular diameter distances. The analysis will require MCMC analysis, so the model will be constrained in addition to many other cosmological parameters.

• Angular diameter distances do not discriminate models as efficiently as luminosity distances.

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Updated constrains on spatial variations of the fine structure constant

Phys. Lett. B 756 (2015) [1603.04498]

Ana Marta Pinho [1,2]

[1] Faculdade de Ciências da Universidade do Porto
[2] Centro de Astrofísica da Universidade do Porto

29 March 2016

Testing the stability of nature's fundamental couplings

Webb *et al.* analysis

- Spatial variation of the fine structure constant α (at *ppm* level).
- Dipole found to be a good fit to the archival data ($> 4\sigma$).

New dataset

- Dedicated measurements have been obtained with statistical and systematical uncertainties typically smaller than the archival dataset.

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A dipole variation

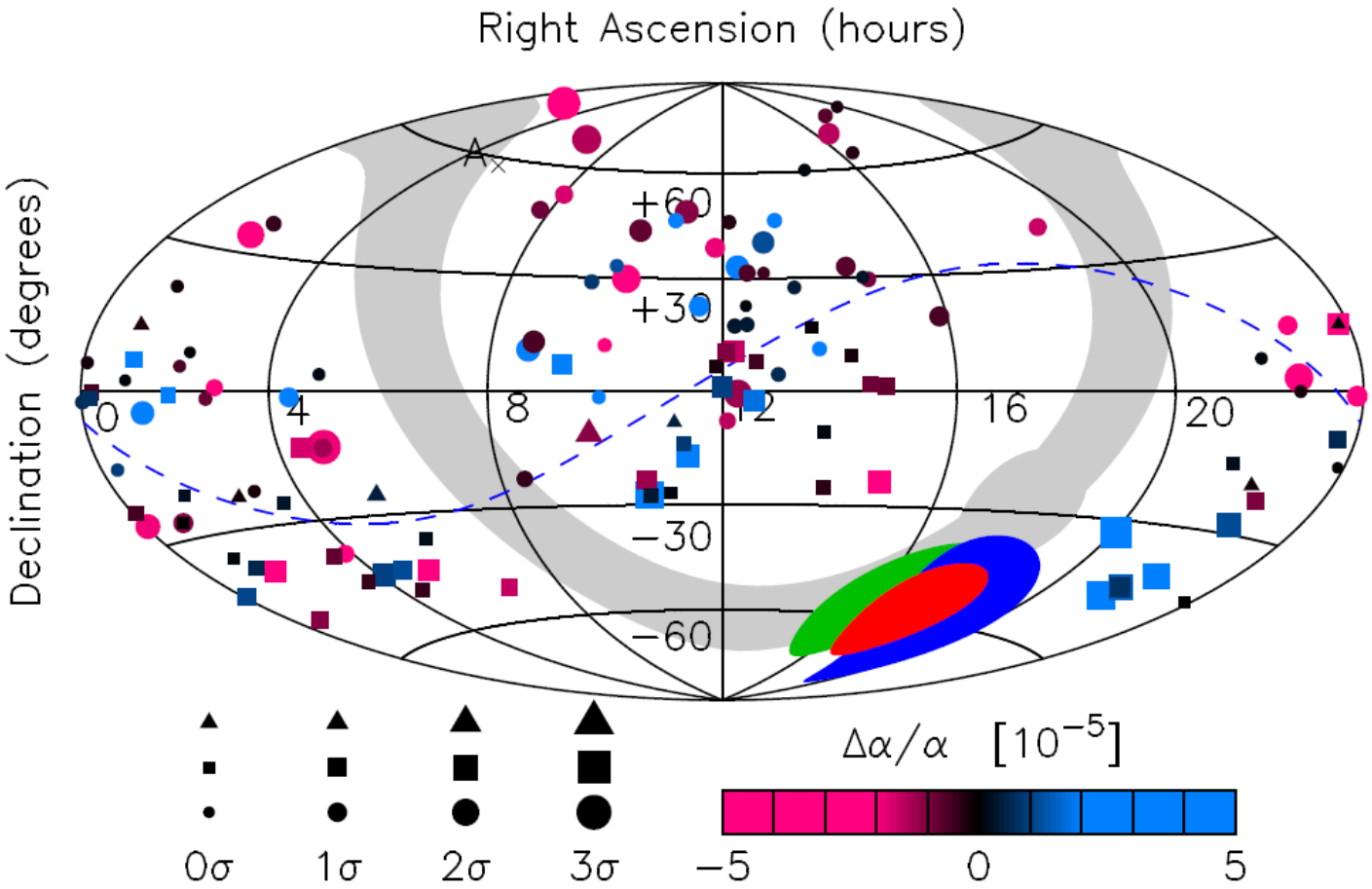

FIGURE – Sky map of the 293 archival measurements sources with 1σ confidence region for a pure dipole.[1]

1. J. Webb, *et al.*, Phys. Rev. Lett. 107 (2011) 191101.

Archival measurements dataset summary

Sample	$< \Delta\alpha/\alpha >_{z<1.8}$	$< \Delta\alpha/\alpha >_{z>1.8}$
Keck	-5.4 ± 1.2	-7.4 ± 1.7
VLT	-0.6 ± 1.6	$+6.1 \pm 2.0$

TABLE – Average values of $\Delta\alpha/\alpha(z)$ in ppm sampled in low and high redshift.

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Recent dedicated measurements

Object	z	$< \Delta\alpha/\alpha >$	Spectrograph
3 sources	1.08	4.3 ± 3.4	UVES
HS1549+1919	1.14	-7.5 ± 5.5	UVES-HIRES-HDS
HE0515-4414	1.15	-0.1 ± 1.8	UVES
HE0515-4414	1.15	0.5 ± 2.4	HARPS-UVES
HS1549+1919	1.34	-0.7 ± 6.6	UVES-HIRES-HDS
HE0001-2340	1.58	-1.5 ± 2.6	UVES
HE1104-1805A	1.66	-4.7 ± 5.3	HIRES
HE2217-2818	1.69	1.3 ± 2.6	UVES
HS1946+7658	1.74	-7.9 ± 6.2	HIRES
HS1549+1919	1.80	-6.4 ± 7.2	UVES-HIRES-HDS
Q1101-264	1.84	5.7 ± 2.7	UVES

TABLE – Values of $\Delta\alpha/\alpha(z)$ in ppm.

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Pure spatial dipole

In this case, the relative variation of α is given by

$$\frac{\Delta\alpha}{\alpha}(A, \Psi) = A cos\Psi \tag{1}$$

where A is the amplitude and Ψ is the orthodromic distance between the Declination and Right Ascension of the i-th measurement (θ_i, ϕ_i) and the north pole (θ_0, ϕ_0) which can be found by

$$cos\Psi = sin\theta_i sin\theta_0 + cos\theta_i cos\theta_0 cos(\phi_i - \phi_0). \tag{2}$$

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Adding a time dependence

We will assume a logarithmic dependence on redshift z which takes the form as

$$\frac{\Delta\alpha}{\alpha}(A, z, \Psi) = A ln(1+z) cos\Psi. \quad (3)$$

This redshift dependence is typical of models with dilatons.

Pure spatial dipole

Method

- Standard χ^2 analysis with a 200^3 grid considering the parameters (A, θ_0, Ψ_0).
- Uniform prior for all three parameters with A $\geq$ 0.

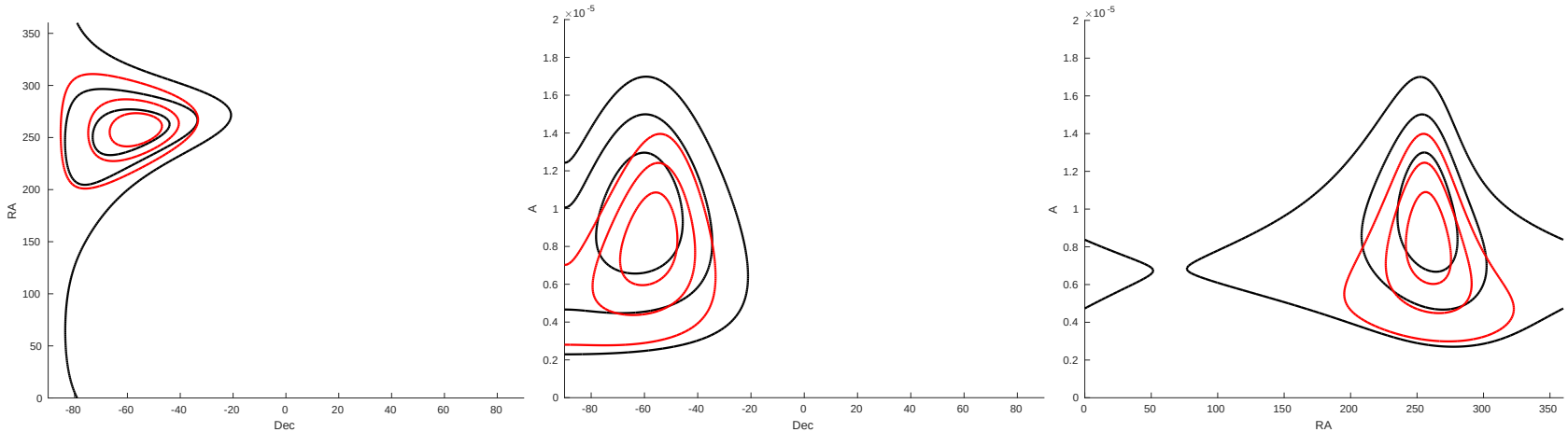

FIGURE – 2D likelihood contours for a pure spatial dipole parametrization. Webb *et al.* dataset in black and all data in red.

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Pure spatial dipole

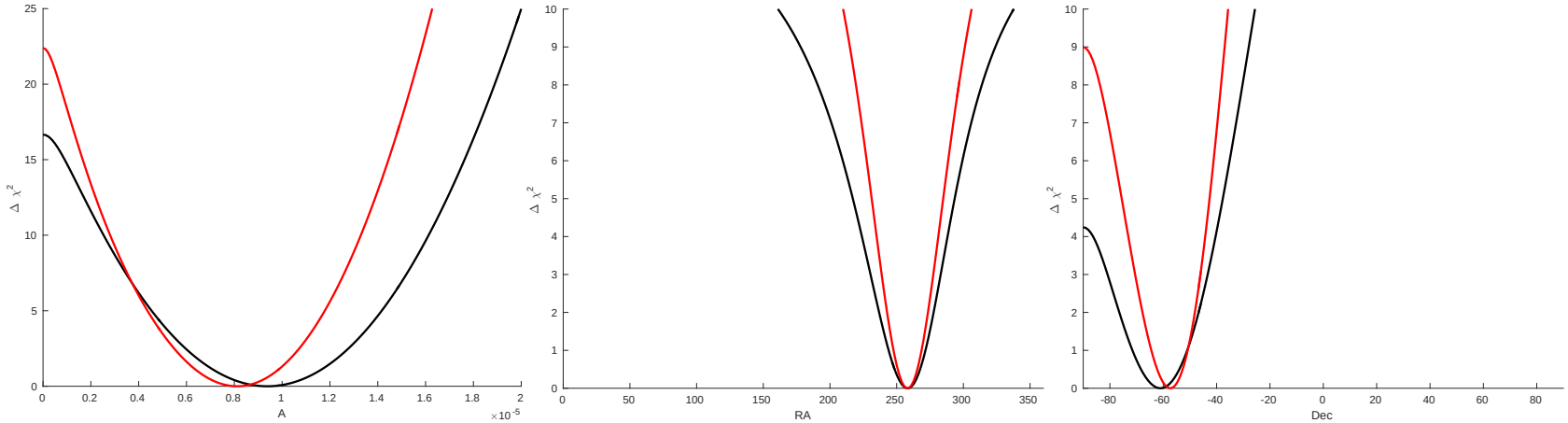

FIGURE – 1D likelihood contours for a pure spatial dipole parametrization. Webb *et al.* dataset in black and all data in red.

1σ and 3σ constrains on the free parameters for a pure spatial dipole			
Dataset & c.l.	Ampltude(*ppm*)	RightAscension(*h*)	Declination(°)
Webb *et al.* (68.3%)	9.4 ± 2.2	17.2 ± 1.0	-61 ± 10
Webb *et al.* (99.7%)	9.4 ± 6.4	$17.2^{4.4}_{-5.3}$	< -28
All data (68.3%)	8.1 ± 1.7	17.2 ± 0.7	-58 ± 7
All data (99.7%)	8.1 ± 5.0	17.2 ± 2.9	< -37

Spatial dipole with redshift dependence

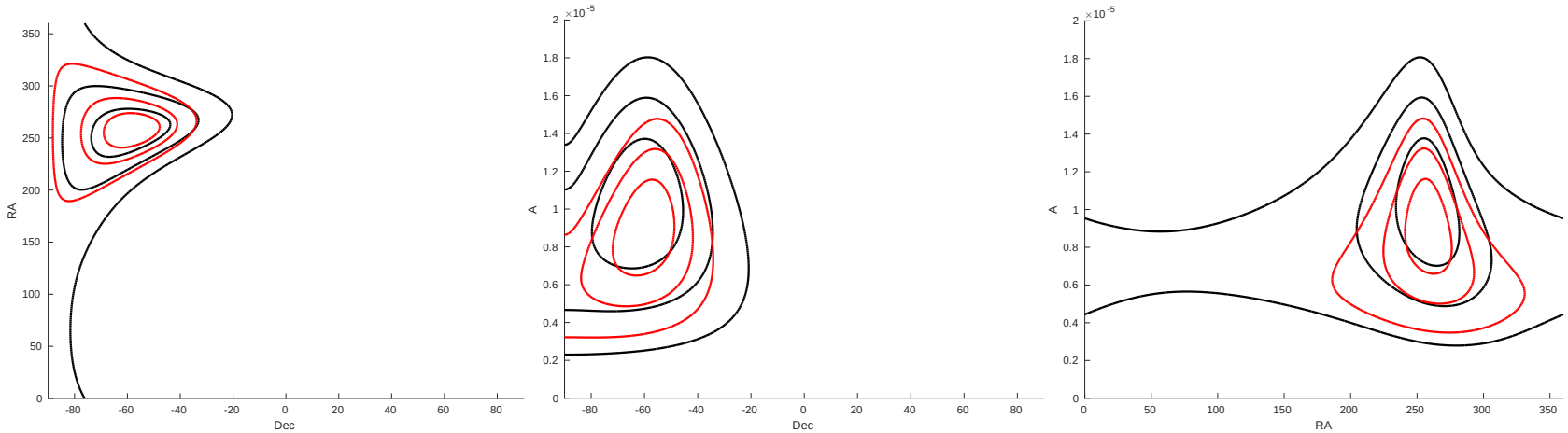

FIGURE – 2D likelihood contours for a spatial dipole with redshift dependence parametrization. Webb *et al.* dataset in black and all data in red.

Spatial dipole with redshift dependence

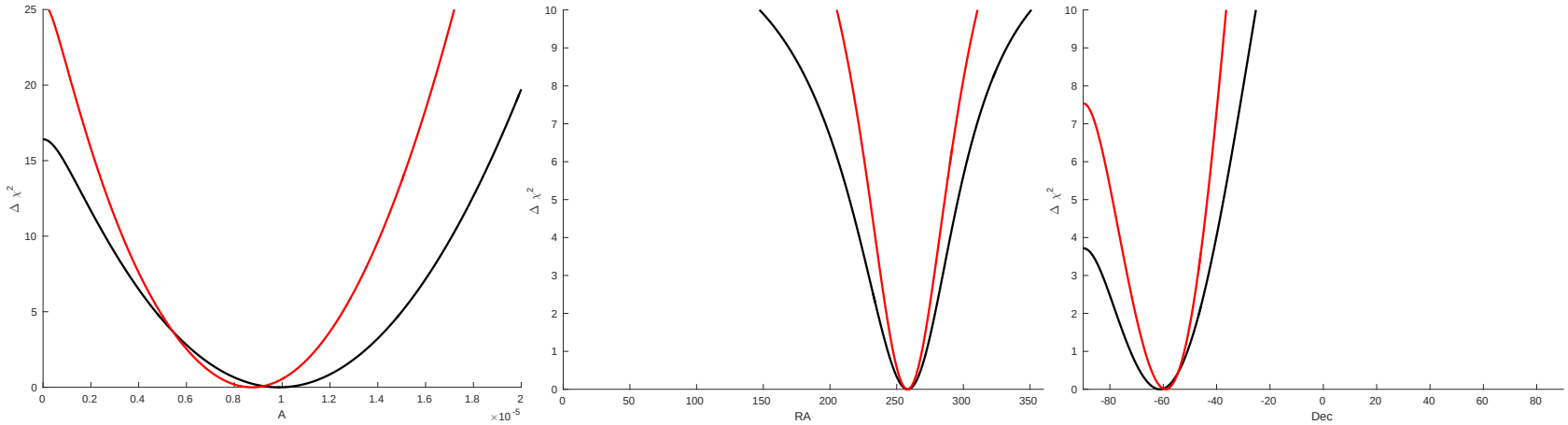

FIGURE – 1D likelihood contours for a spatial dipole with redshift dependence parametrization. Webb *et al.* dataset in black and all data in red.

1σ and 3σ constrains on the free parameters for a spatial dipole with redshift dependence			
Dataset & c.l.	Amplitude(*ppm*)	RightAscension(*h*)	Declinarion(°)
Webb *et al.* (68.3%)	9.9 ± 2.3	17.2 ± 1.0	-61 ± 11
Webb *et al.* (99.7%)	9.9 ± 6.9	$17.2^{5.0}_{-5.9}$	< -27
All data (68.3%)	8.7 ± 1.7	17.2 ± 0.7	-58 ± 8
All data (99.7%)	8.7 ± 5.1	17.2 ± 3.1	< -38

Outlook

- Small number of tight measurements have a significant impact ;
- Dipole still good fit to the overall data ;
- Data can't distinguish parametrizations ;
- Possible hidden systematics, but future facilities such as ESPRESSO will allow measurements with smaller uncertainties and a better control over systematics.

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Dark Energy Constraints from the ESPRESSO Fundamental Physics GTO

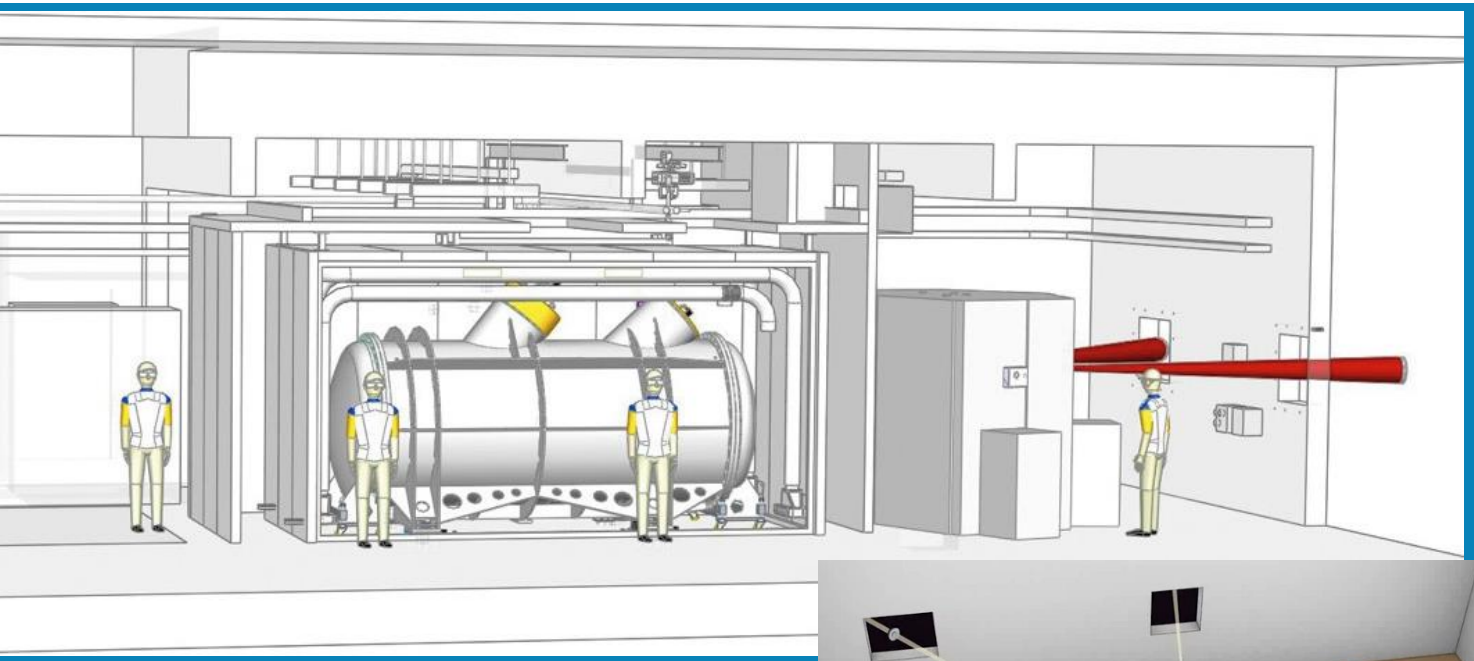
Ana Catarina Leite

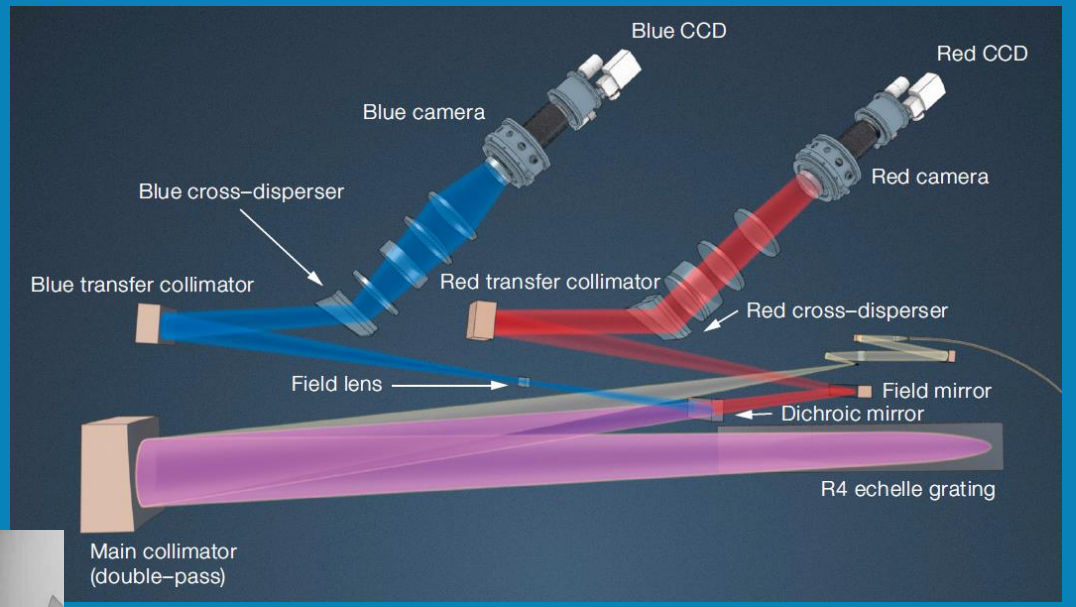
In colaboration with:

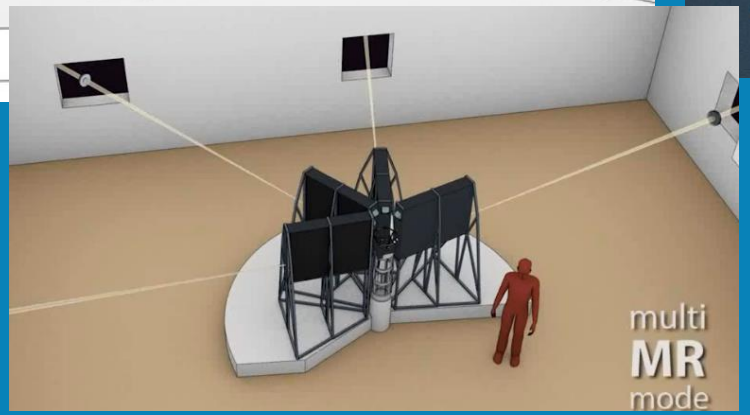
- Carlos Martins
- Paolo Molaro
- David Corre

FUNDAÇÃO CALOUSTE GULBENKIAN

Echelle SPectrograph for Rocky Exoplanet- and Stable Spectroscopic Observations





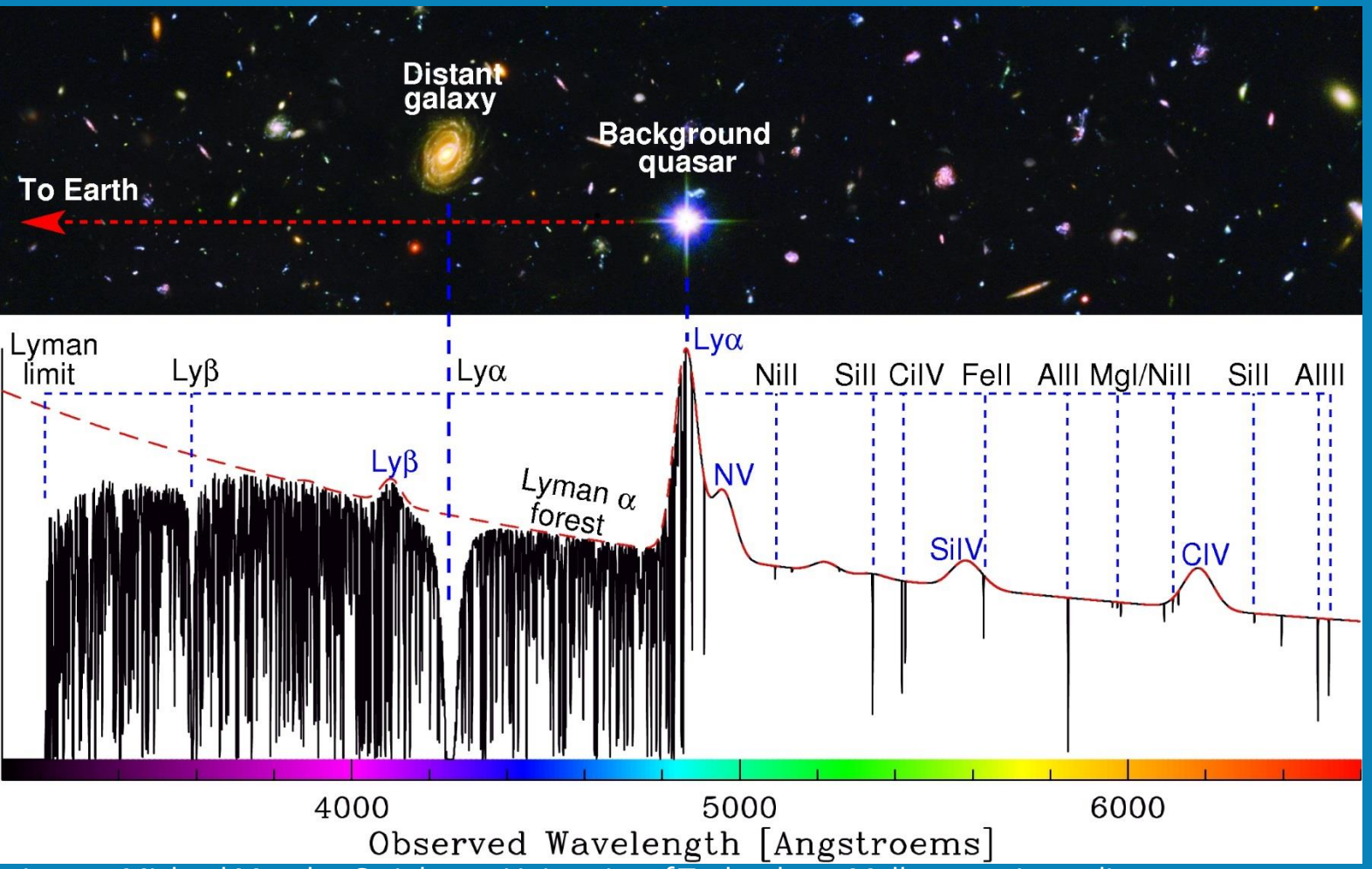


80% Rocky Planets, 10% Varying Constants, 10% to be decided: ToO + Exquisite Science

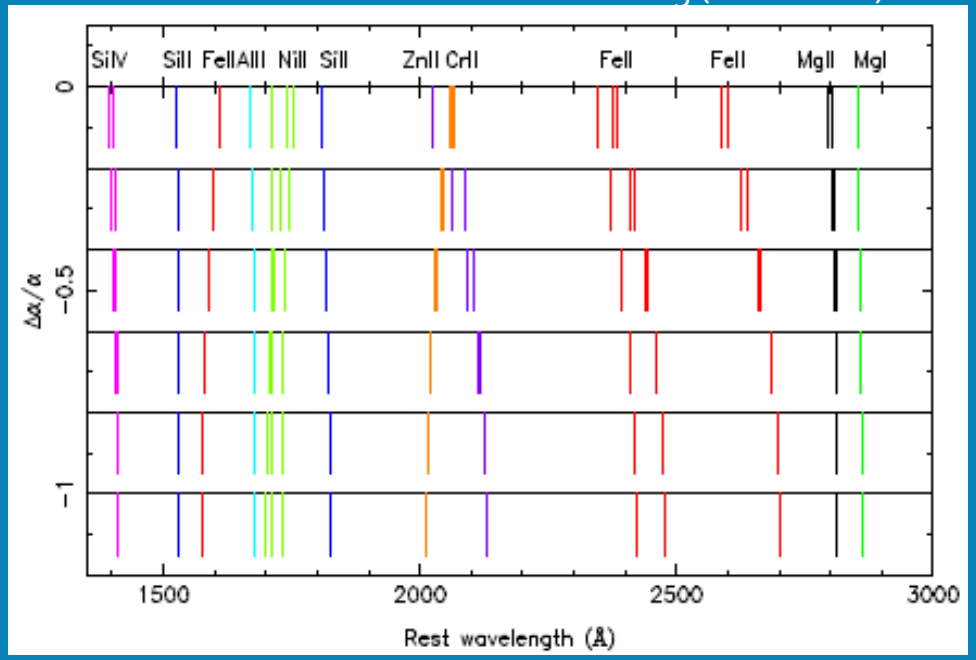
First Light: Beginning of next year!

Pepe et al. 2013, ESPRESSO — An Echelle SPectrograph, The Messenger, 153, 6

Quasar Absortion Spectrum: Powerfull Science Labs



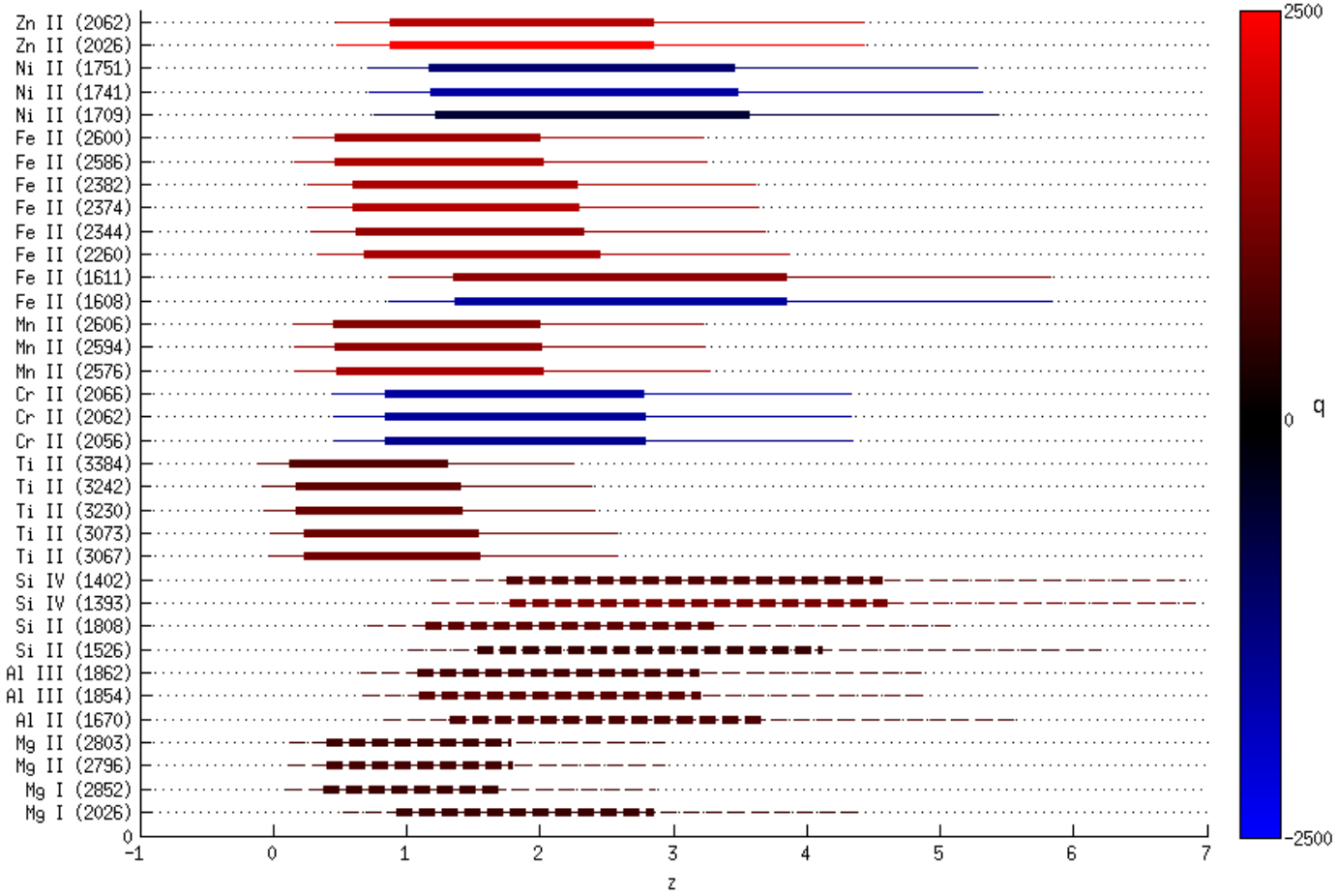
King (PhD thesis) 2011



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

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

Target Selection for ESPRESSO



Wavelength range: 380 – 780 nm

Priority Sistems:

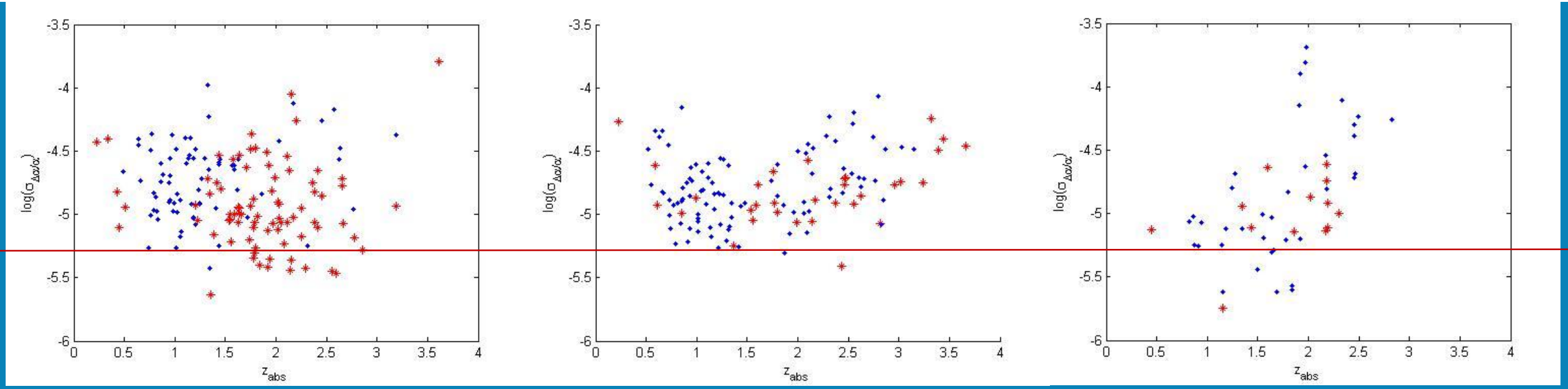
- Uncertainty lower than 10ppm
- Measurements with anchors and sensitivity transitions (Δq)
- Brighteness
- Sky position
- Simplicity of the spectra

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

Some transitions out ESP. range



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)

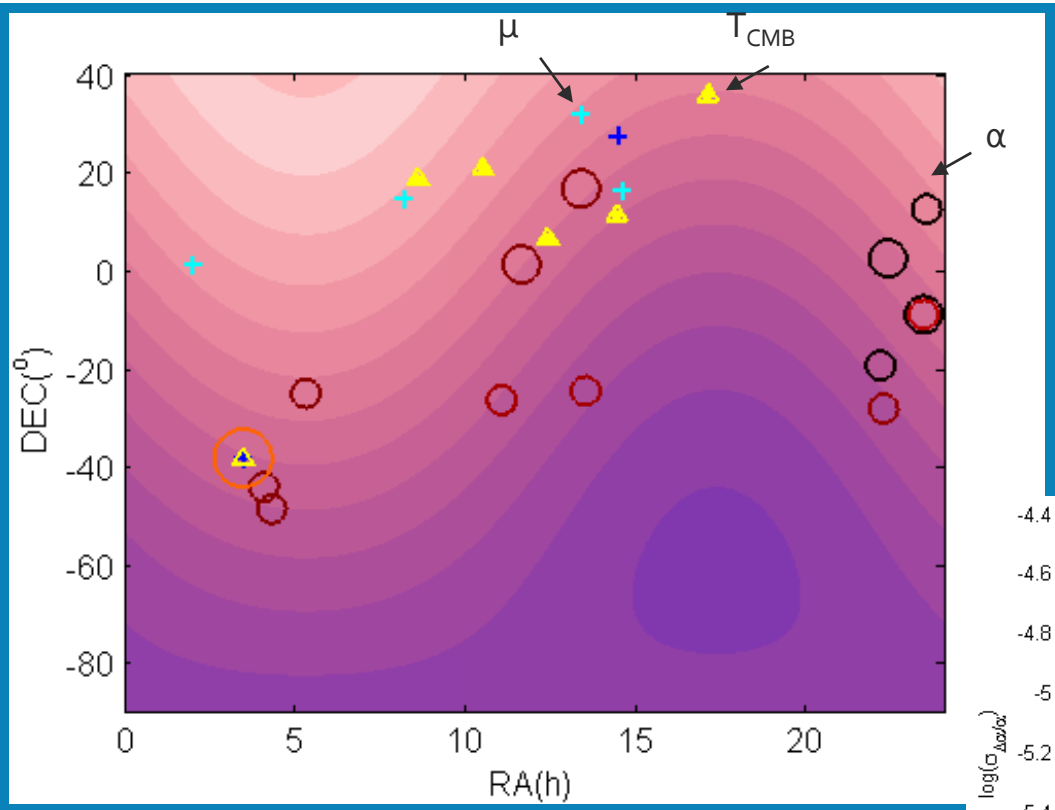
Criteria of selection:

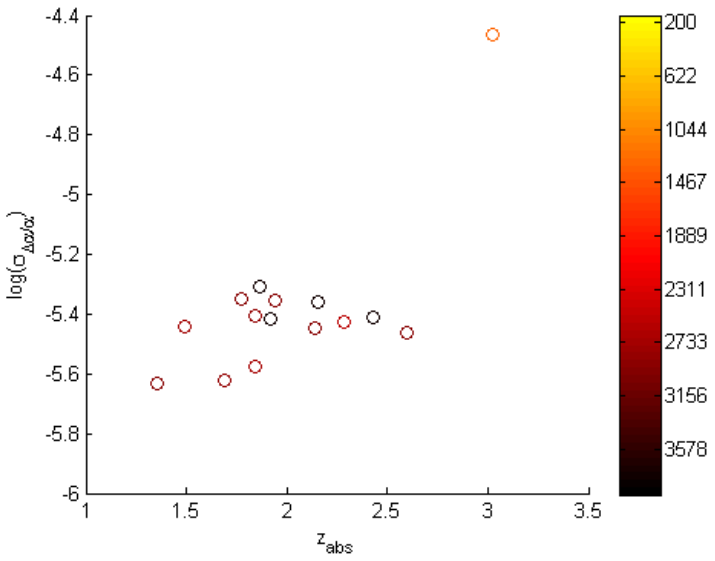
- **Dec<30°**
- $\sigma < 5ppm$
- $\Delta q \geq 2000$

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

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

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

Principal Component Analyses to Constraining Dark Energy

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

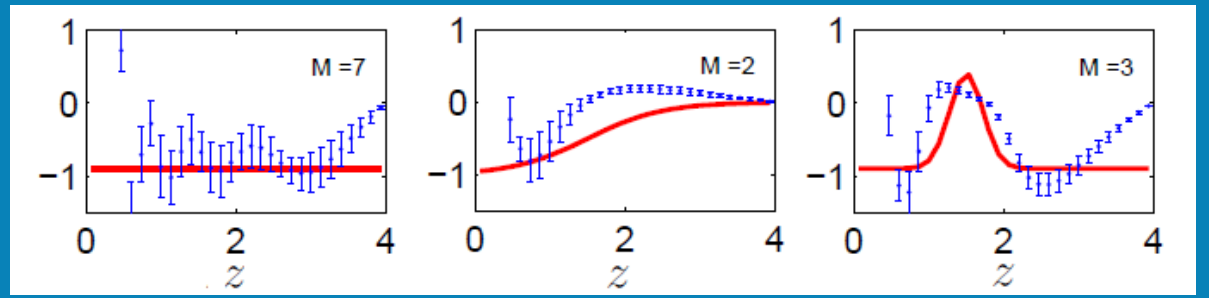
- Type Ia Supernova data
- Spectroscopic α measurements

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.

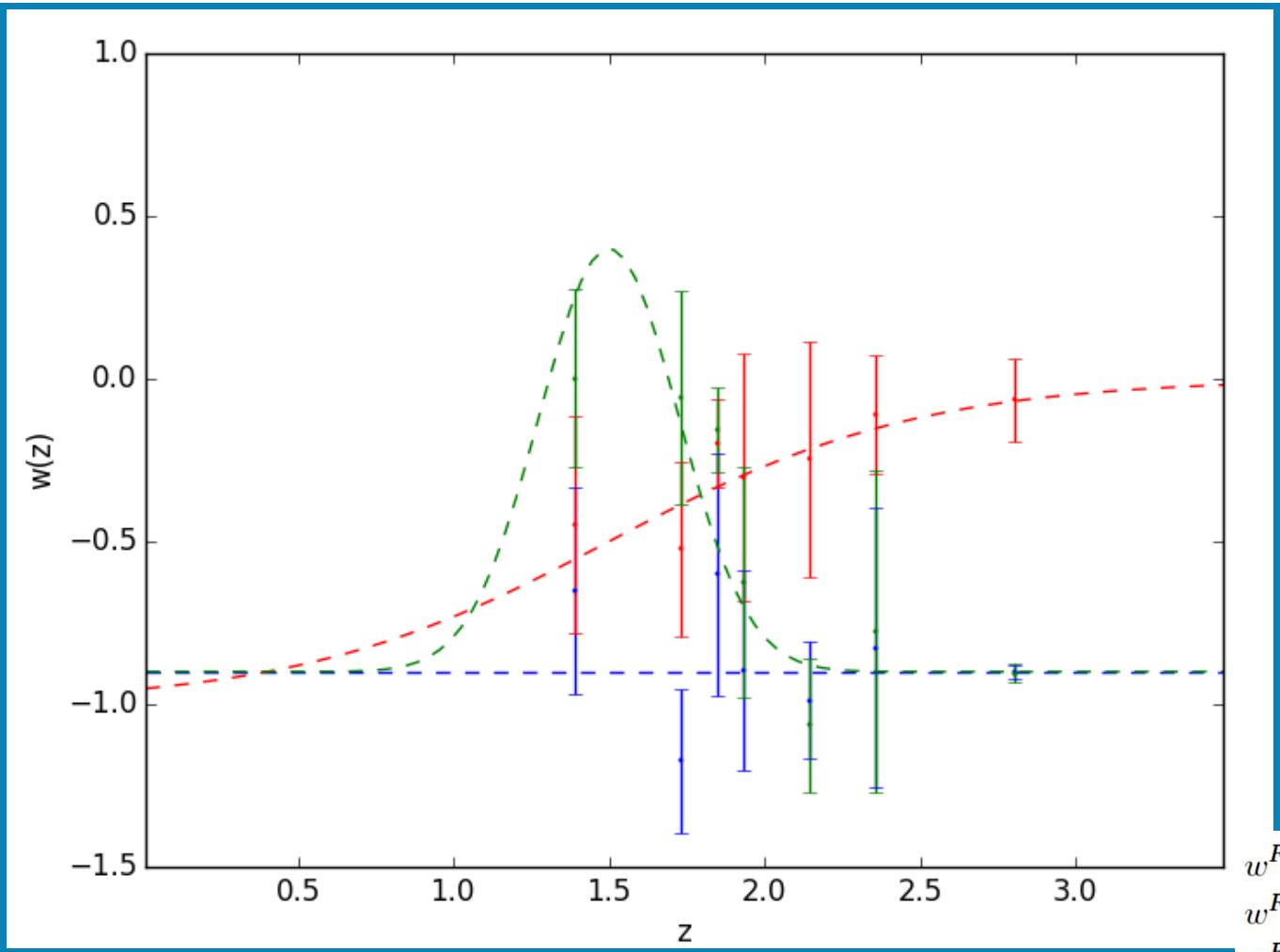
- Fiducial forms

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



ESPRESSO 14 targets for GTO

Name	z_{abs}	M
J034943-381031	3.02	17.3
J040718-441013	2.59	17.3
J043037-485523	1.35	16.5
J053007-250329	2.14	18.8
J110325-264515	1.84	15.9
J110325-264515	1.84	15.9
J115944+011206	1.94	17.5
J133335+164903	1.77	16.7
HE1347-2457	1.43	16.3
J220852-194359	1.92	17.0
HE2217-2818	1.69	16.0
Q2230+0232	1.86	18.0
J233446-090812	2.15	18.0
J233446-090812	2.28	18.0
Q2343+1232	2.43	17.5



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

Ideal - $\sigma_{\Delta\alpha/\alpha} = 2 \times 10^{-7}$

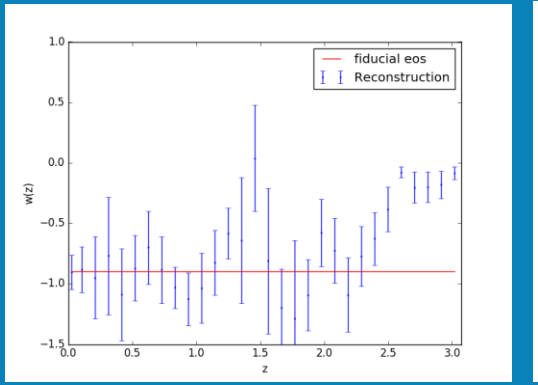
$$w^F(z) = -0.9,$$
$$w^F(z) = -0.5 + 0.5\tanh(z - 1.5),$$
$$w^F(z) = -0.9 + 1.3\exp\left(-(z - 1.5)^2/0.1\right)$$

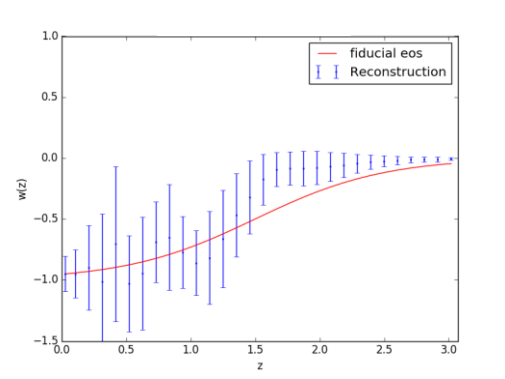
Future Sna Ia Surveys + GTO ESPRESSO

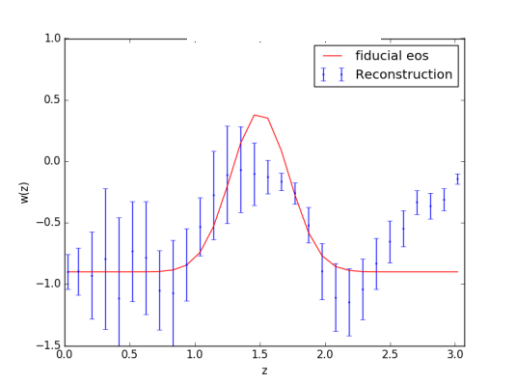
- **LOW (SNAP)** - 3000 SN - z: 0 - 1.7
- **MID (EUCLID)** - 1700 SN - z: 0.75 - 1.5

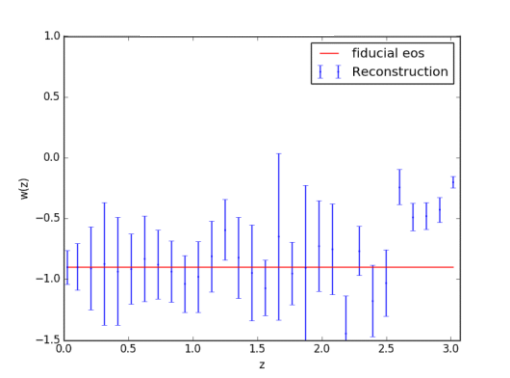
$\sigma_m = 0.11$

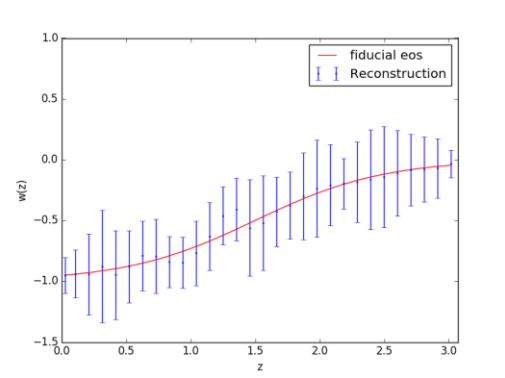
Number of modes under 0.3

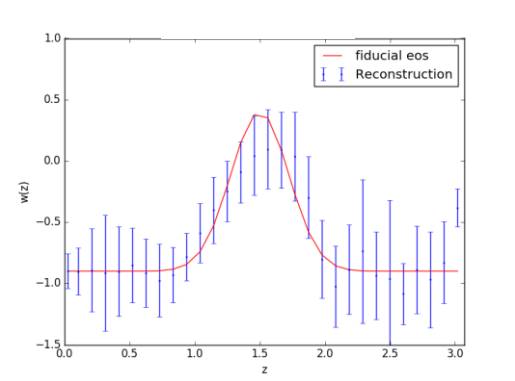












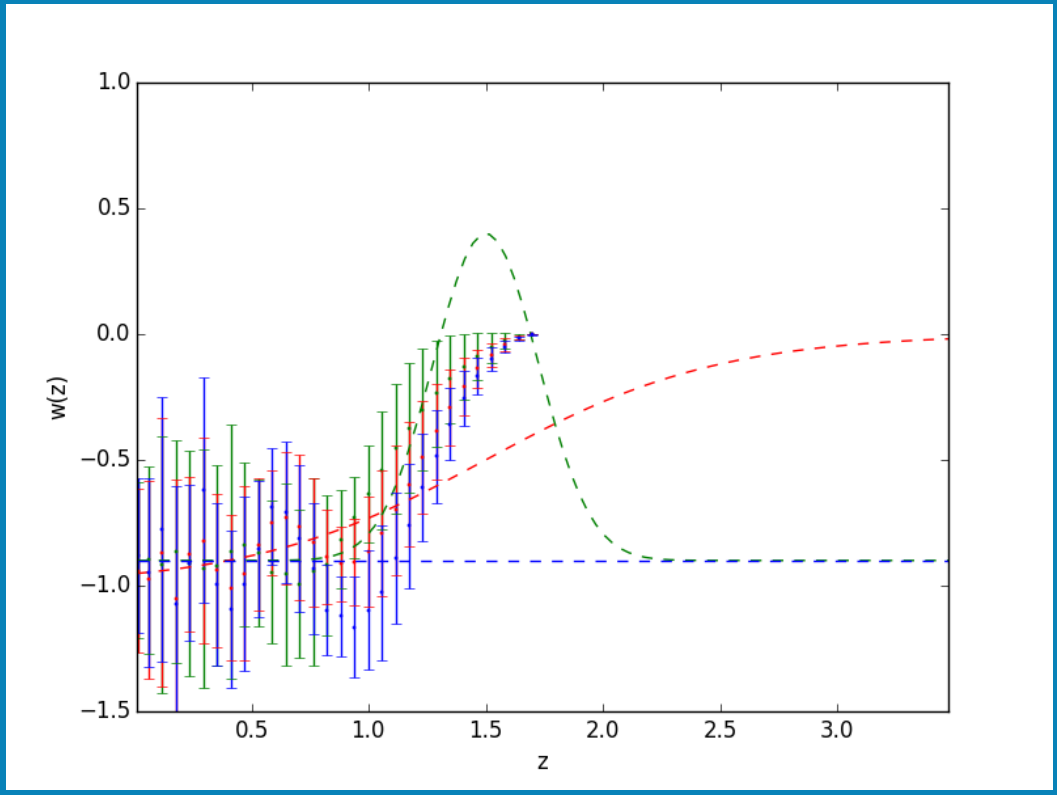
- **Baseline** uncertanty for GTO measurements

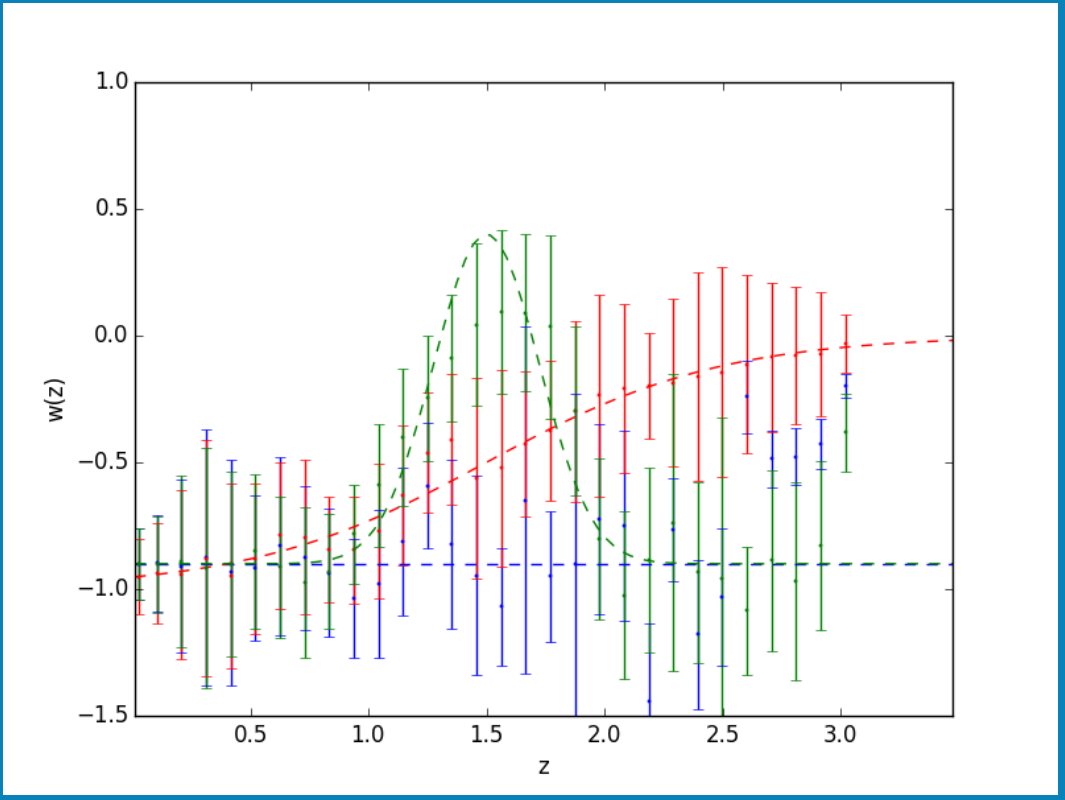
	constant	step	bump
GTO	1	-	1
GTO + SNAP	4	4	4
GTO + SNAP + Euclid	4	4	5

- **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 ~ 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

VILA DO CONDE,
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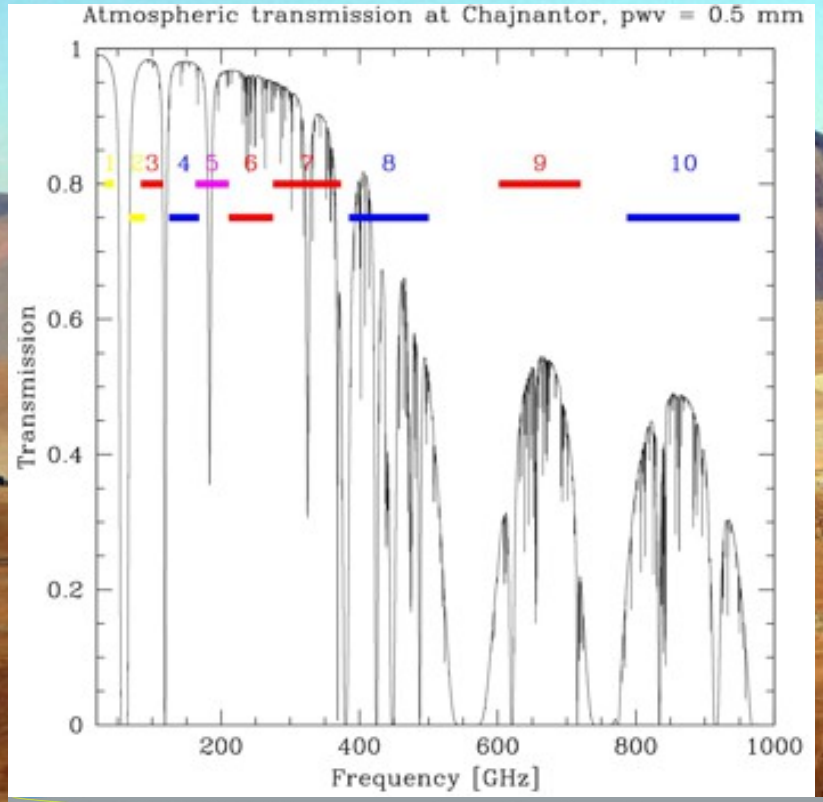
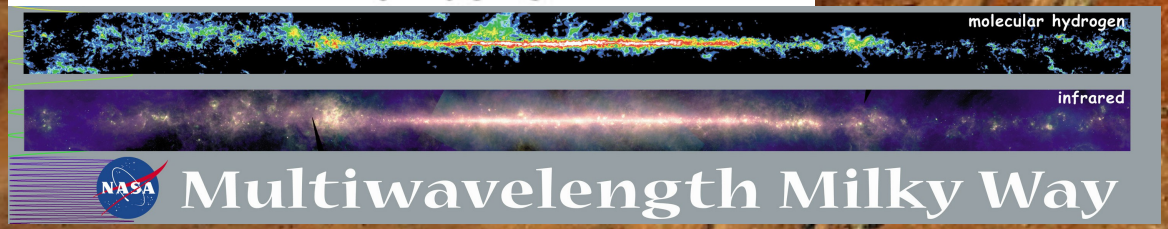
Hugo Messias
PACE Lead Scientist
hmessias@oal.ul.pt

Atacama Large Millimetre Array (ALMA)

Atacama Large Millimetre Array (ALMA)





Spectral coverage

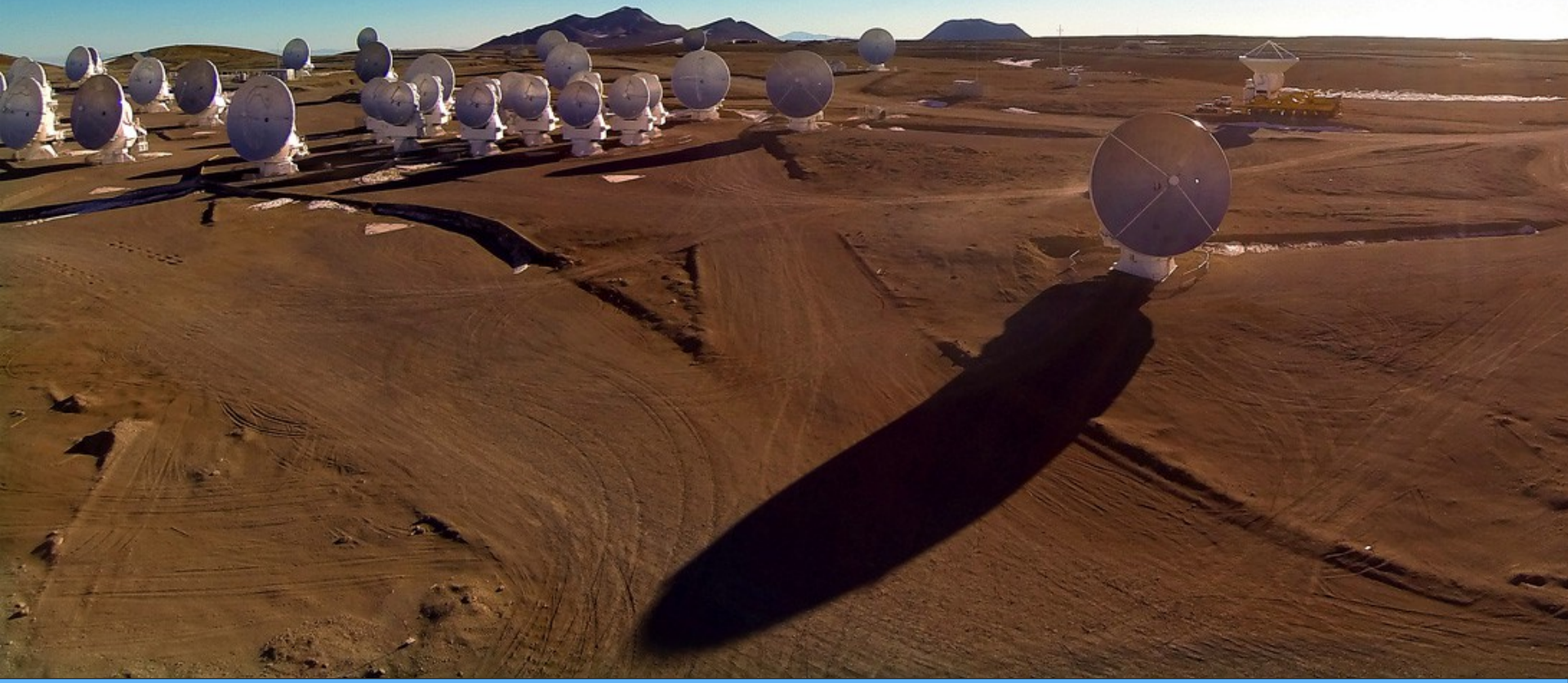
3—0.3mm (84—950GHz)
0.014—0.001km/s
R~22k—250k
7—0.3mm (40—950GHz)
0.03—0.001km/s
R~11k—250k

ALMA

The array(s)

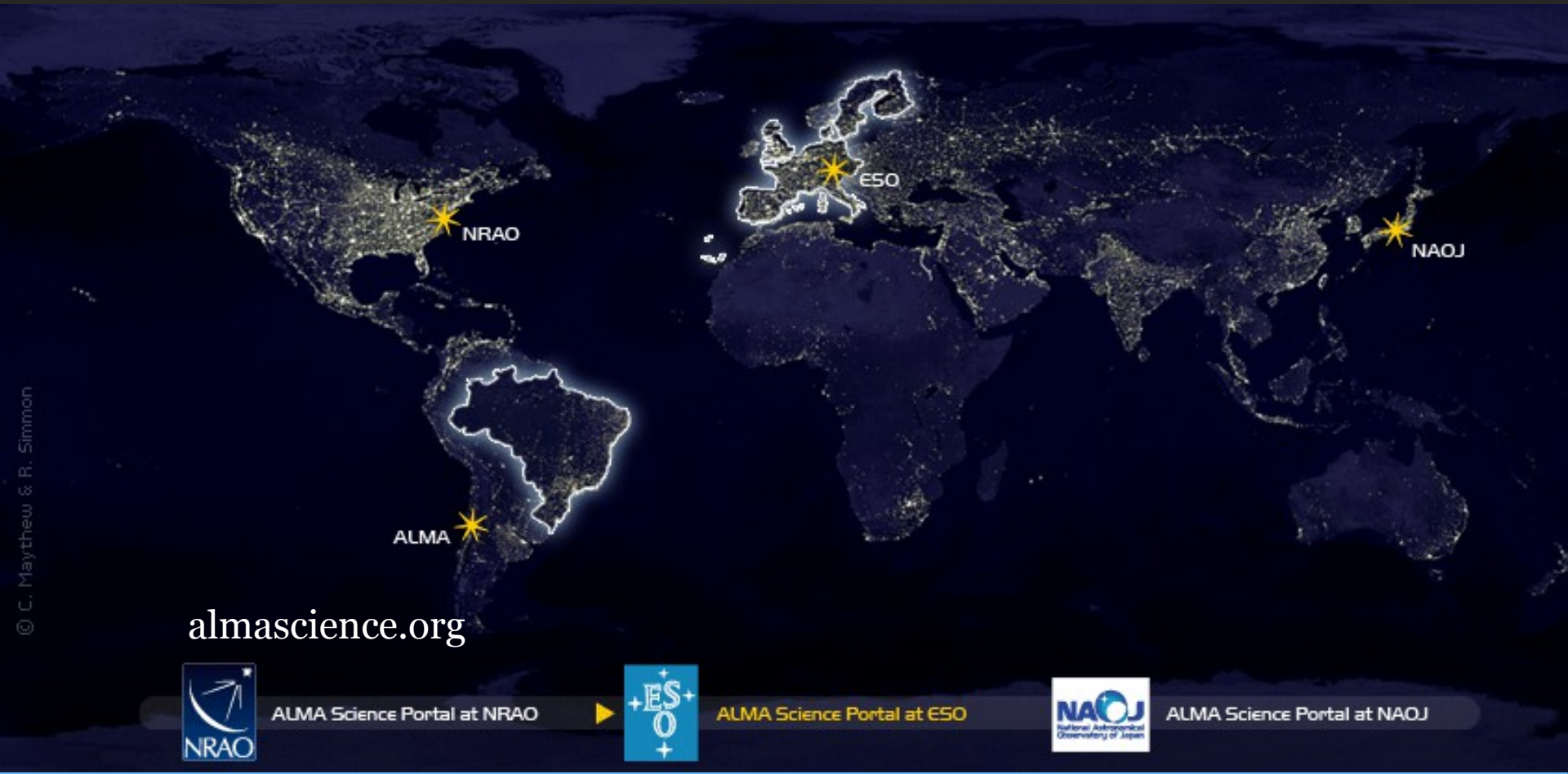
Main array (12m-array) — ≥40 12m antennas (50 in full-ALMA)

Atacama Compact Array (ACA) — ≥10x7m + ≥3x12m (12x7m + 4x12m)



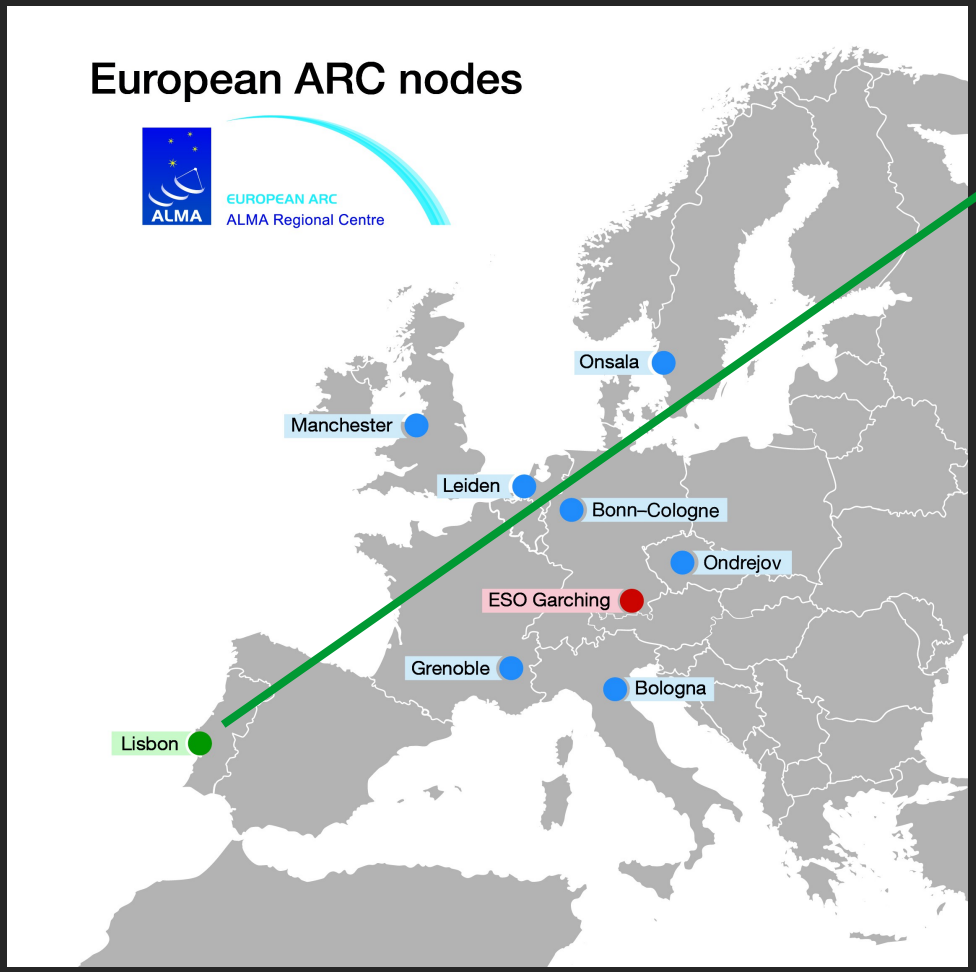
ALMA

The consortium



ALMA

The European ALMA support network



Portuguese
ALMA
Centre of
Expertise

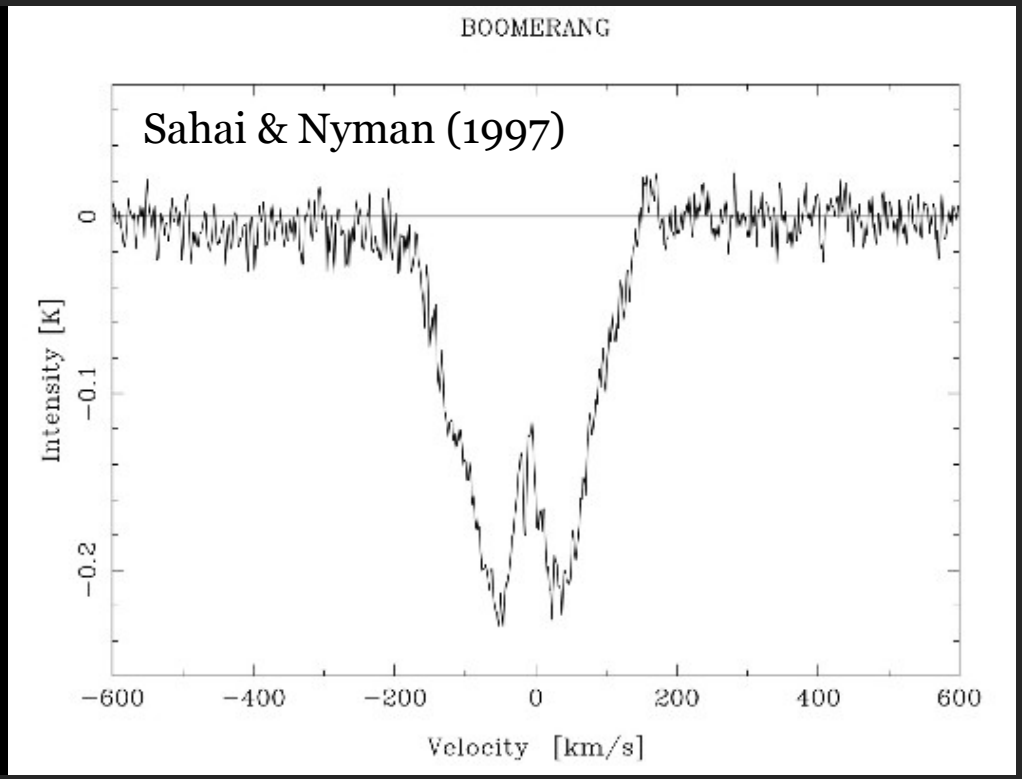
PACE

pace.oal.ul.pt

CMB

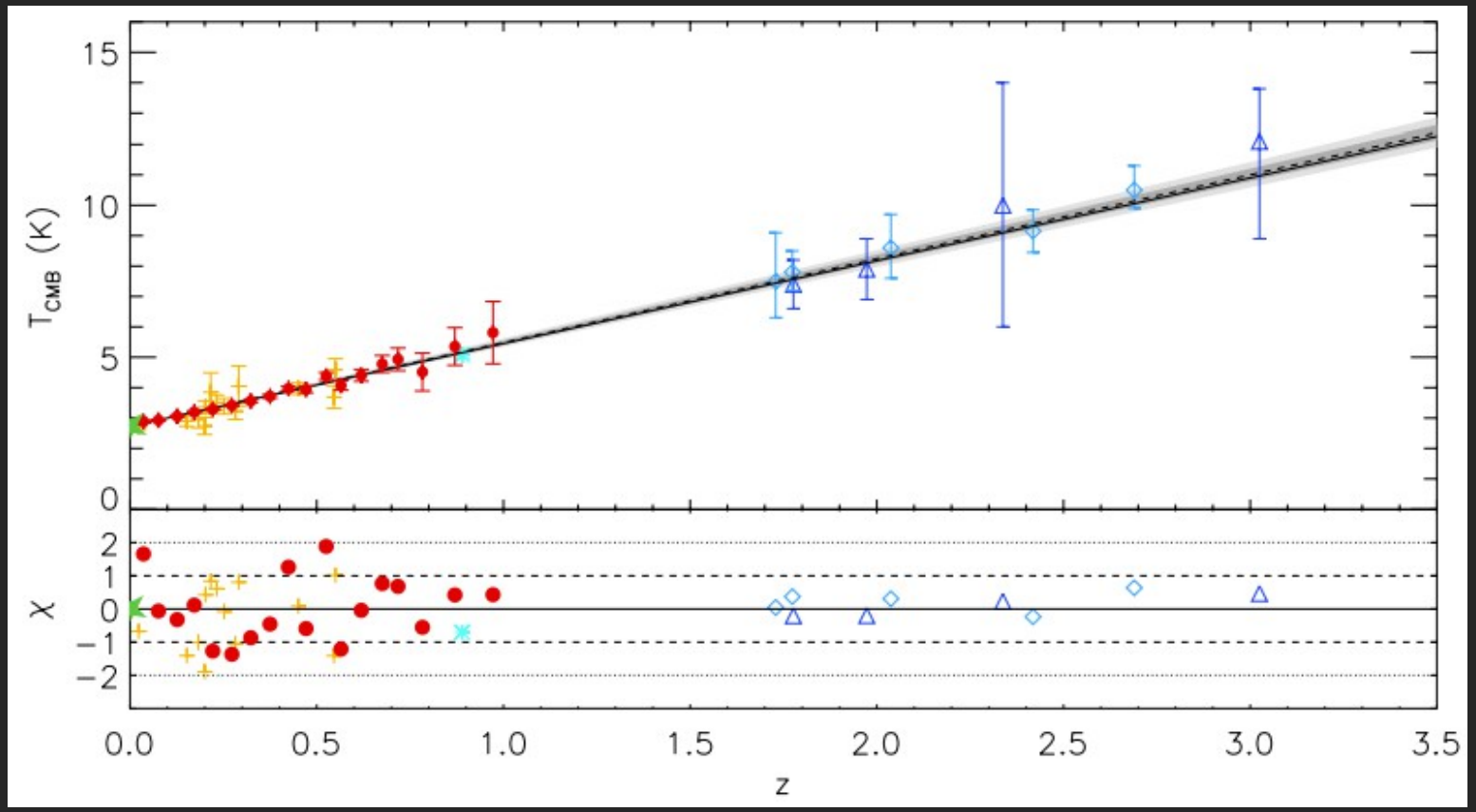
Temperature

Sunyaev-Zel'dovich effect (e.g., Hurier et al. 2014)
Line-absorption against the CMB



CMB

Temperature

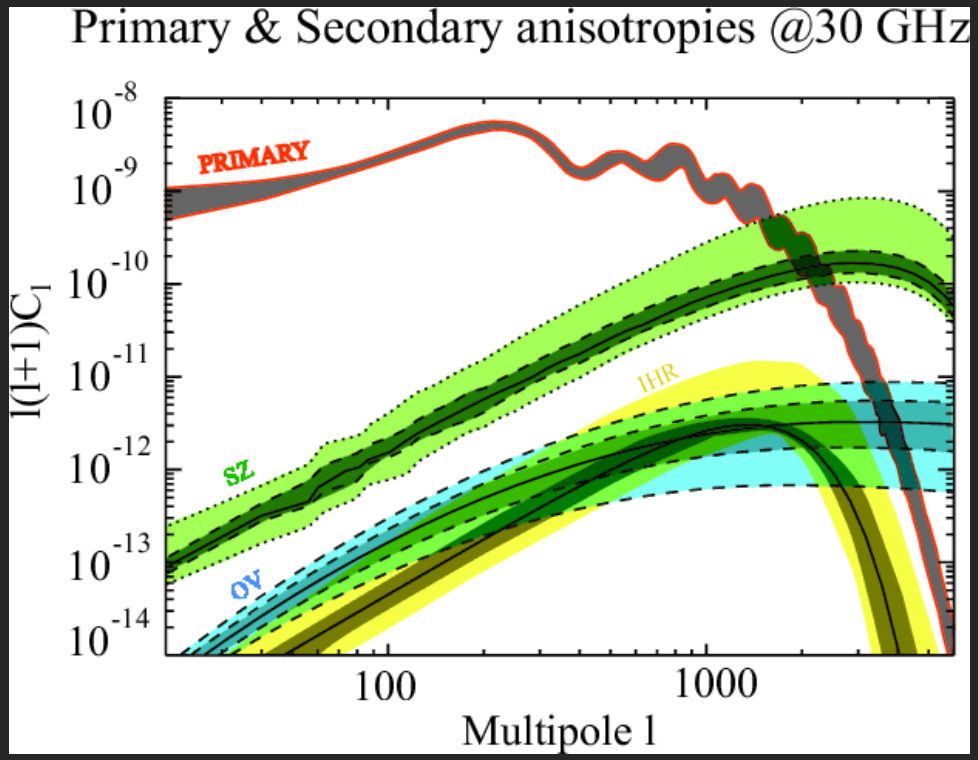


Hurier et al. (2014, fig. 8: T_{CMB} evolution compatible with adiabatic expansion)

CMB

Secondary anisotropies

Sunyaev-Zel'dovich (thermal / kinetic) effect
Inhomogeneous reionization
Ostriker-Vishniak effect

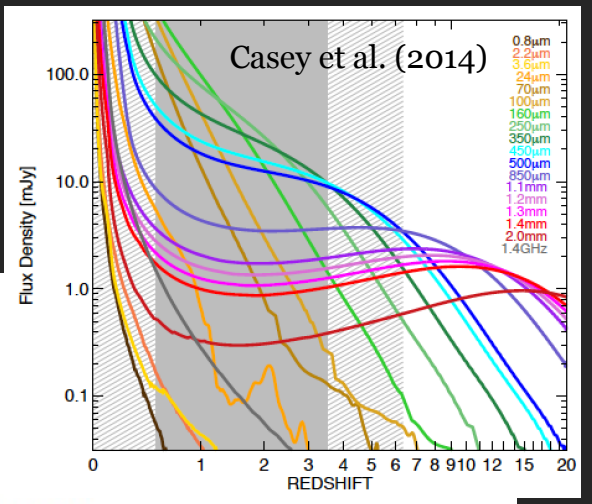


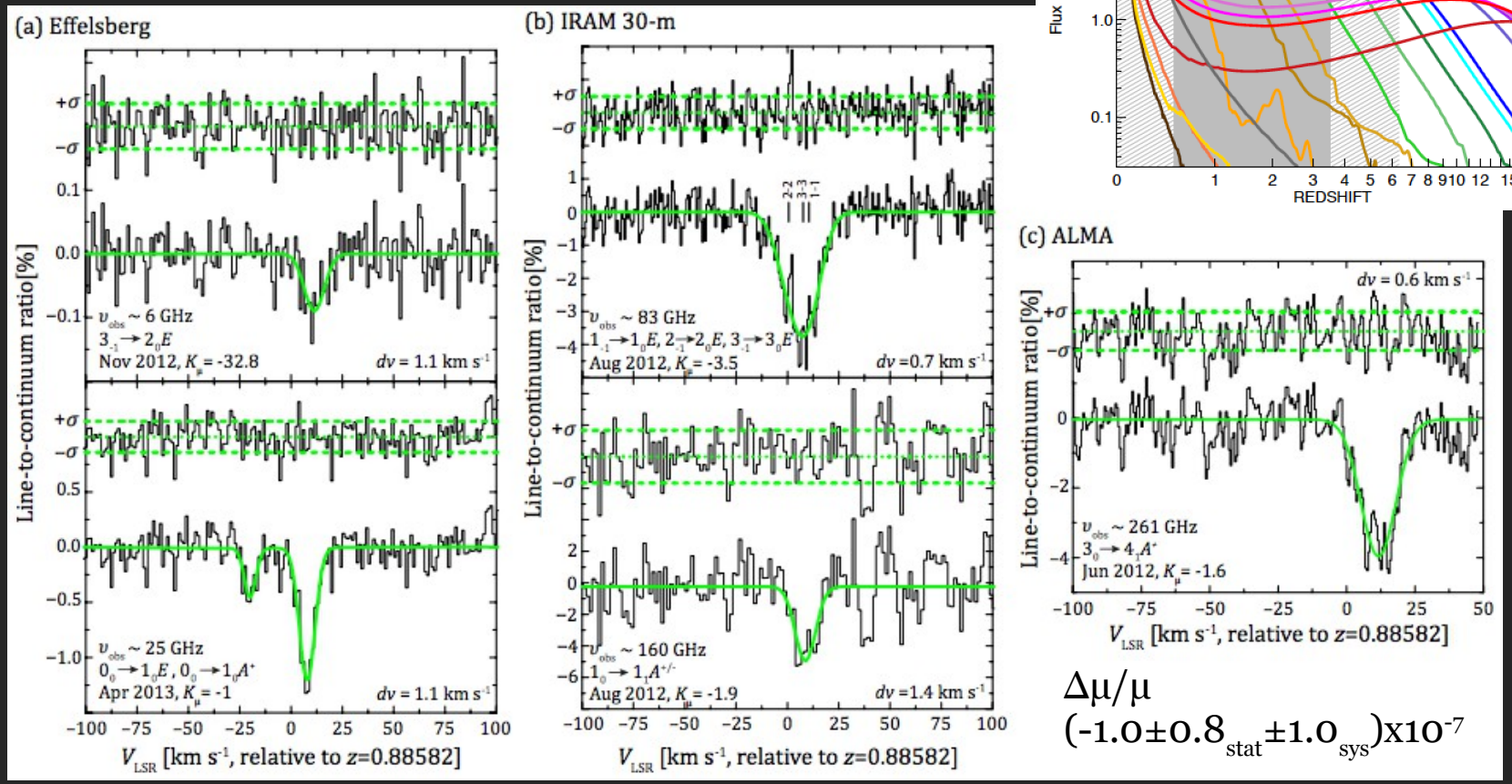
Aghanim et al. (2002, fig.2)

Physics

Nature's Fundamental Couplings

Proton-to-electron mass ratio: $\mu = m_p/m_e$





$\Delta\mu/\mu$

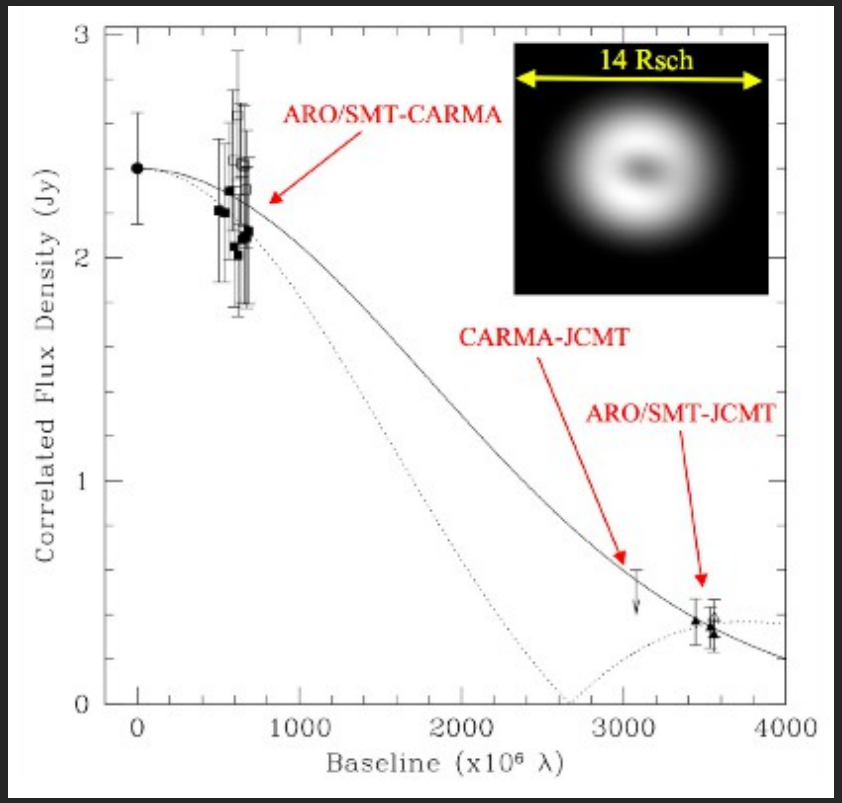
$(-1.0 \pm 0.8_{stat} \pm 1.0_{sys}) \times 10^{-7}$

Bagdonaite et al. (2013, fig. 1: CH3OH/methanol lines in absorption toward PKS1830-211)

Seeing black-holes

Black Hole Event Horizon

Phased-up ALMA



Doeleman et al. (EHT, www.eventhorizontelescope.org)

Atacama Large Millimeter/submillimeter Array
In search of our Cosmic Origins

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ALMA Cycle 4 Call for Proposals is now open

Mar 22, 2016

The ALMA Director, on behalf of the Joint ALMA Observatory and the partner organizations in East Asia, Europe, and North America, is pleased to issue the Cycle 4 Call for Proposals.

The ALMA Cycle 4 proposal submission deadline is:

15:00 UT on Thursday 21 April 2016.

We invite members of the scientific community to submit observing proposals for ALMA Cycle 4. Cycle 4 will start in October 2016 and span 12 months. Users of any professional background, nationality or affiliation may submit proposals.

Time remaining until deadline:

23 days 05:00:00

General News

1mm VLBI Call for Proposals is Now OPEN
Mar 25, 2016

ALMA Cycle 4 Call for Proposals is Now OPEN!
Mar 22, 2016

1mm VLBI Pre-announcement
Feb 26, 2016

ALMA Cycle 4 Information for Large Programs
Feb 01, 2016

Participation of ALMA in GMVA observations in ALMA Cycle 4
Jan 13, 2016

More…

Local News

ALMA ARC Postdoc Position: Short Spacings and polarization
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