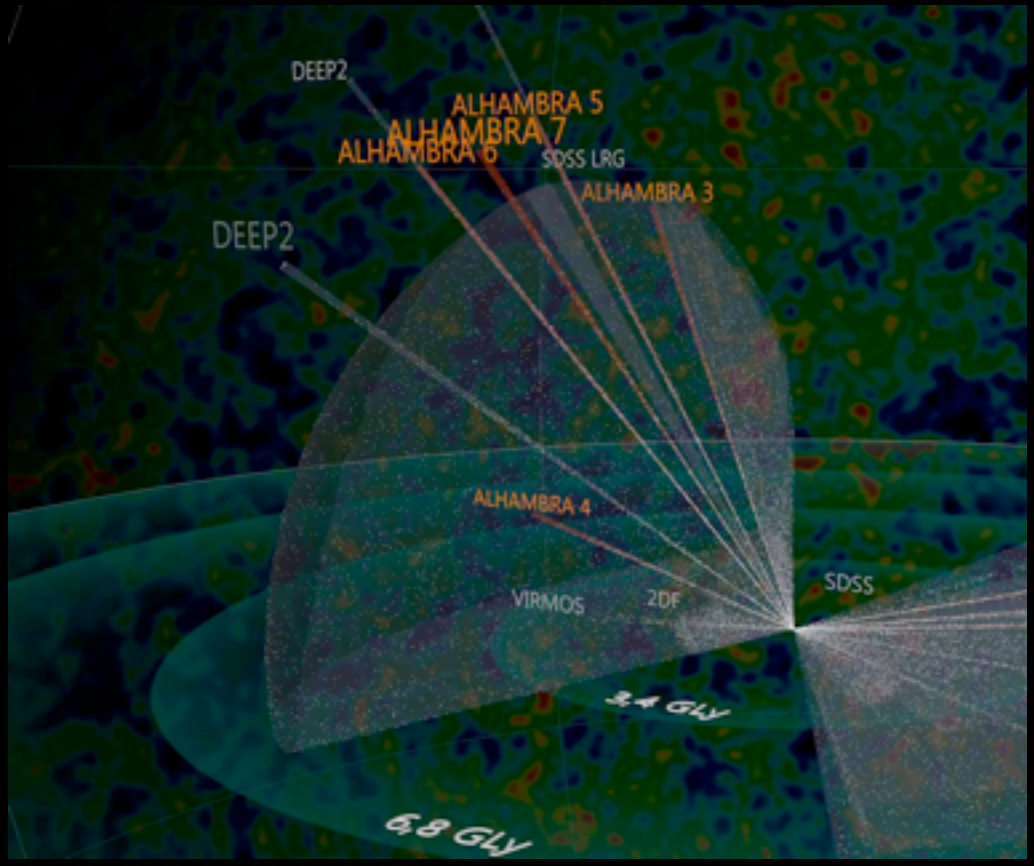

The ALHAMBRA survey: First data release and early scientific results

Alberto Fernández-Soto
(on behalf of the ALHAMBRA team)

IFCA
Instituto de Física de Cantabria
CSIC
UC
UNIVERSIDAD DE CANTABRIA

Summary

- What is the ALHAMBRA survey?
- What kind of science can be done?
- What is the quality of the data?
- How can the data be handled?
- First scientific results
- ALHAMBRA-Gold and First Data Release

ALHAMBRA SURVEY

Advanced Large, Homogeneous Area, Medium-Band Redshift Astronomical Survey

Moles et al. 2008, AJ 136, 1325

The ALHAMBRA Project: A large area multi medium-band optical and NIR photometric survey[1]

M. Moles[1], N. Benítez[1,2], J. A. L. Aguerri[3], E. J. Alfaro[1], T. Broadhurst[4], J. Cabrera-Caño[5], F. J. Castander[6], J. Cepa[3,7], M. Cerviño[1], D. Cristóbal-Hornillos[1], A. Fernández-Soto[8], R. M. González Delgado[1], L. Infante [9], I. Márquez[1], V. J. Martínez[8,10], J. Masegosa[1], A. del Olmo[1], J. Perea[1], F. Prada[1], J. M. Quintana[1], and S. F. Sánchez[11]

The ALHAMBRA Survey: Bayesian Photometric Redshifts with 23 bands for 3 squared degrees.

Molino et al. 2014, MNRAS 441, 2891

A. Molino[1], N. Benítez[1], M. Moles[2], A. Fernández-Soto[3,4], D. Cristóbal-Hornillos[2], B. Ascaso[1], Y. Jiménez-Teja[1], W. Schoenell[1], P. Arnalte-Mur[5], M. Pović[1], D. Coe[6], C. López-Sanjuan[2], L. A. Díaz-García[2], J. Varela[2], I. Matute[1], J. Masegosa[1], I. Márquez[1], J. Perea[1], A. Del Olmo[1], C. Husillos[1], E. Alfaro[1], T. Aparicio-Villegas[1,7], M. Cerviño[1,8], M. Huertas-Company[9,10], J. A. L. Aguerri[8], T. Broadhurst[11], J. Cabrera-Caño[12], J. Cepa[8,13], R. M. González Delgado[1], L. Infante[14], V. J. Martínez[3,4], F. Prada[1], J. M. Quintana[1]

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[2]*Centro de Estudios de Física del Cosmos de Aragón (CEFCA), Plaza San Juan 1, 44001 Teruel, Spain*

The ALHAMBRA-survey Science Team

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Nicolas Gruel	CEFCA Teruel (España)
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Leopoldo Infante	PUC Santiago (Chile)
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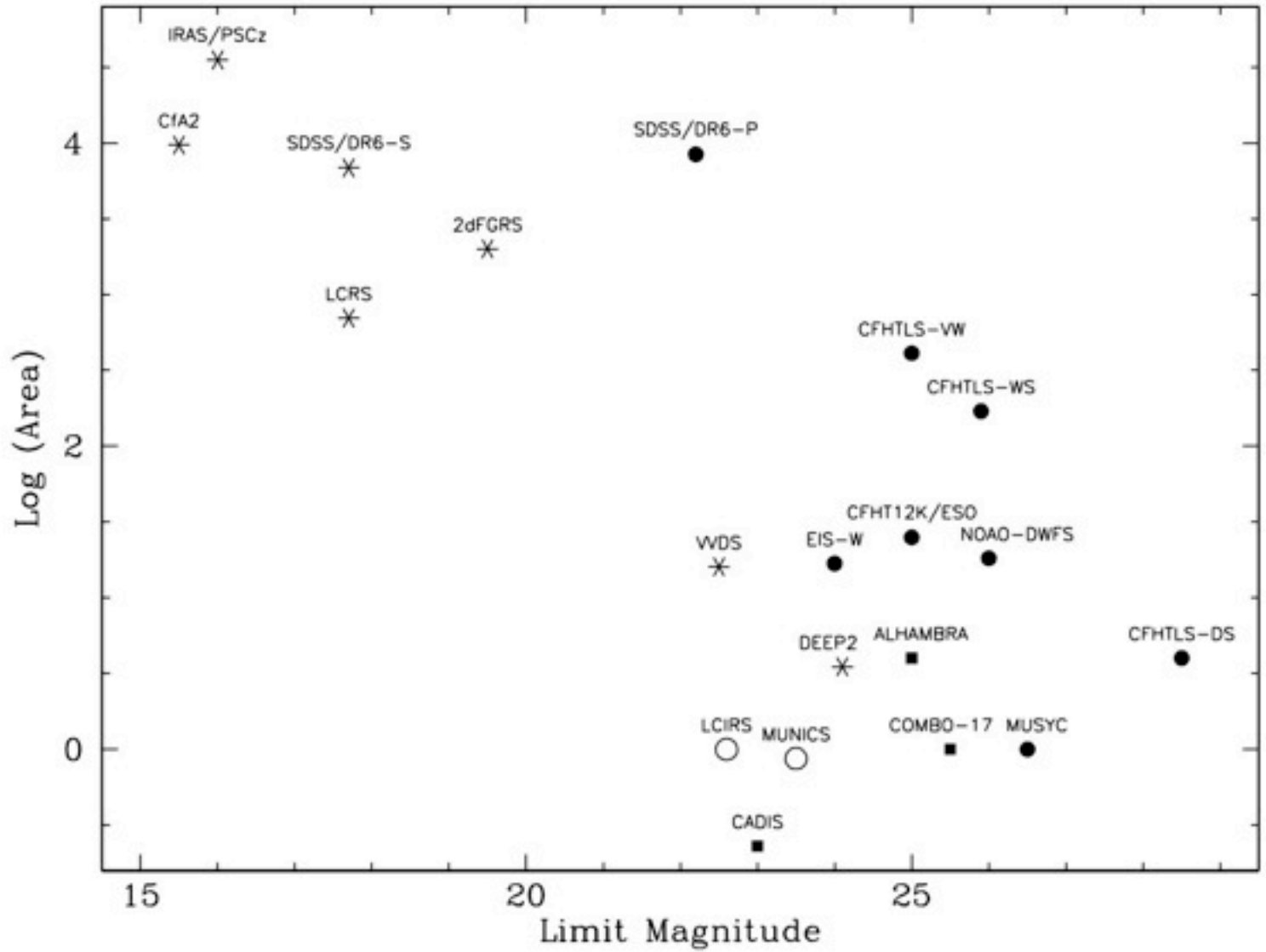
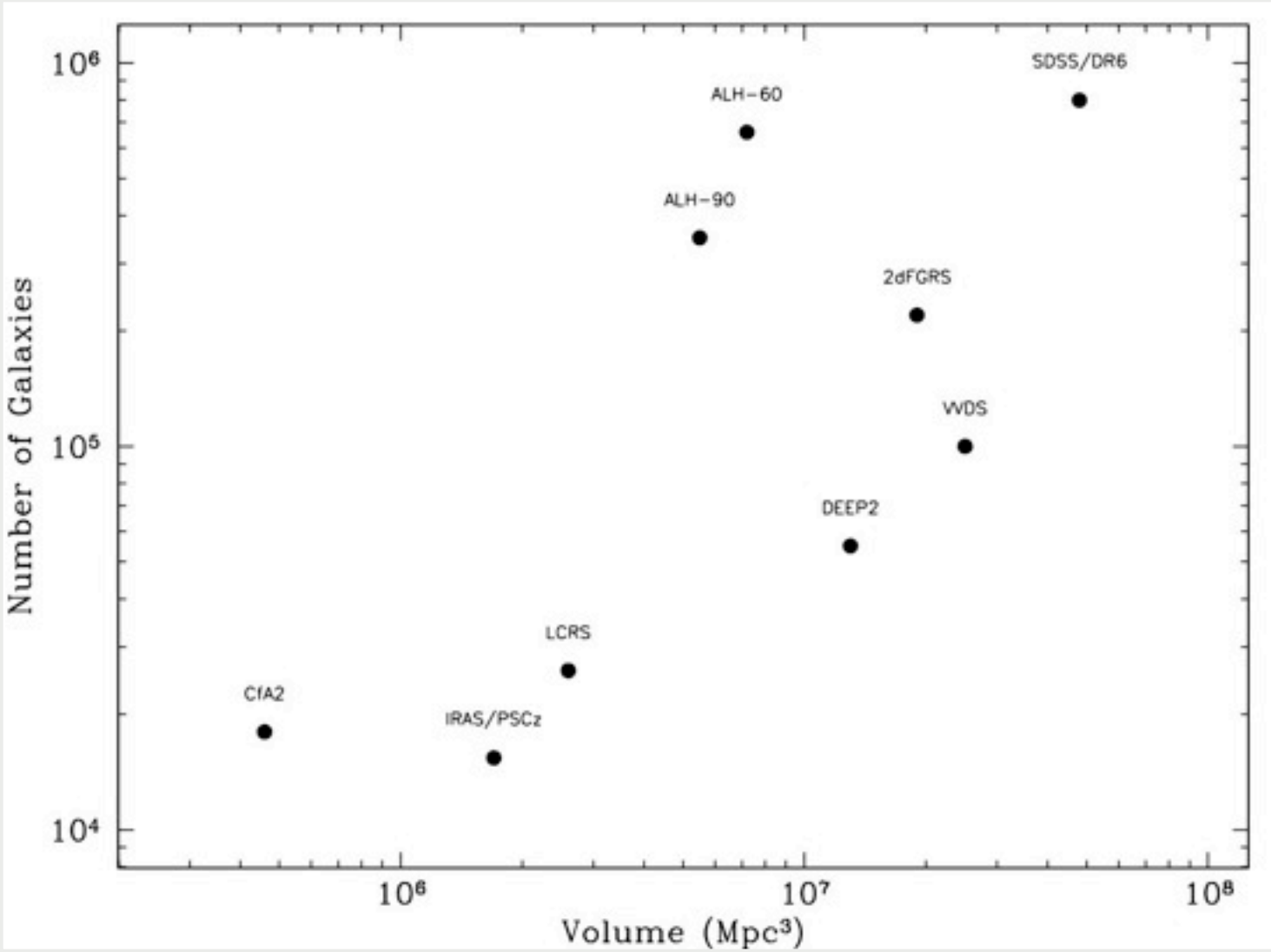
José María Quintana	IAA-CSIC Granada (España)
José Ruedas Sánchez	IAA-CSIC Granada (España)
Lara Santolaya Rams	OAUV Valencia (España)
Mauro Stefanon	OAUV Valencia (España)

P.I. & Co-P.I. / Post-Doctoral Fellows / PhD-Students

The ALHAMBRA-survey: Area vs. Magnitude



The ALHAMBRA-survey: Number of galaxies vs. Volume



ALHAMBRA SURVEY

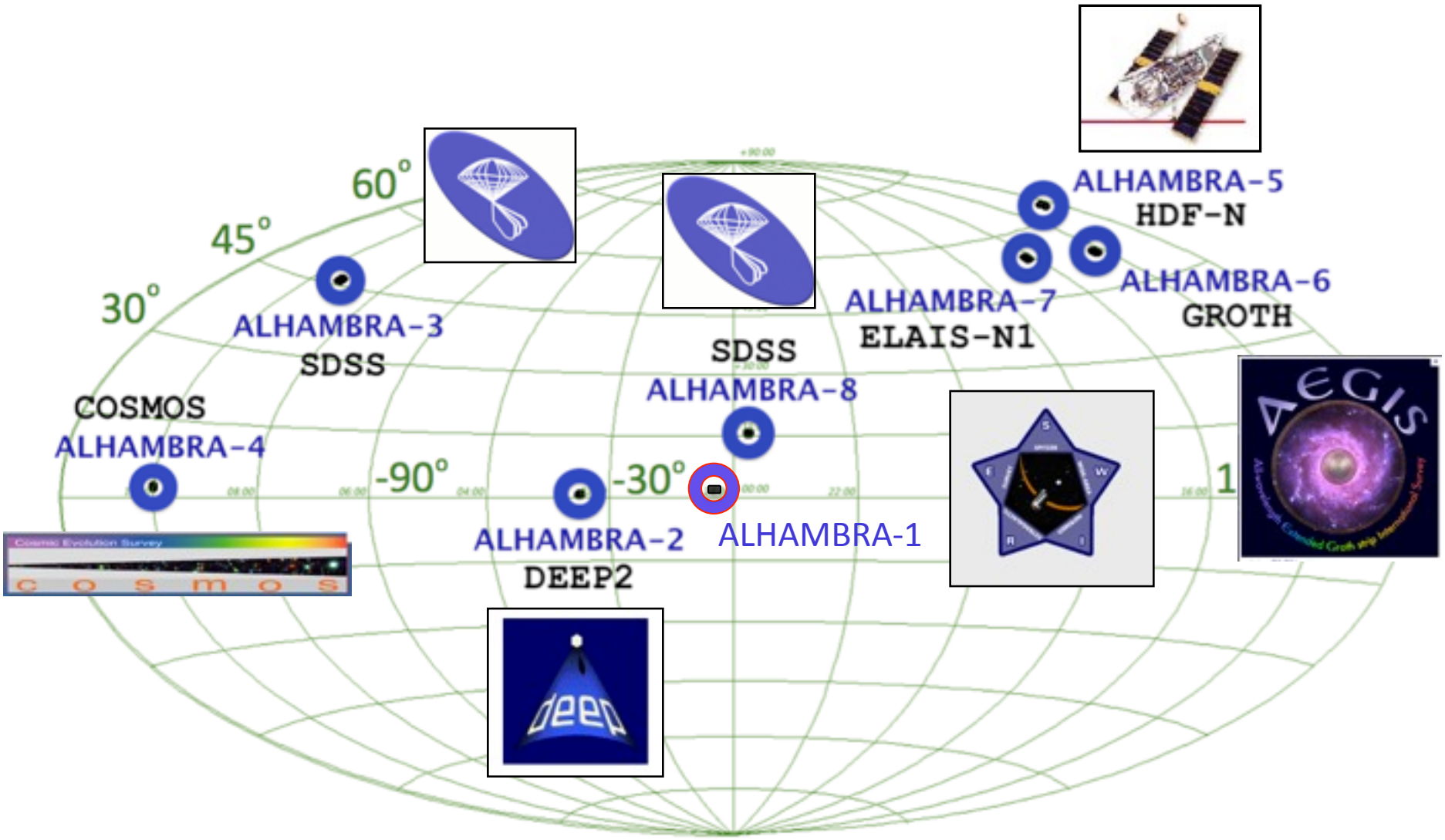
$$t = \int_0^t d_t = -\int_0^z \frac{dz}{H_0(1+z)\sqrt{\sum_i \Theta_{i0}(1+z)^{3(1+\omega_i)}}}$$

Study the Cosmological Evolution of Galaxies through the last ~10.000 million years ("Cosmological tomography").

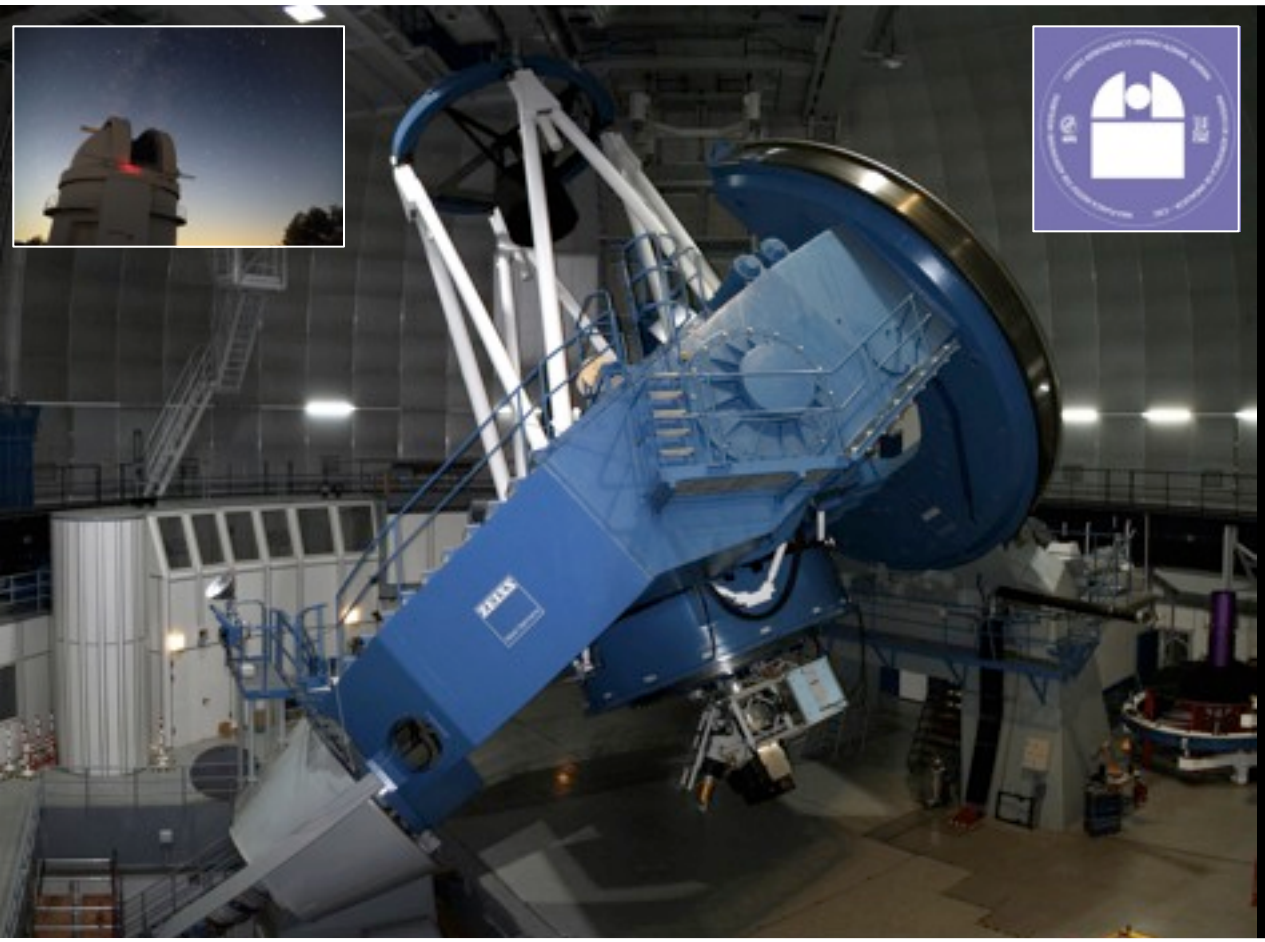
Differentiate between Cosmic evolution and Cosmic Variance by means of both: 1. the analysis of large Cosmological volumes (to average out local inhomogeneities), and 2. precise measurements of every galaxy redshift, without selection functions.

Fill-in a gap between shallow full-sky surveys (SDSS) and very deep pencil-beam surveys (COSMOS), providing a secure knowledge about the processes undertaking in between $0.1<z<1.5$

ALHAMBRA-survey: 4□², 8 fields, # ~600k sources



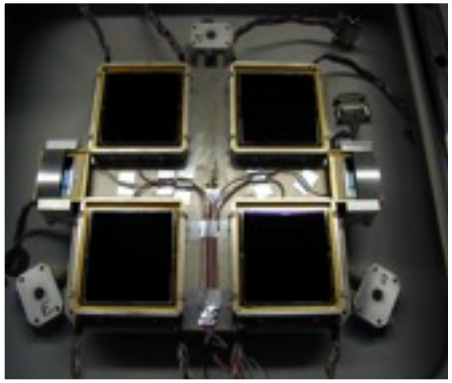
Observations: CAHA 3.5m Telescope



Period : 2005-2012
Obs.Time: ~700hrs
(on-target images)
Seeing: <1.5”

Cristóbal-Hornillos et al. (2009)
Cristóbal-Hornillos et al. (2014,prep.)

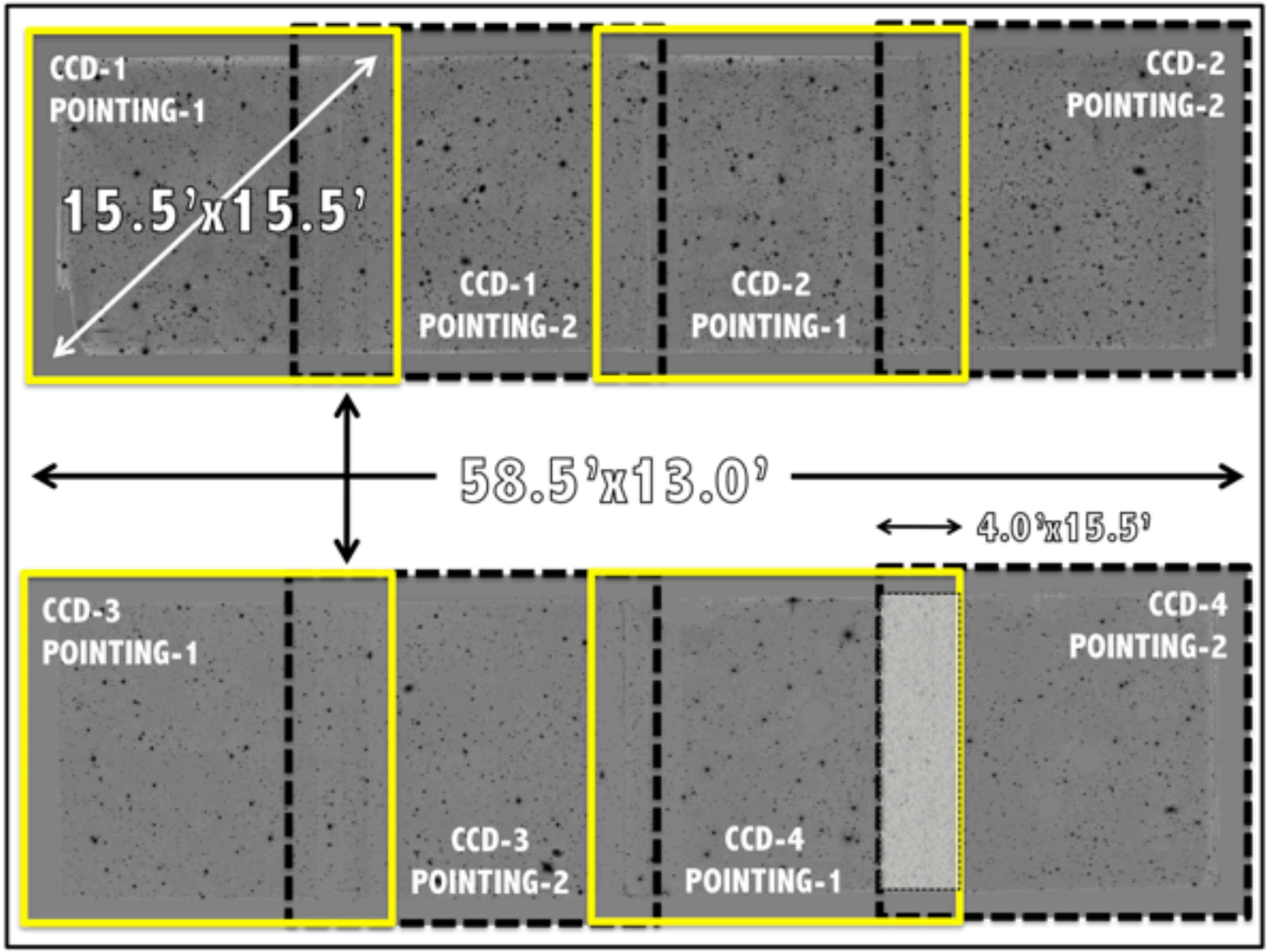
OPTICAL IMAGER: LAICA



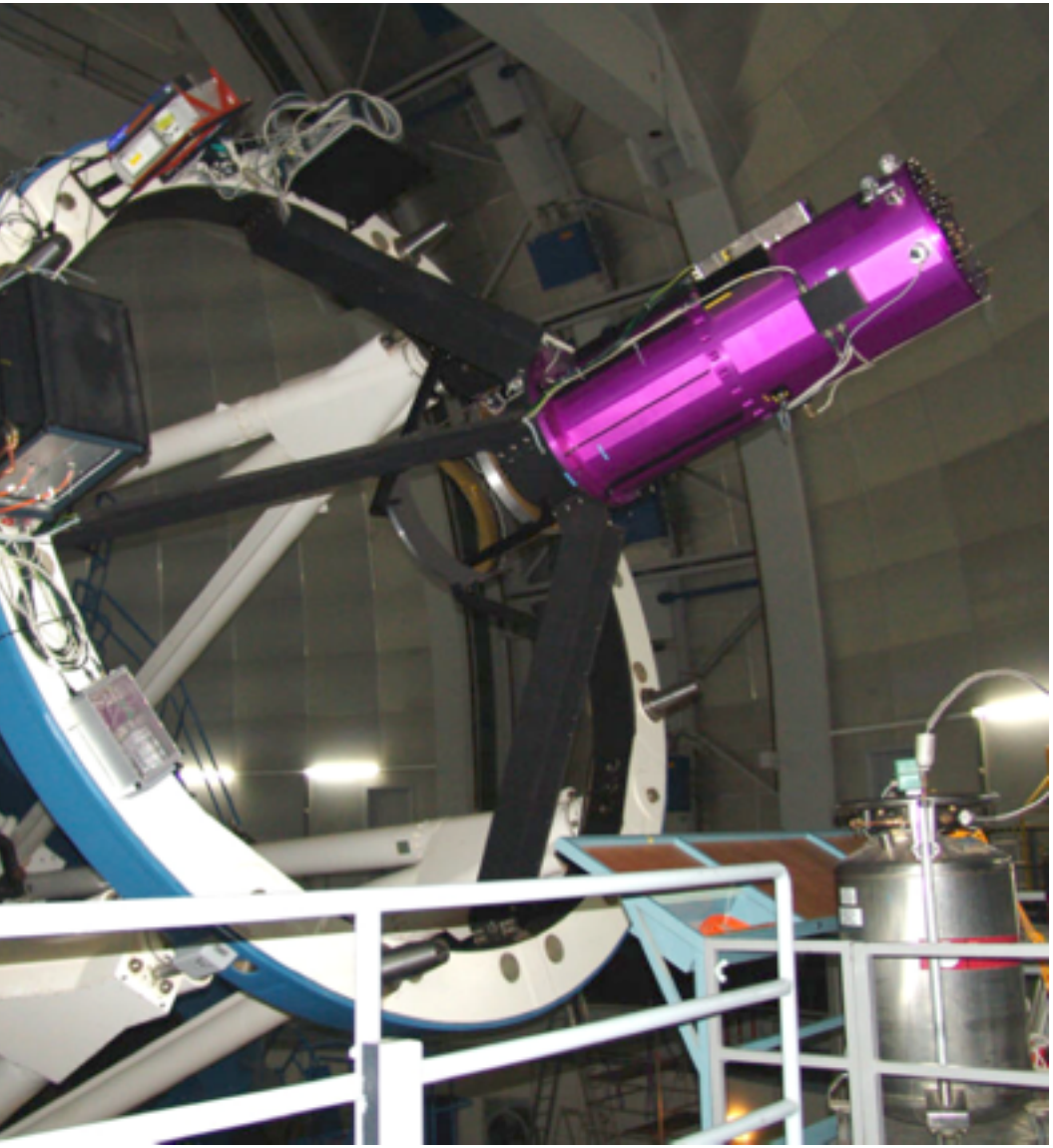
LAICA instrumental setup:

Telescope focus	Prime Focus K3
corrector	
F Ratio	f/3.9
FoV	44.36' x 44.36' (Wide
Field)	
Pixel scale	0.225 arcsec/
pixel	
Detector	2 x 2 mosaic of 4k x 4k
CCDs	
Filling factor	100%
Read-out time	< 100 seconds
Dynam. range	16 bit
Wavel. range	Atmospheric cutoff to
1micron	
Intrinsic IQ	0.3 arcsec
Geom. Distort.	<= 2%

The ALHAMBRA Layout & Notation



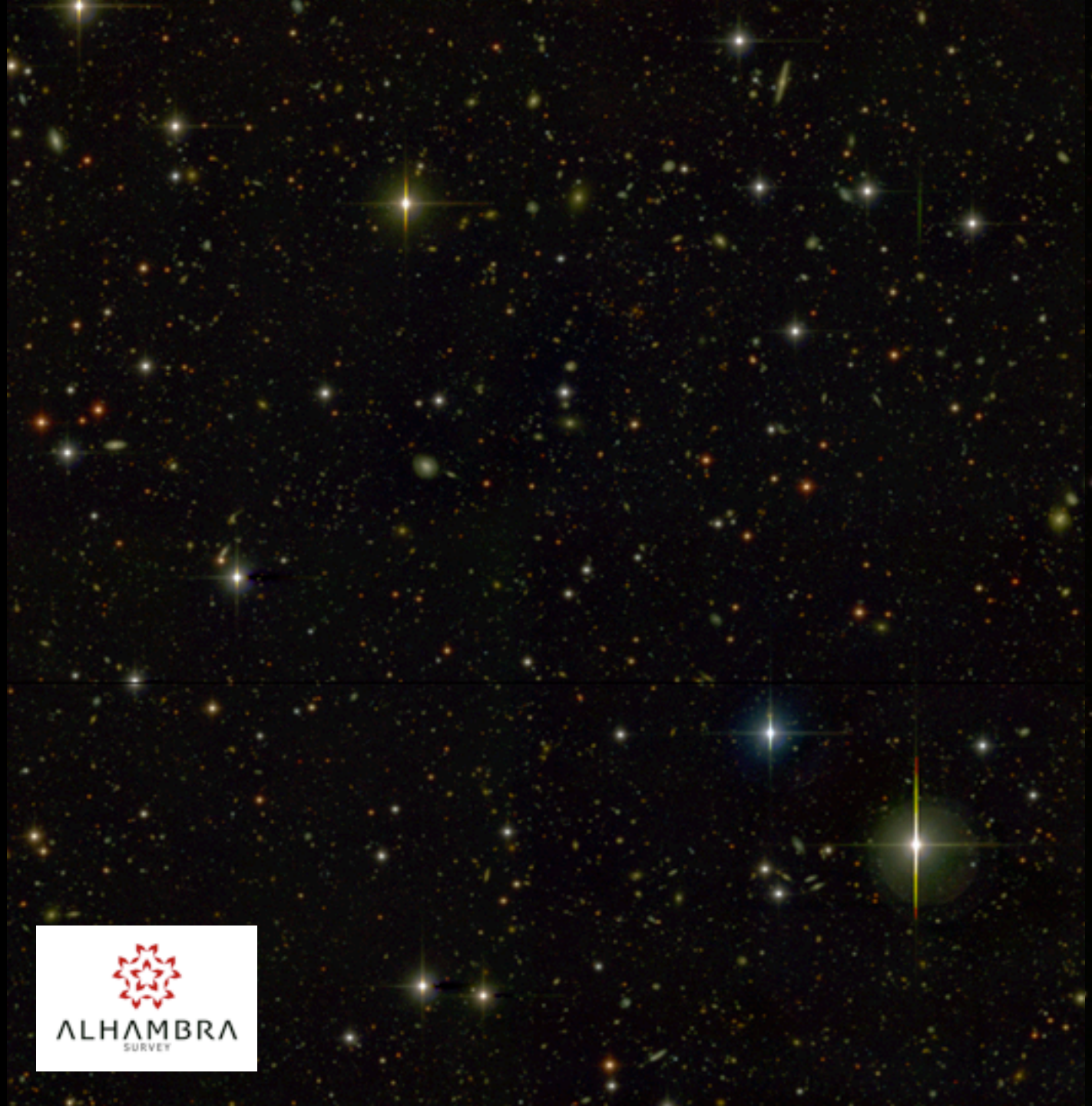
NIR IMAGER: OMEGA2000

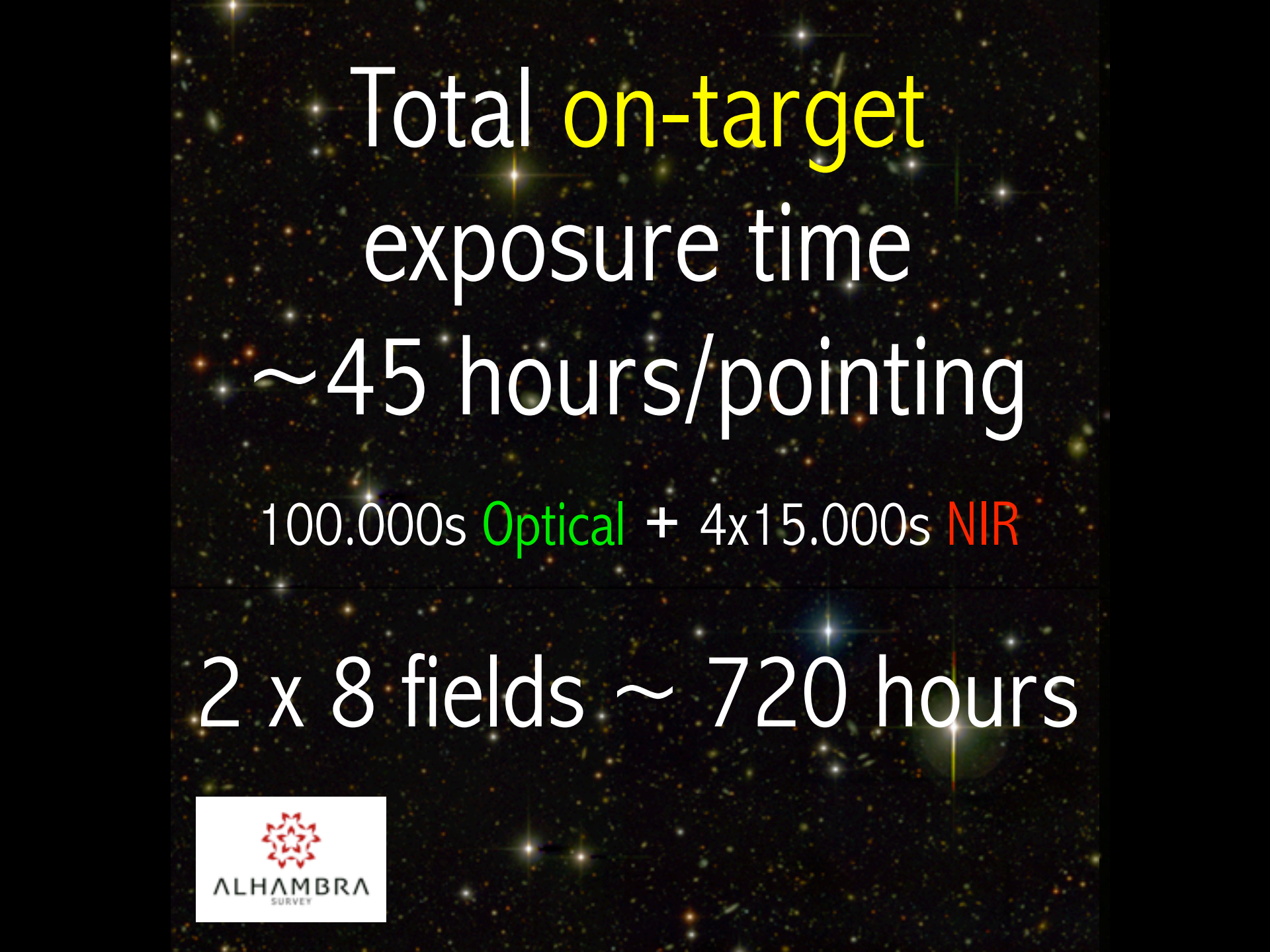


Omega2k instrumental setup:

Telescope focus	Prime Focus HAWAII-2
F Ratio	f/2.35
FoV	15.4' x 15.4'
Pixel scale	0.44962 arcsec/pixel
Detector	2048 x 2048 pixels
Filling factor	100%
Read-out time	< 200 seconds
Dynam. range	32 bit
Wavel. range	< 2600 nm (Quant.Eff)
Intrinsic IQ	0.12 arcsec
Geom. Distort.	< 1%
Data format	FITS

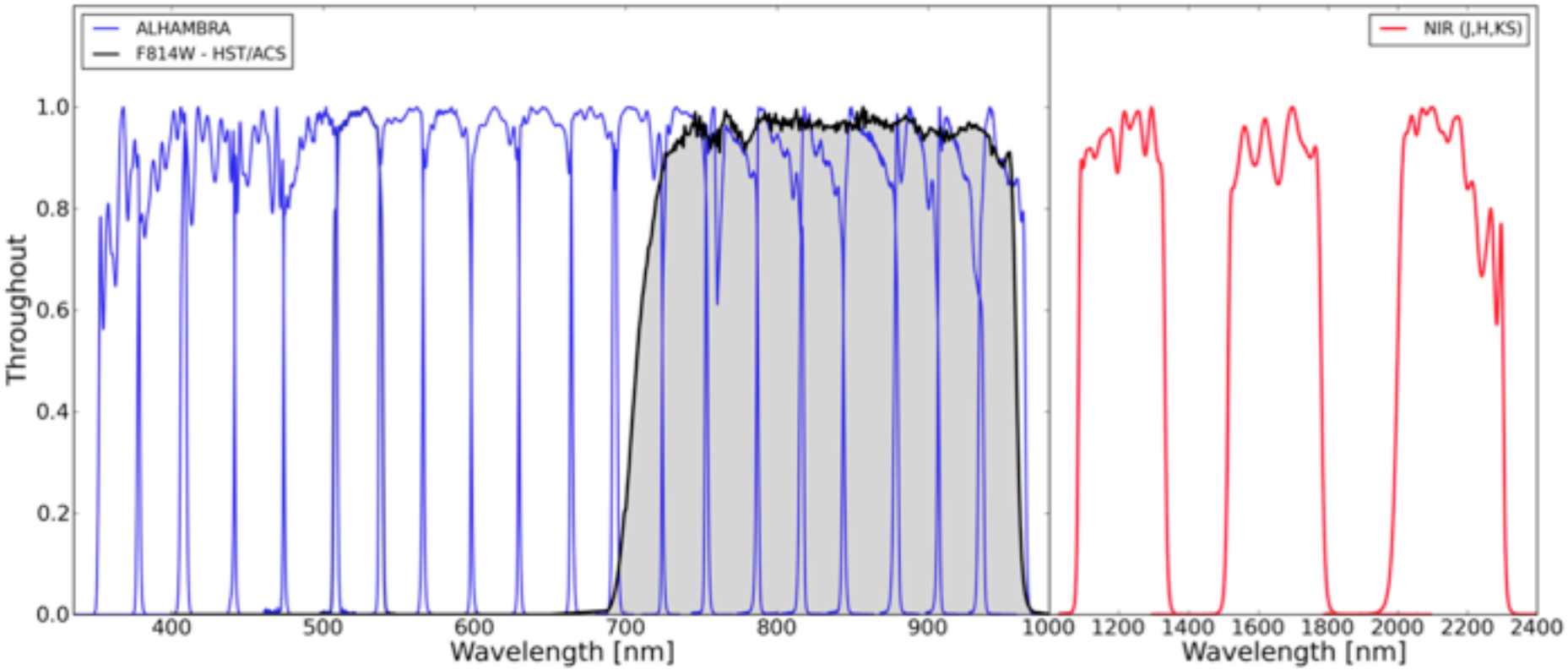

SDSSIII


ALHAMBRA
SURVEY

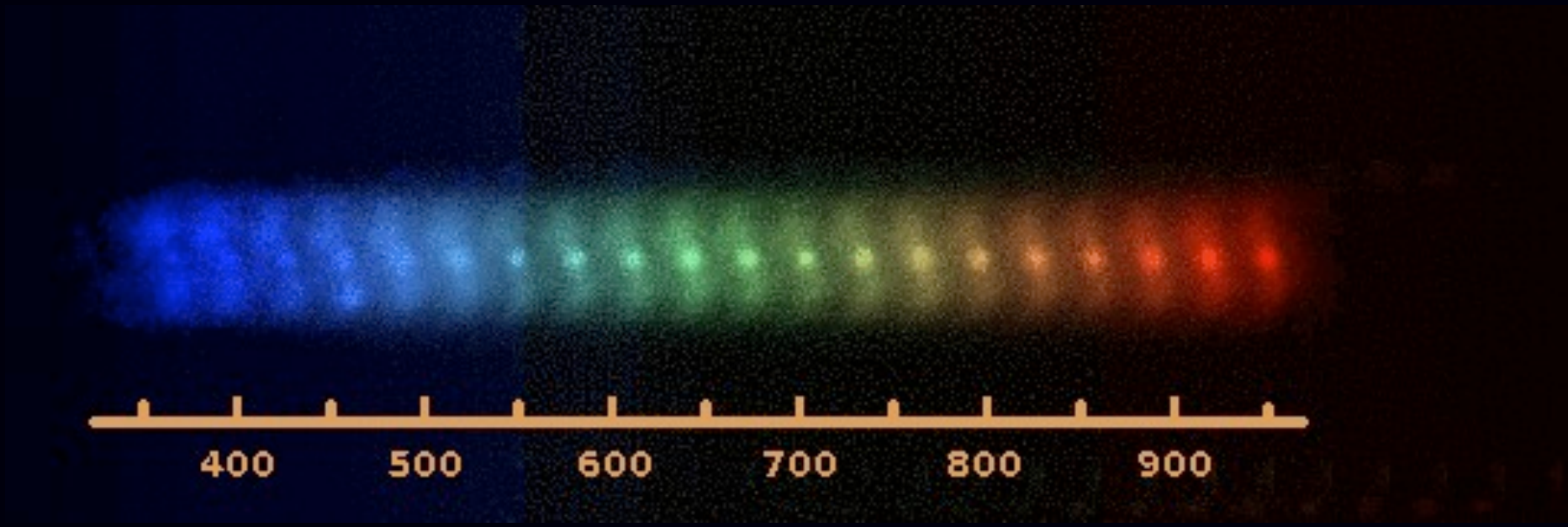

Total on-target
exposure time
~45 hours/pointing
100.000s Optical + 4x15.000s NIR
2 x 8 fields ~ 720 hours
ALHAMBRA
SURVEY

The ALHAMBRA survey
Filter system

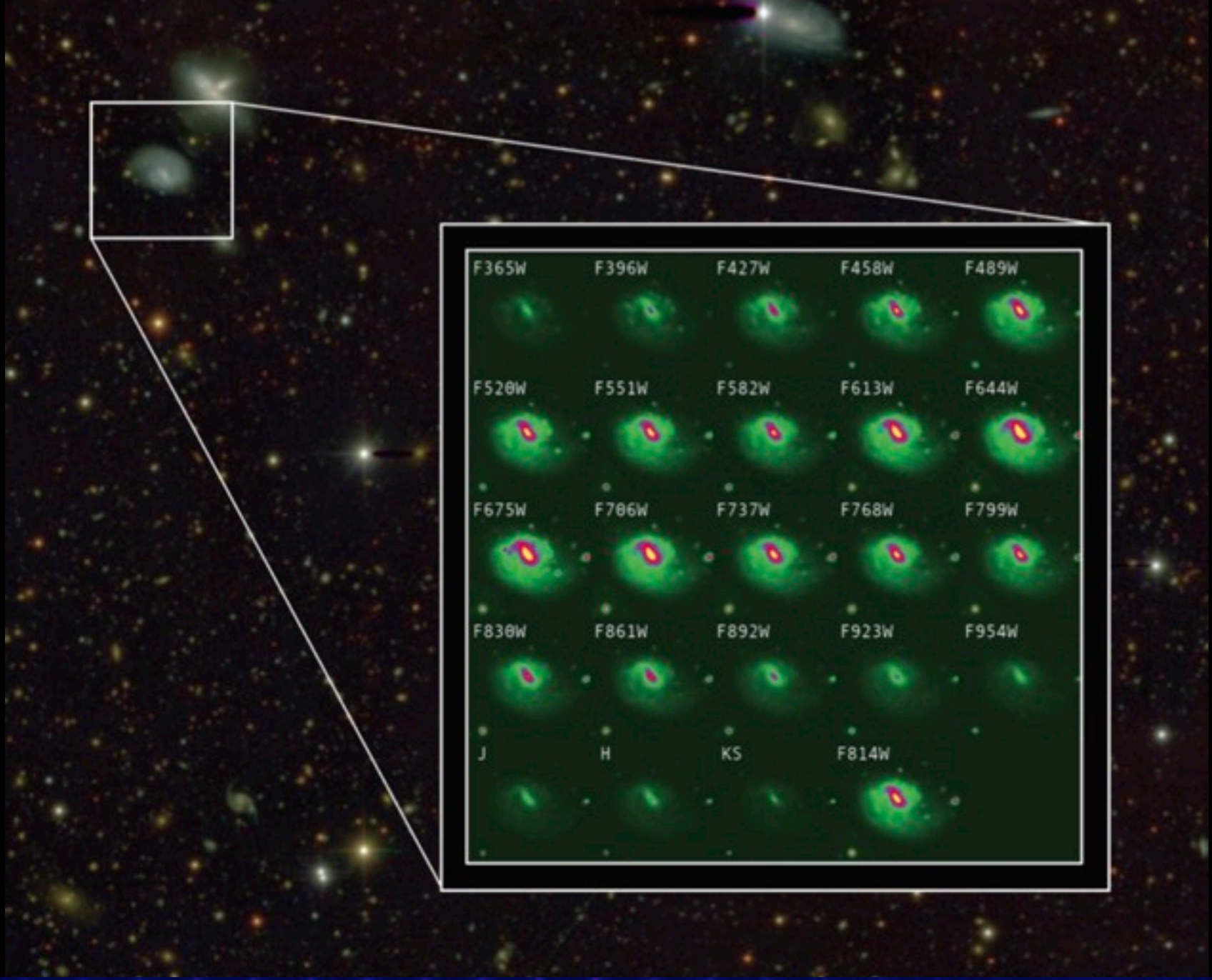
Moles et al. 2008
Benítez et al. 2009
Aparicio-Villegas et al. 2010

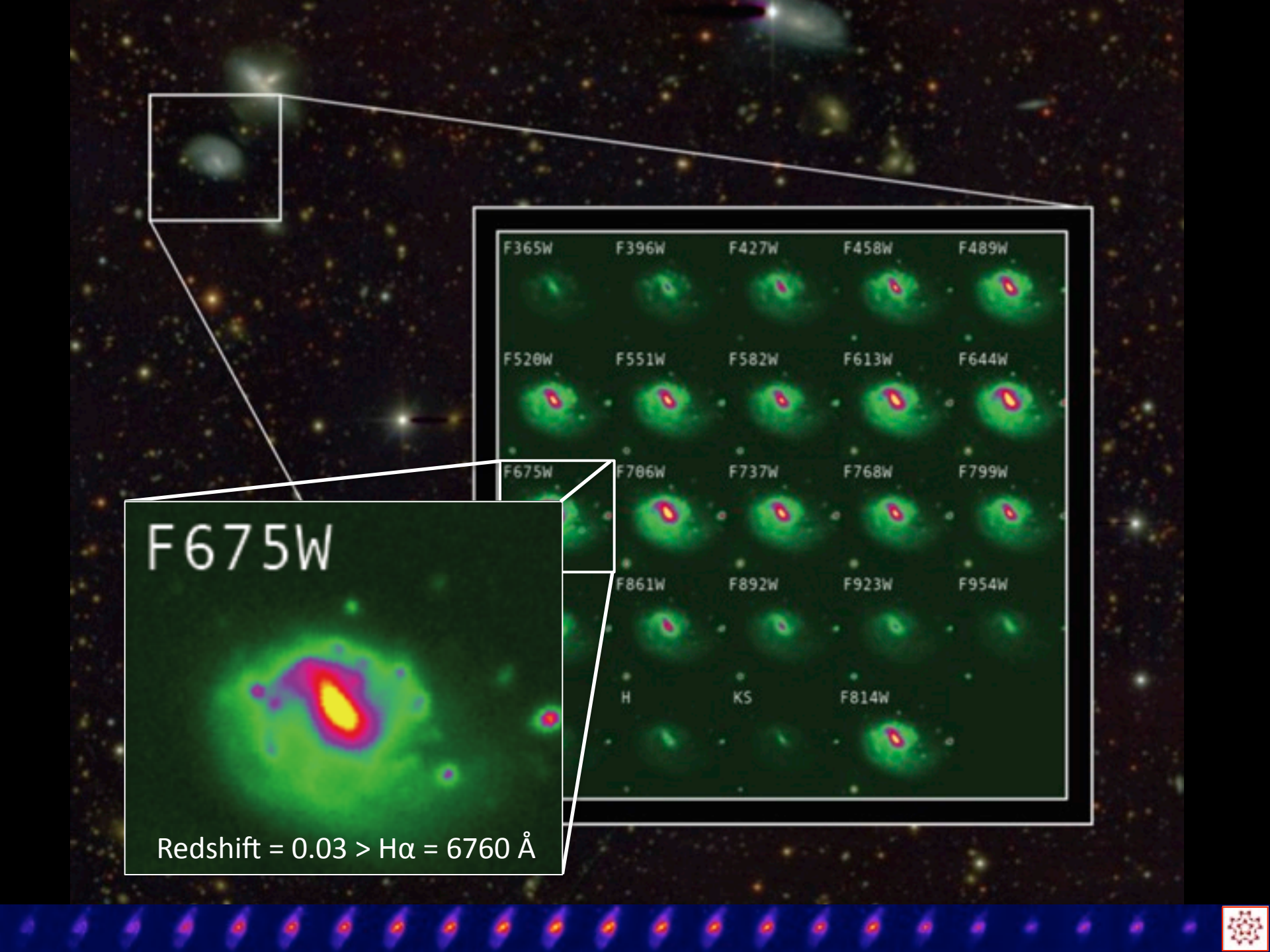


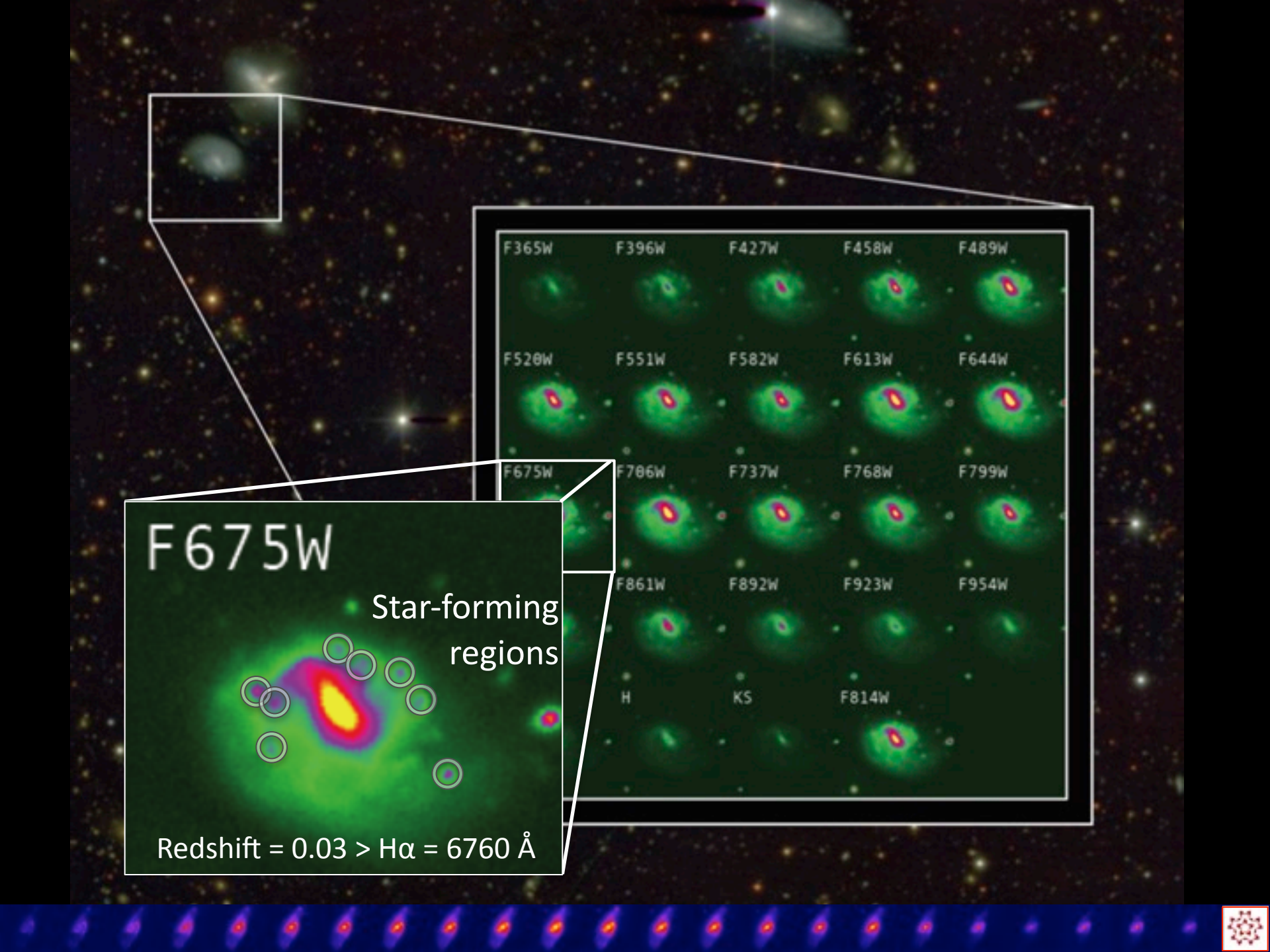
ALHAMBRA
SURVEY



ALHAMBRA data are similar, in concept, to objective prism surveys of the past

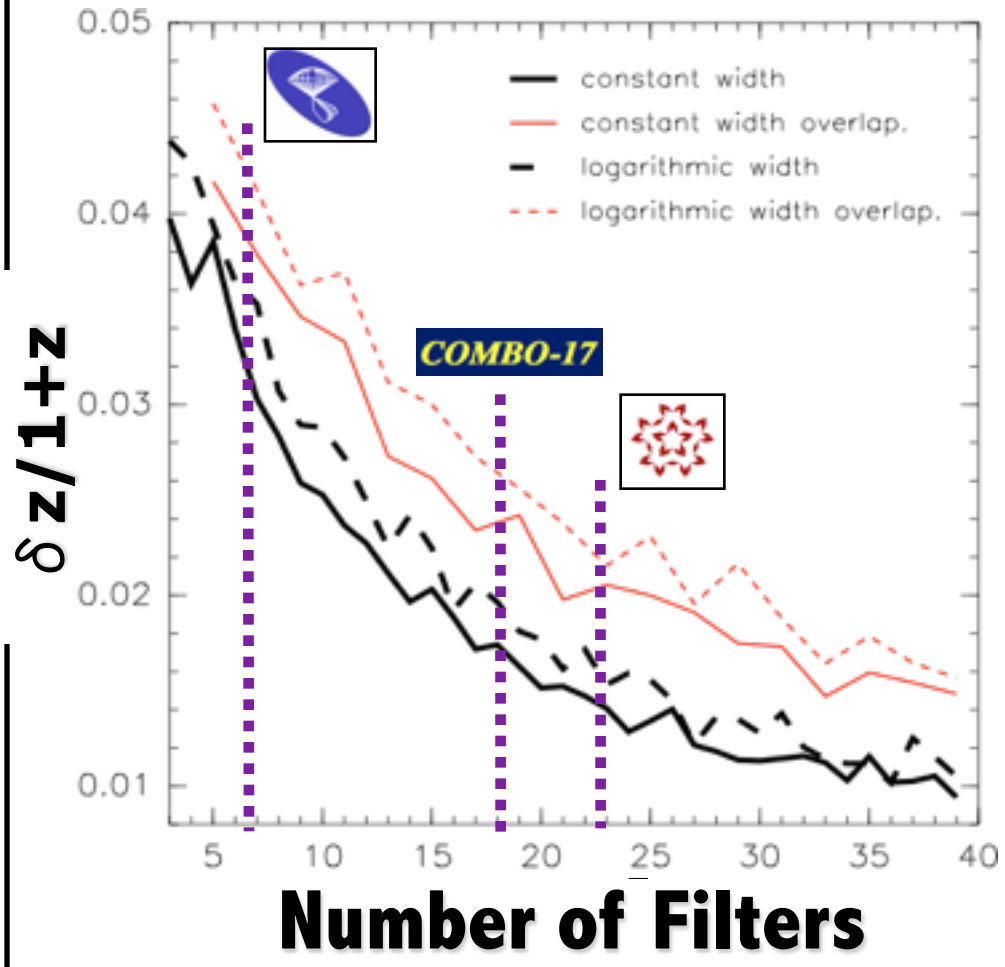

F365W
F396W
F427W
F458W
F489W
F520W
F551W
F582W
F613W
F644W
F675W
F706W
F737W
F768W
F799W
F830W
F861W
F892W
F923W
F954W
J
H
KS
F814W

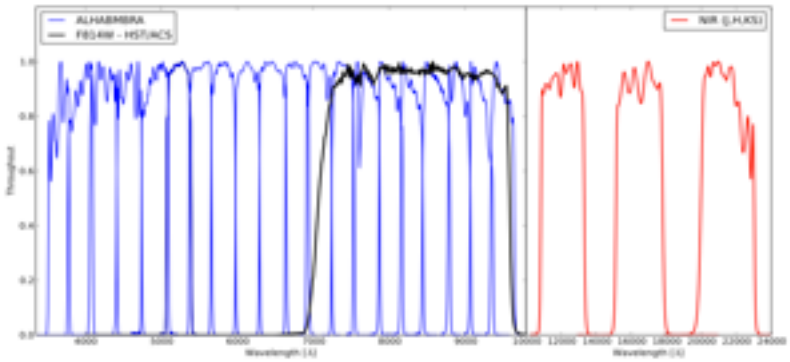

F365W
F396W
F427W
F458W
F489W
F520W
F551W
F582W
F613W
F644W
F675W
F706W
F737W
F768W
F799W
F861W
F892W
F923W
F954W
H
KS
F814W
F675W
Redshift = 0.03 > Hα = 6760 Å


F365W
F396W
F427W
F458W
F489W
F520W
F551W
F582W
F613W
F644W
F675W
F706W
F737W
F768W
F799W
F861W
F892W
F923W
F954W
H
KS
F814W
F675W
Star-forming regions
Redshift = 0.03 > Hα = 6760 Å

Number of filters vs Accuracy

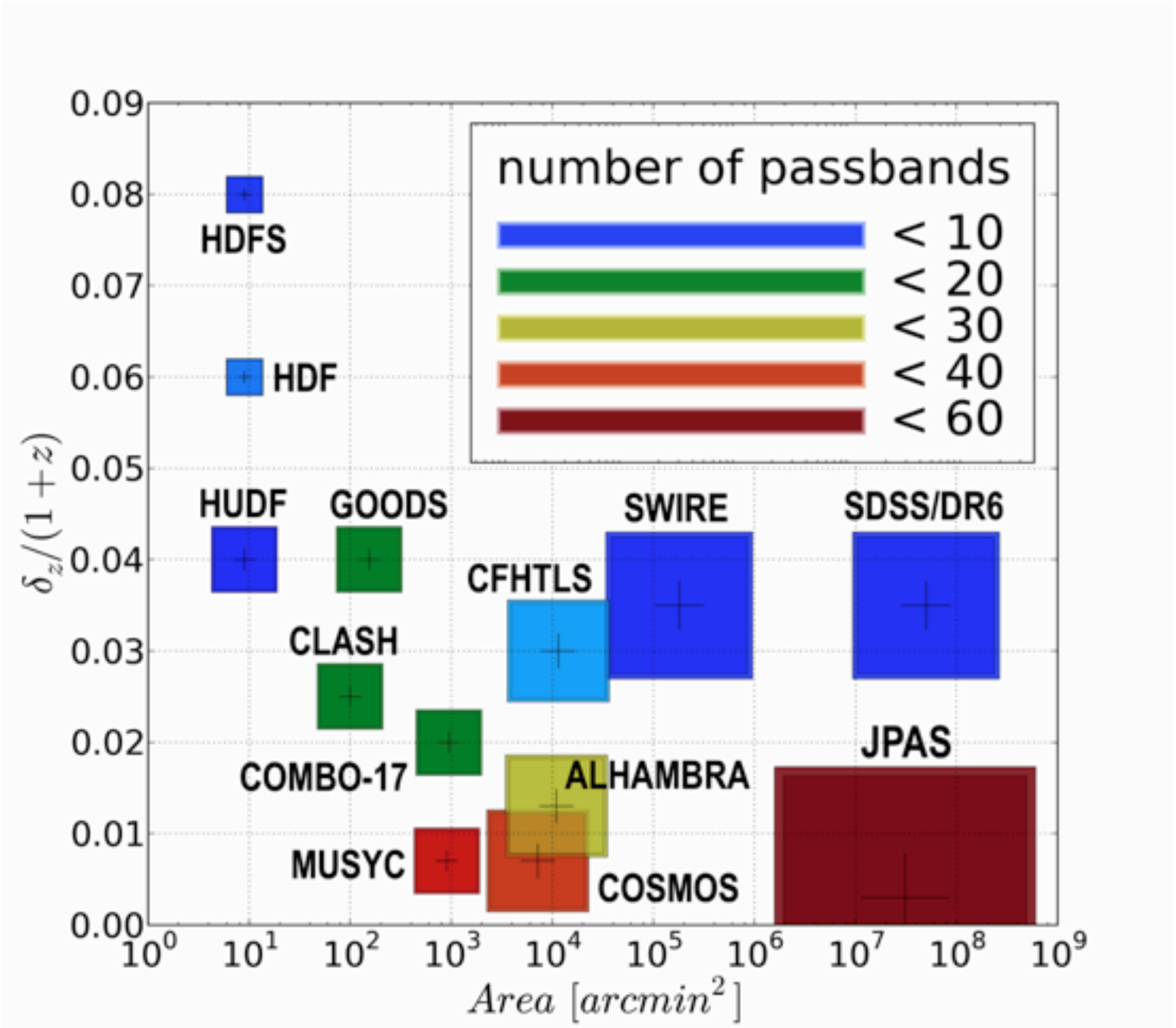
Benítez et al. 2009



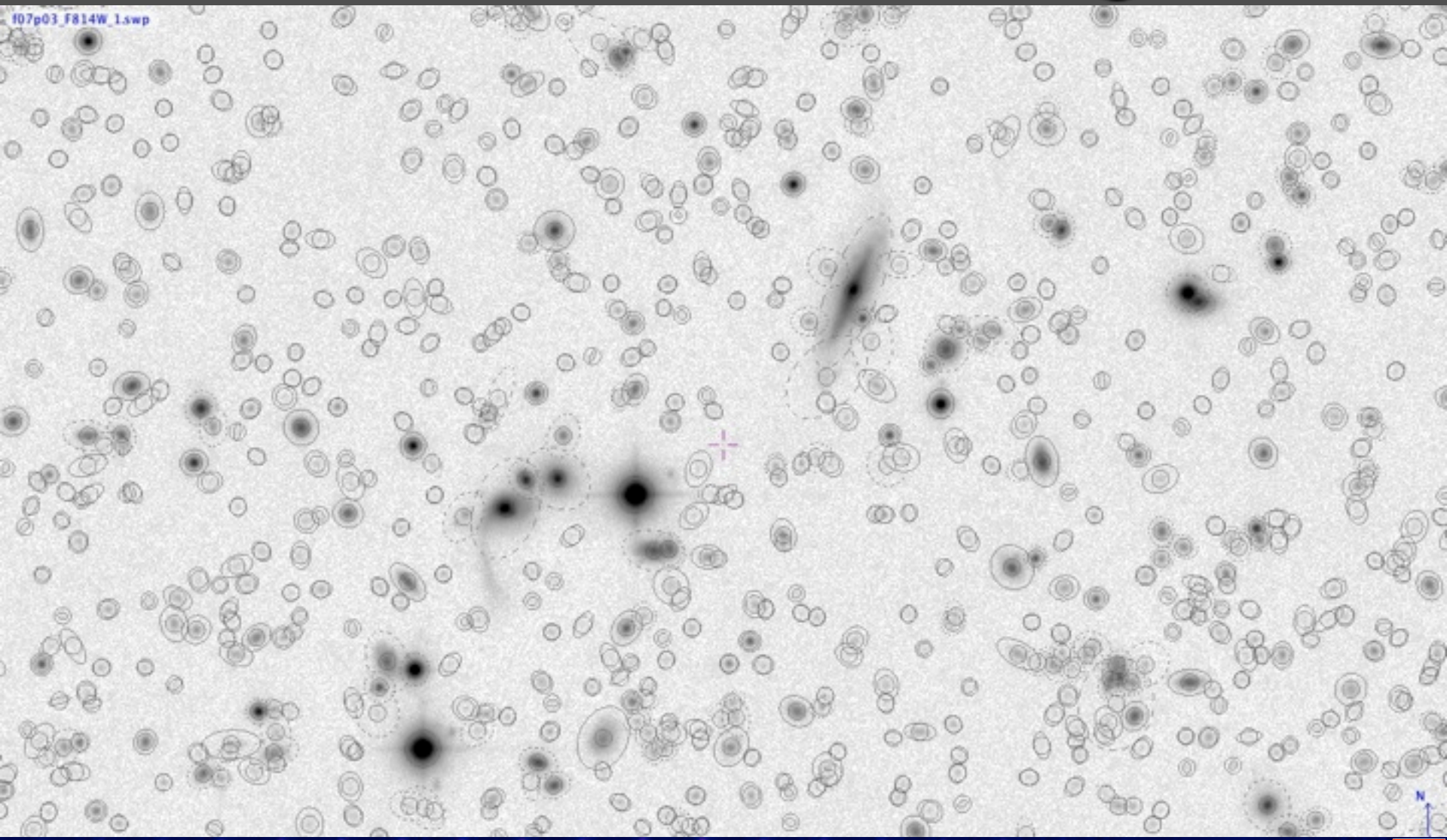


Photometric Redshift surveys

survey	Reference	Bands	$\delta_z/(1+z)$
HDF	Sawicki (1997)	4	0.080
SDSS/DR6	Csabai (2003)	5	0.035
SWIRE	Rowan-Robinson (2008)	5	0.035
HUDF	Coe (2006)	6	0.040
HDF	Fernández-Soto (1999)	7	0.060
CFHTLS	Ilbert (2006)	9	0.030
GOODS	Dahlen (2010)	12	0.040
CLASH	Molino (2013, prep.)	16	0.025
COMBO-17	Wolf (2004)	17	0.020
ALHAMBRA	Molino (this work)	23	0.013
COSMOS	Ilbert (2009)	30	0.007
MUSYC	Cardamone (2010)	32	0.007
JPAS	Benítez (2009a, 2013, prep.)	59	0.003

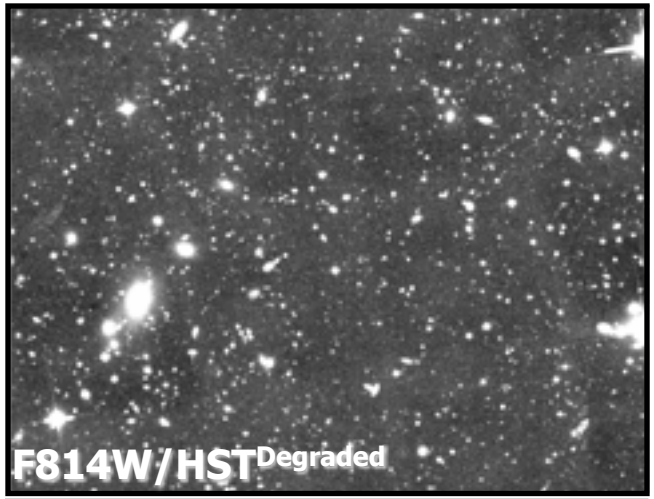

number of passbands
< 10
< 20
< 30
< 40
< 60
HDFS
HDF
HUDF
GOODS
SWIRE
SDSS/DR6
CFHTLS
CLASH
COMBO-17
ALHAMBRA
JPAS
MUSYC
COSMOS
$\delta_z/(1+z)$
$Area\ [arcmin^2]$
0.00
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
10^0
10^1
10^2
10^3
10^4
10^5
10^6
10^7
10^8
10^9

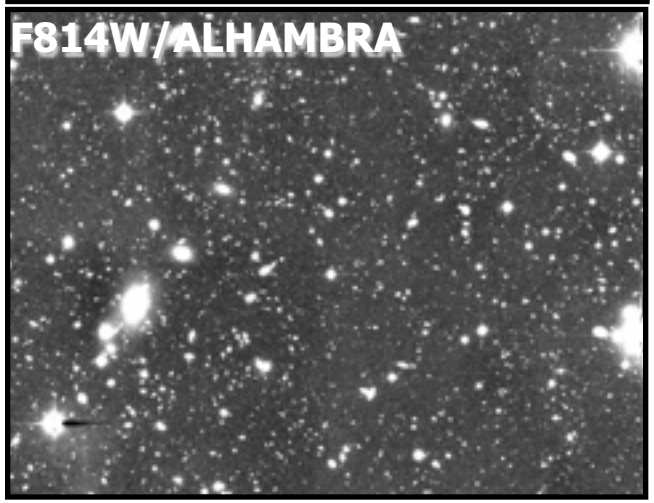
Detection Images

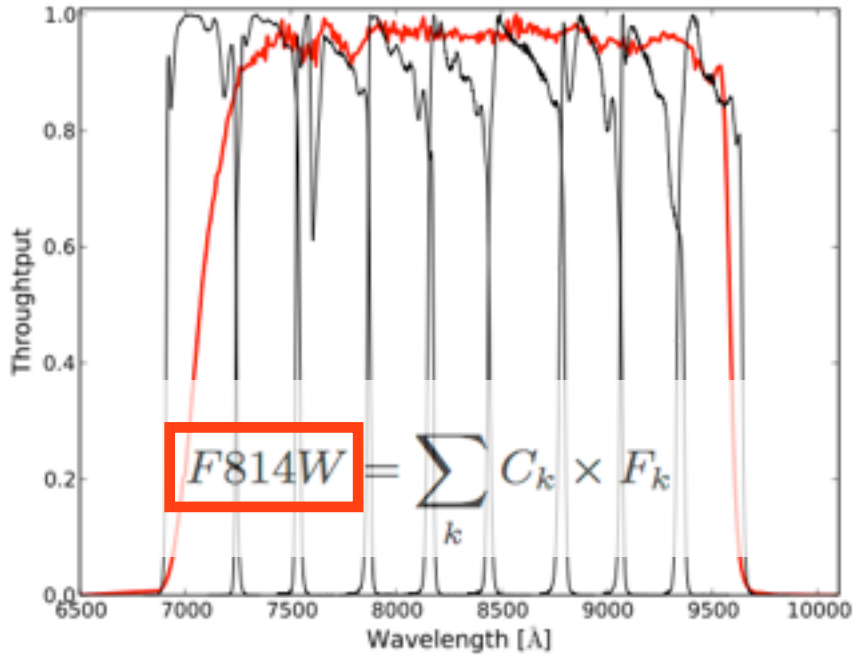


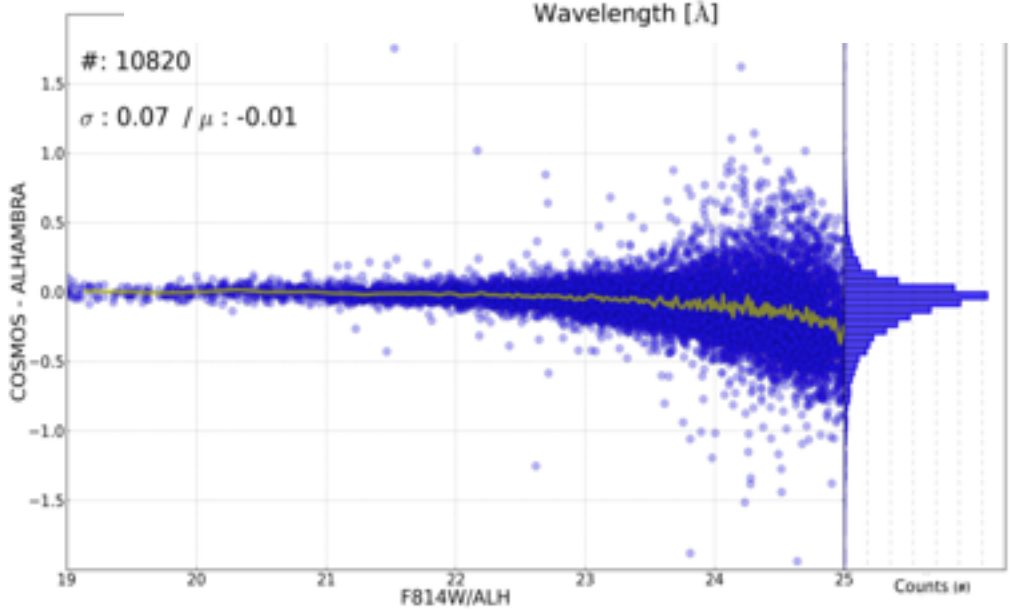
Synthetic Images F814W/ACS

Transformation equations computed
from galaxy colors instead of stellar colors.

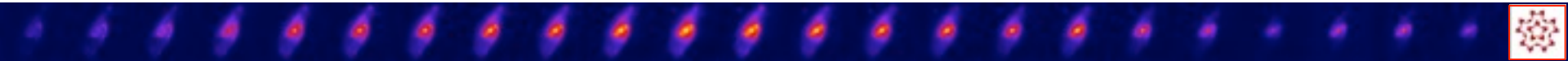








Bayesian Photometric Redshifts

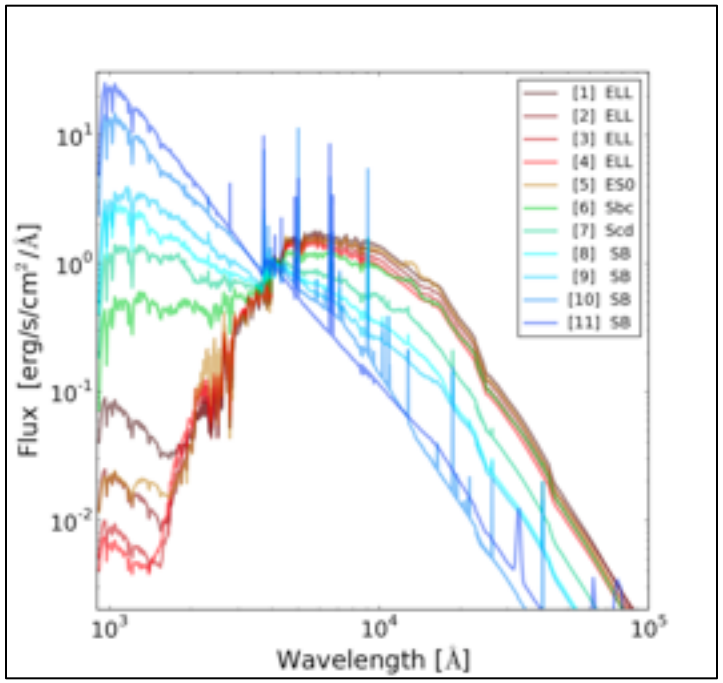


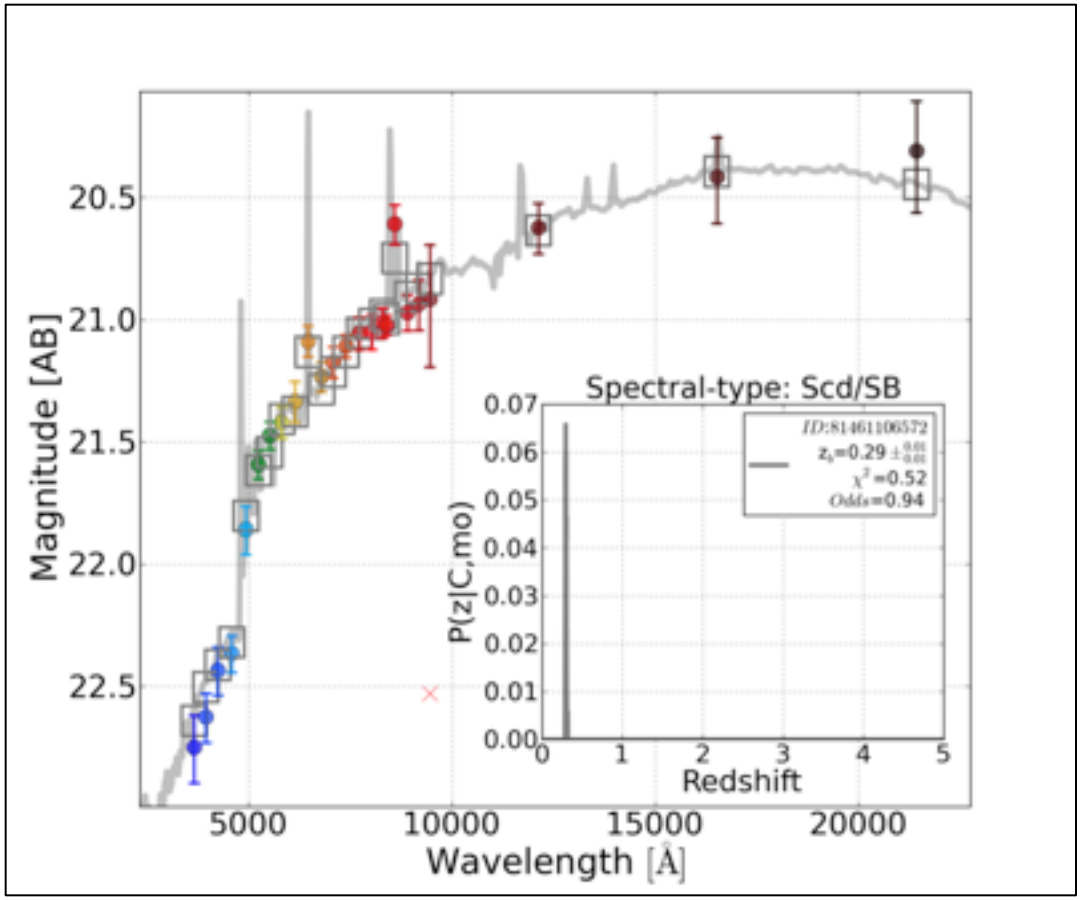
(Benítez, N. 2000, ApJ, 536, 571)

New BPZ (v2.0)

- SED-fitting method, where a maximum likelihood is weighted by a prior probability.
- Provides the most likely redshift, spectral-type, mass content and Absolute Magnitudes.

$$\chi^2 = \sum_{i=1}^{N} \frac{[f_i^{obs} - s f_i^{temp}(z,T)]^2}{\sigma_i^2}$$

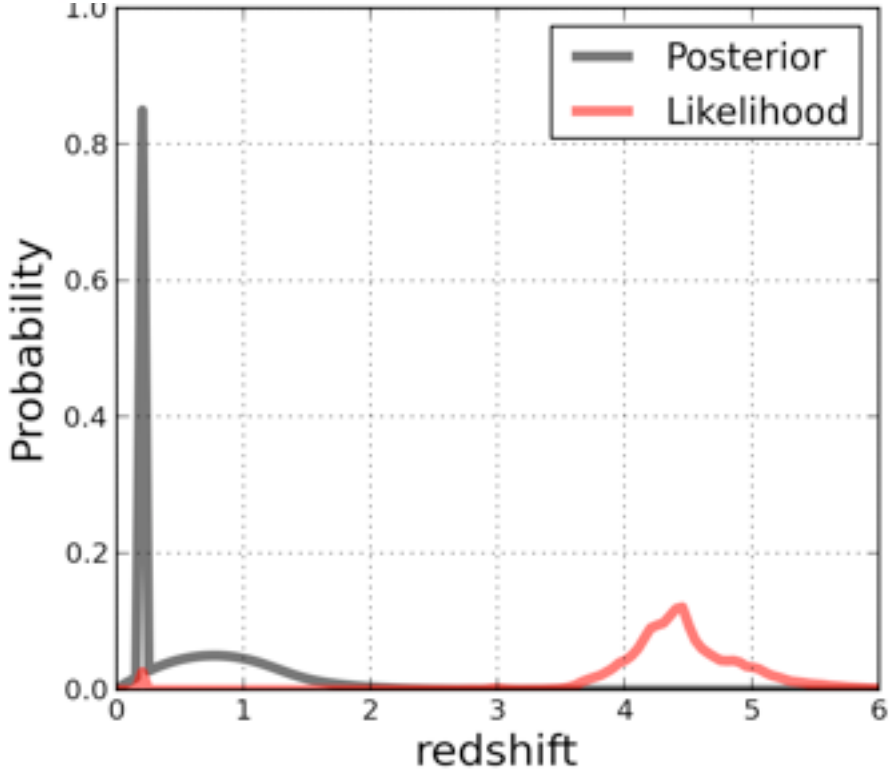




(Benítez, N. 2000, ApJ, 536, 571)

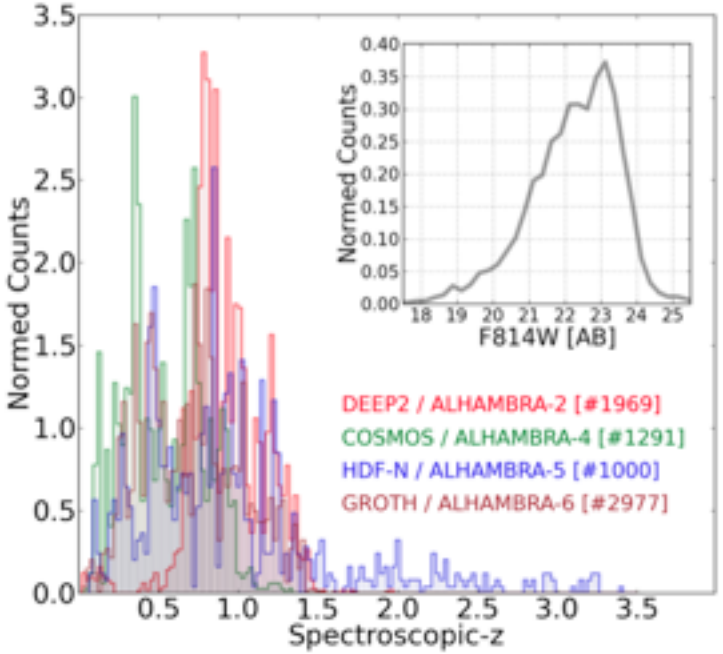
LIKELIHOOD* PRIOR

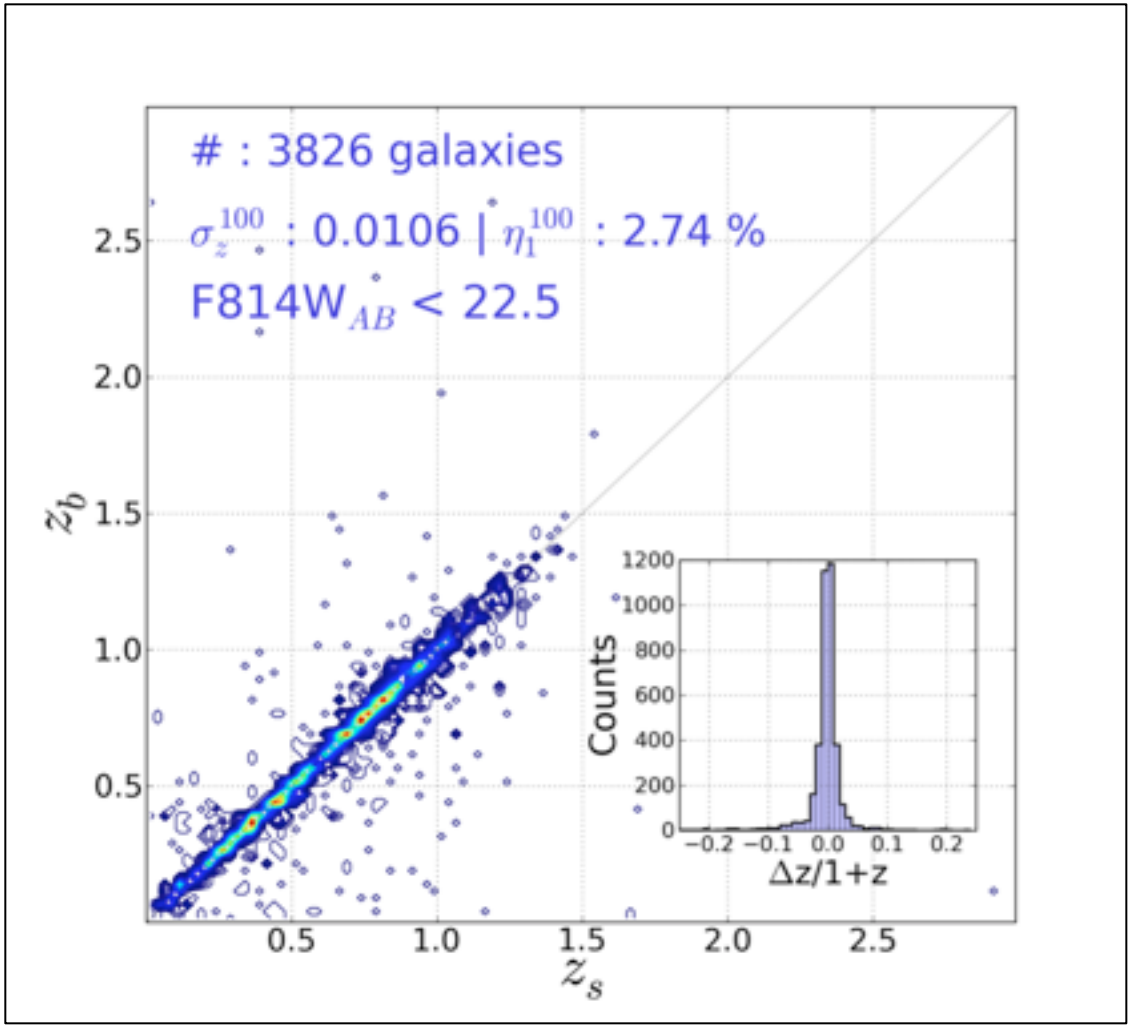
$$p(z|C,m_0) = \sum_T p(z,T|C,m_0) \propto \sum_T p(z,T|m_0)p(C|z,T)$$



Expected photometric redshift accuracy

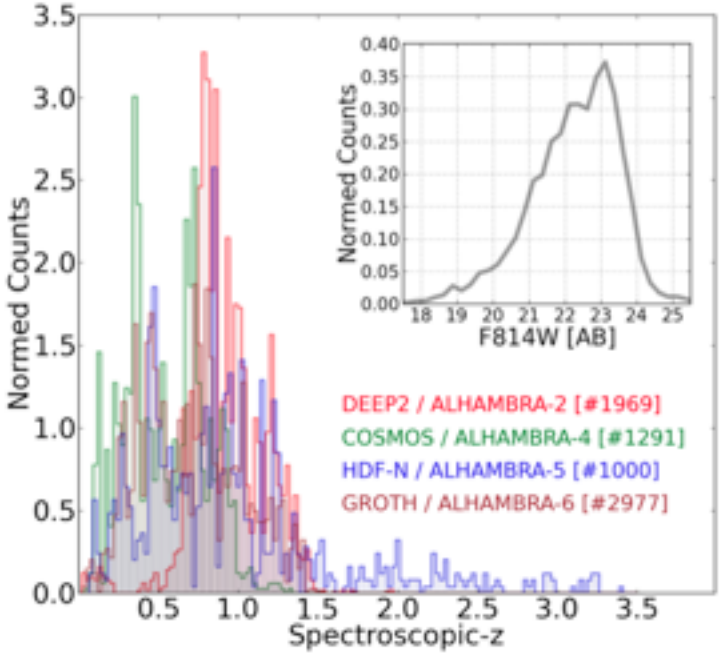
Spectroscopic-Sample

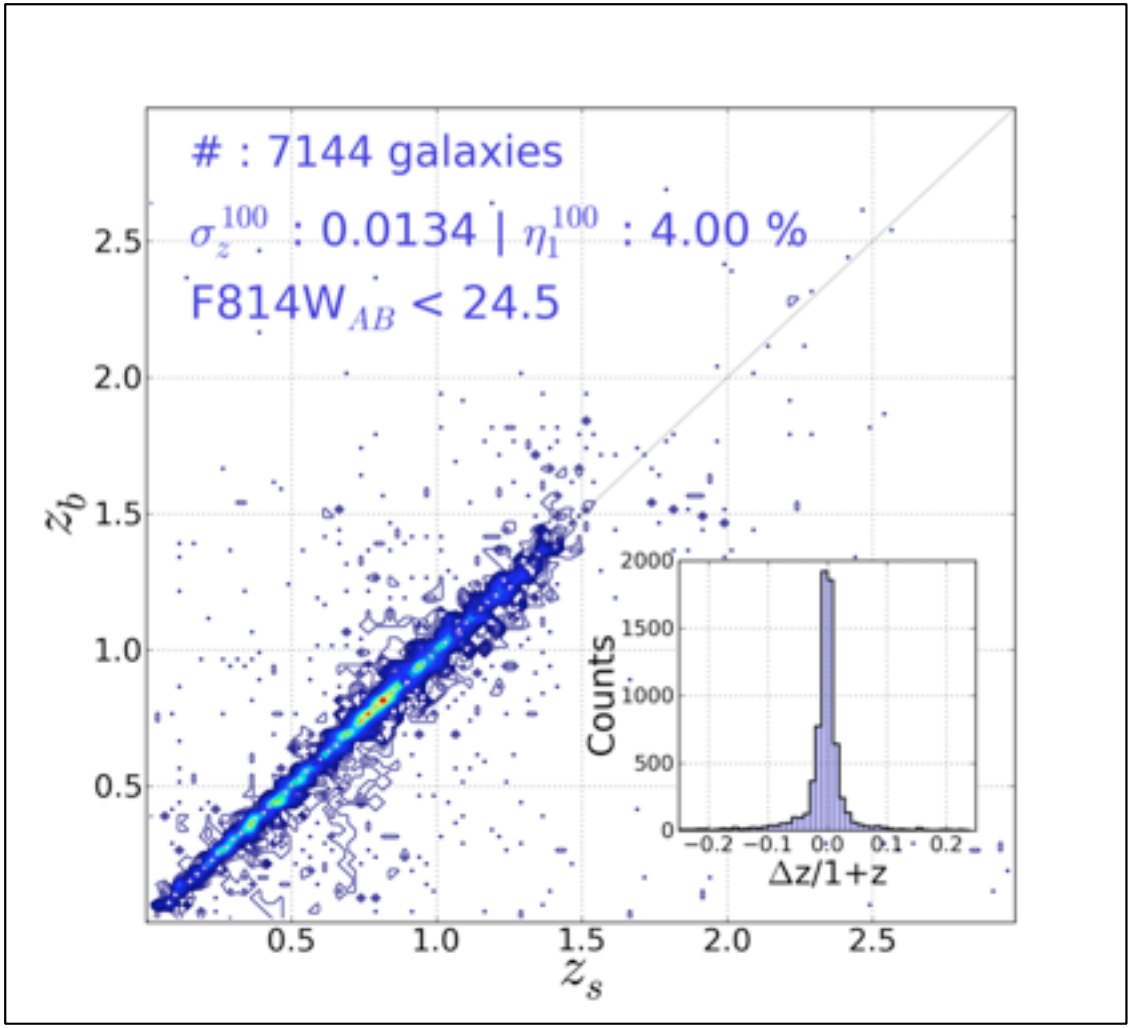




Expected photometric redshift accuracy

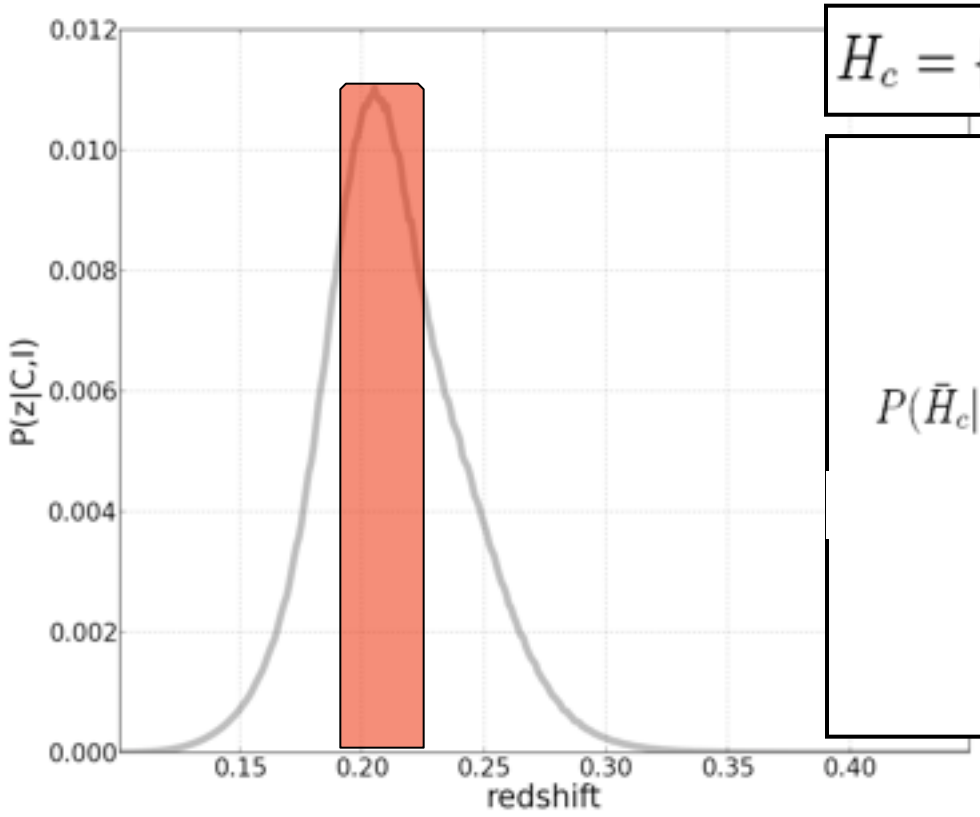
Spectroscopic-Sample





The secret is in the **ODDs**:

- The ODDs parameter represents the amount of integrated probability within a fixed interval around the main peak of the p(z) distribution.
- The ODDS parameter is a measurement of the quality of the photo-z estimation, making possible to select very secure and accurate photometric-z.



$$H_c = \{|z - z_c| < \Delta z\}$$

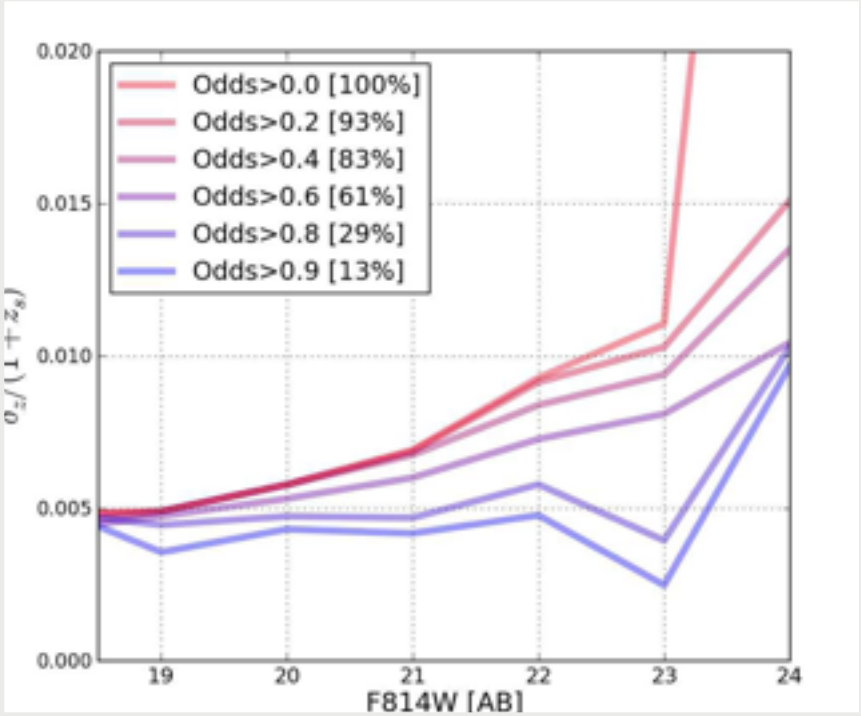
$$P(H_c|D) = \int_{z_c-\Delta z}^{z_c+\Delta z} dz p(z|D)$$

$$P(\bar{H}_c|D = \int_0^{z_c-\Delta z} dz p(z|D) + \int_{z_c+\Delta z}^{\infty} dz p(z|D)$$

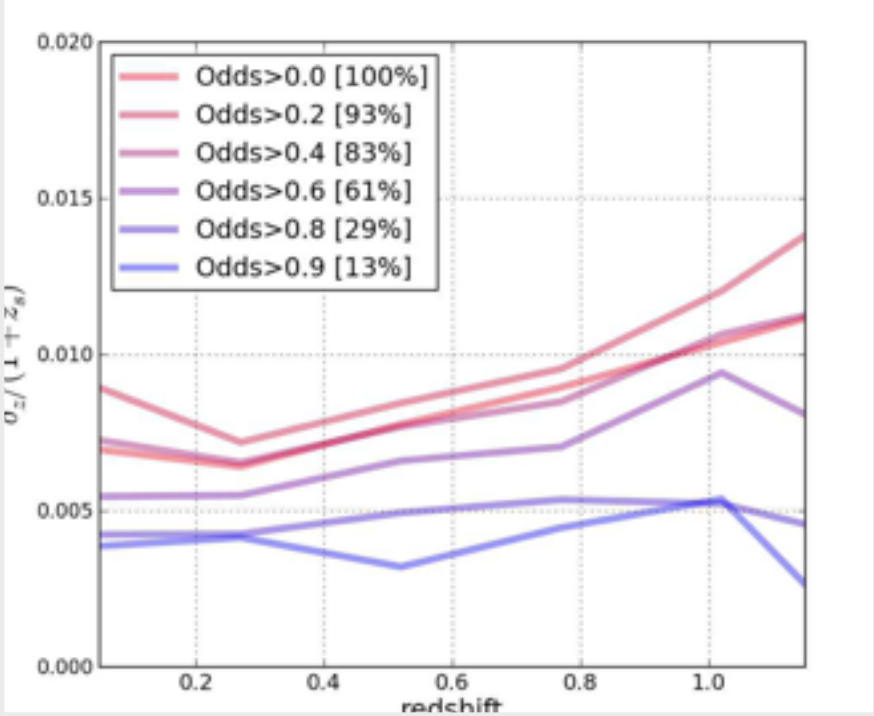
$$O(H_c|D) = \frac{P(H_c|D)}{P(\bar{H}_c|D}$$

Expected accuracy as a function of…

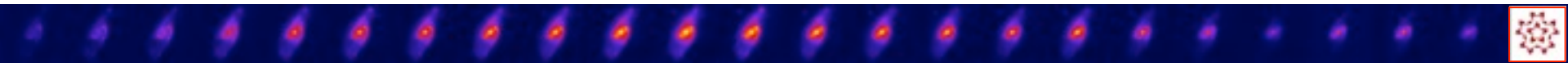
Magnitude



Redshift

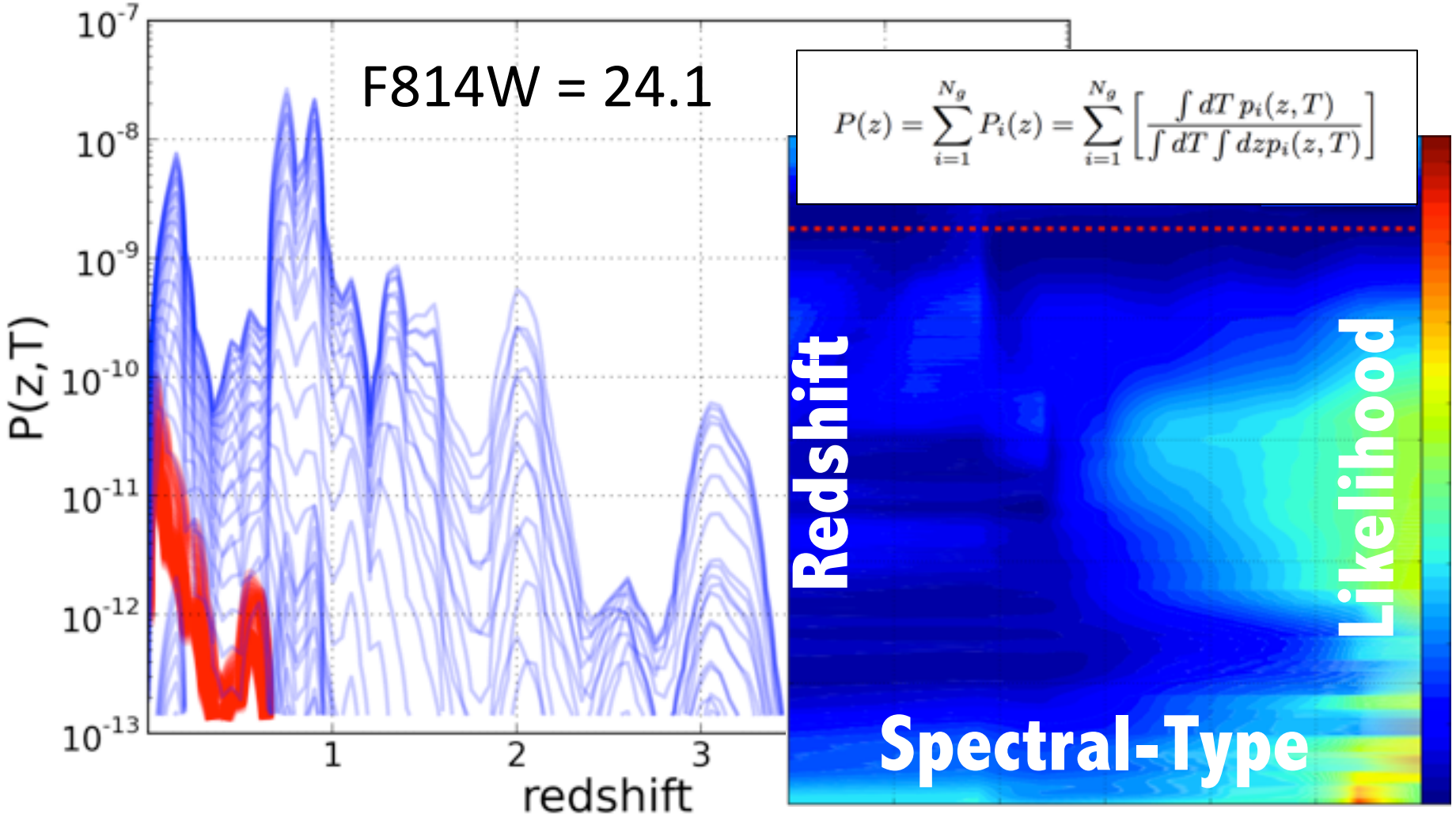


Cosmic Variance
vs
Cosmic Evolution



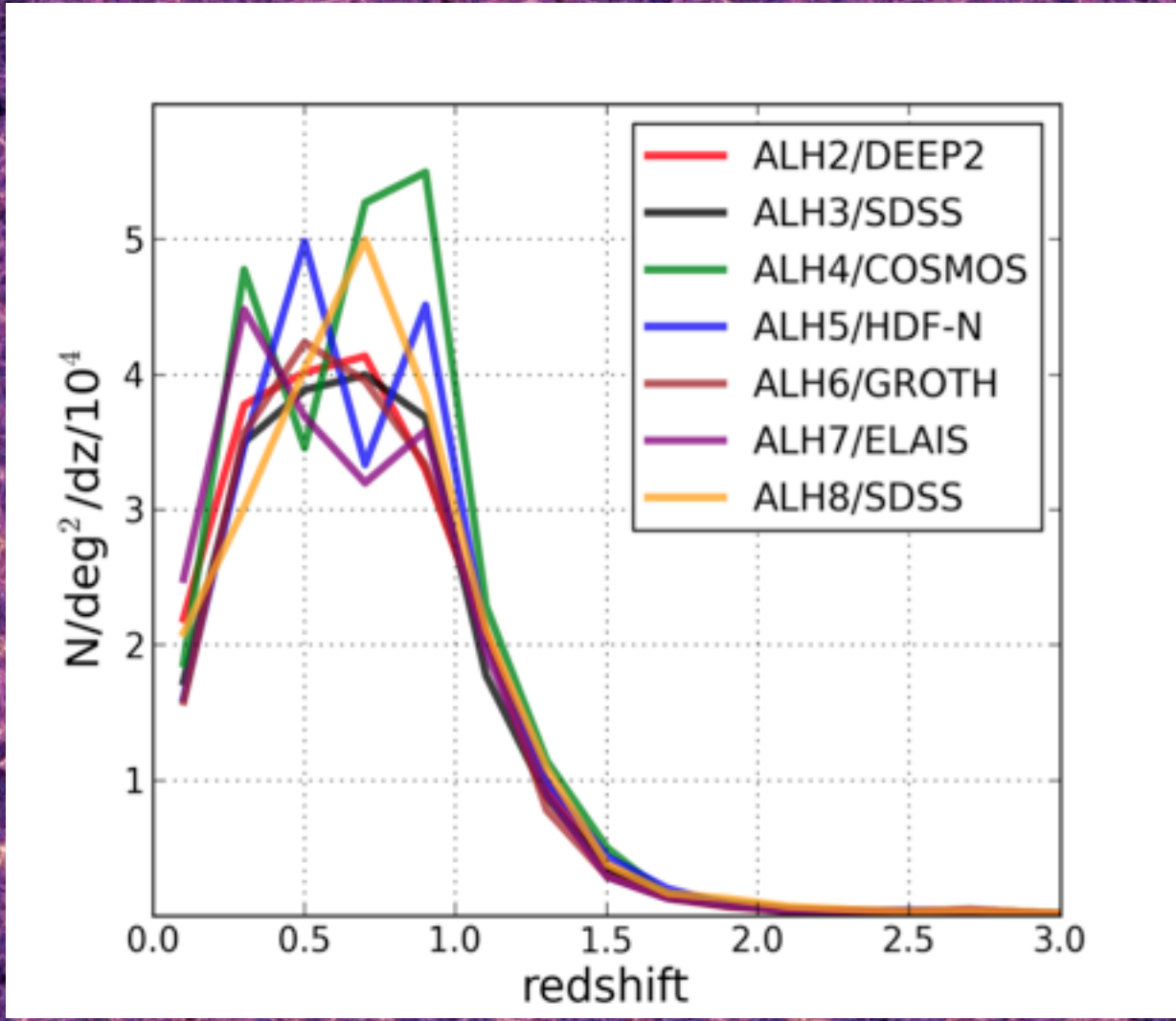
The complete P(z,T) contains every possible scenario

All information provided by the data

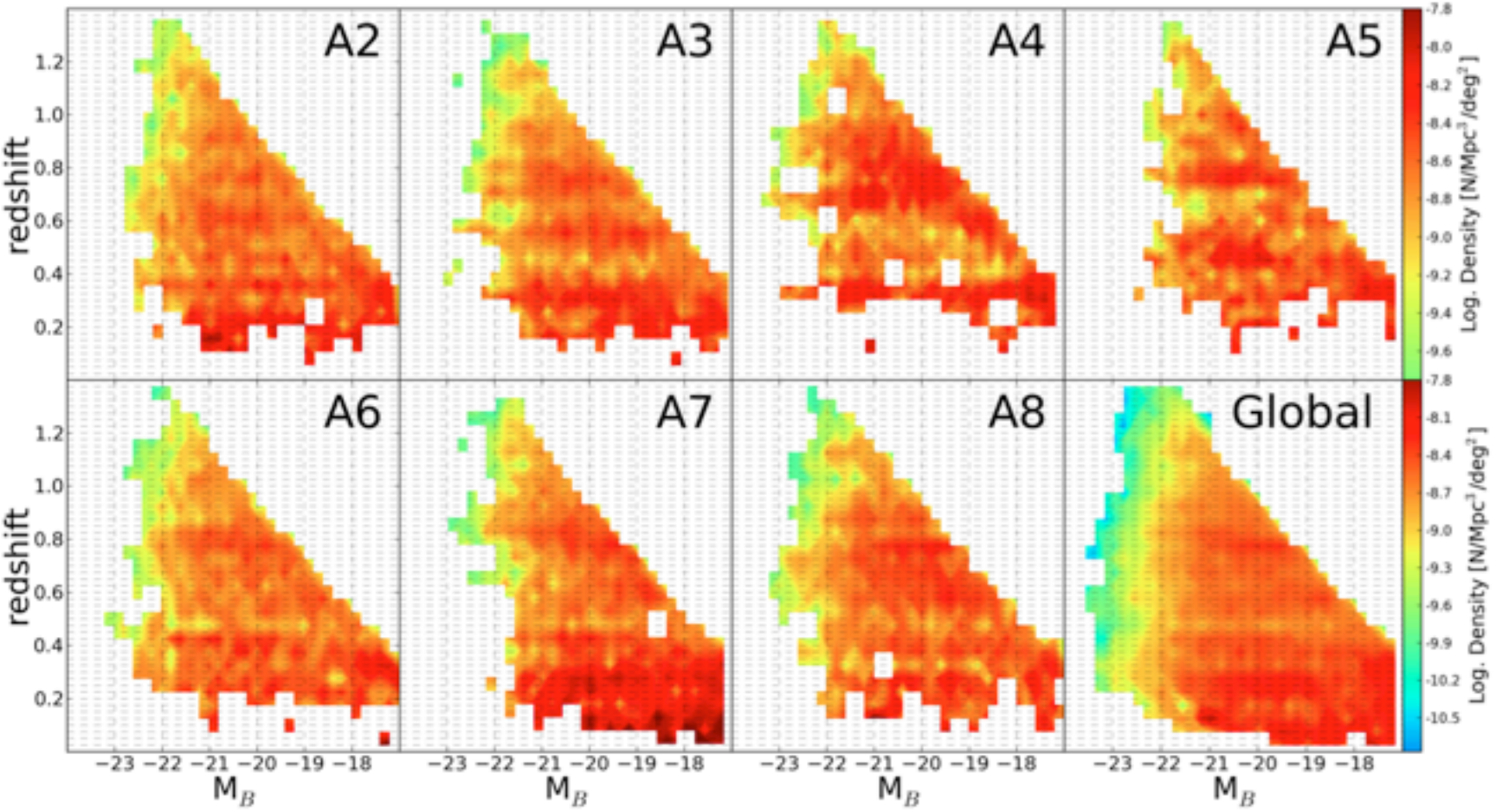


$$P(z) = \sum_{i=1}^{N_g} P_i(z) = \sum_{i=1}^{N_g} \left[\frac{\int dT\, p_i(z,T)}{\int dT \int dz p_i(z,T)} \right]$$

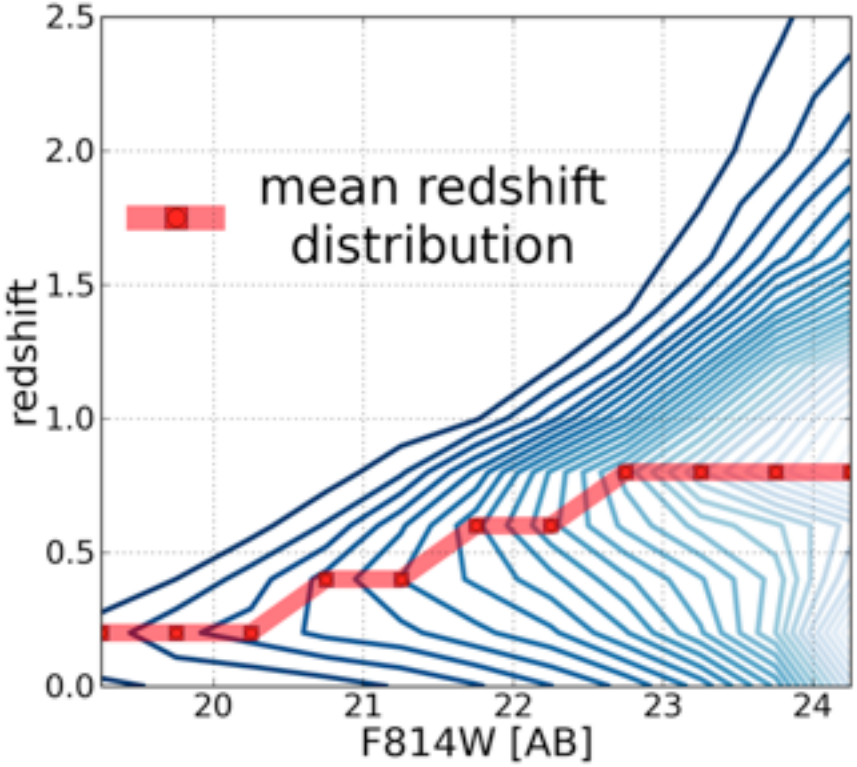
Cosmic Variance (I)

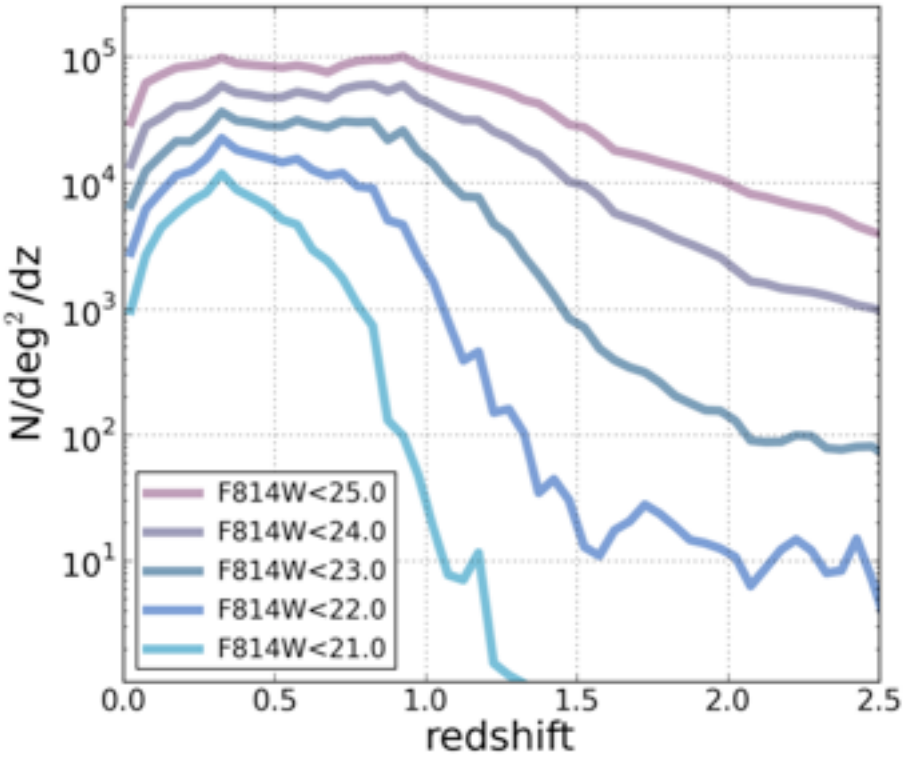


Cosmic Variance (II)

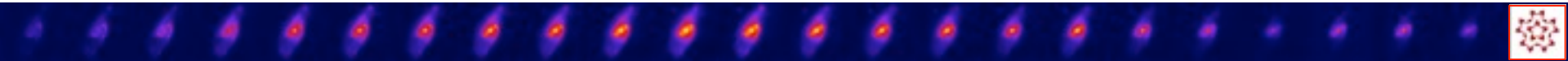


Cosmic Evolution





Early Scientific Results



LAE Candidates at z~2.2

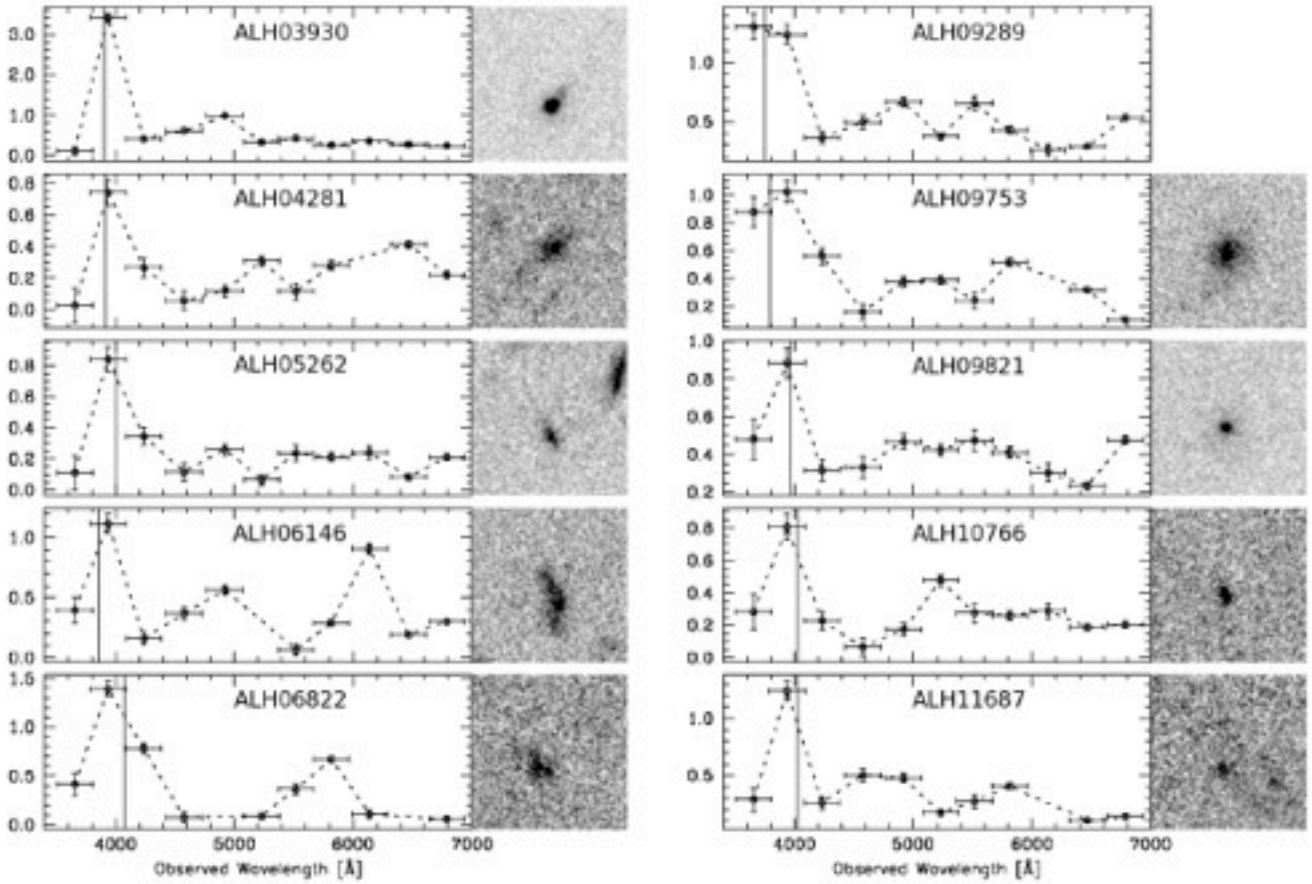


Fig. B.1. Optical pseudo-spectra of $z \sim 2.2$ LAE candidates from ALHAMBRA survey. ACS cutouts (3×3 sq-arcsec) of the objects, when available, are shown in the right side of each pseudo-spectrum. Vertical line inside each panel represent the position of Lyα emission line center at the corresponding photometric or spectroscopic redshift given in Table B.1. Fluxes are in 10^{-18} erg cm^{-2} s^{-1} Å^{-1} units. The horizontal bars represent the effective widths of ALHAMBRA filters. Assumming a concordant cosmology, with $H_0 = 70$ km s^{-1} Mpc^{-3}, the mean scale of the images is ~8.2 kpc arcsec^{-1}.

Bongiovanni et al. 2010, A&A 519, L4

UV Selected galaxies at z~1 (+Galex)

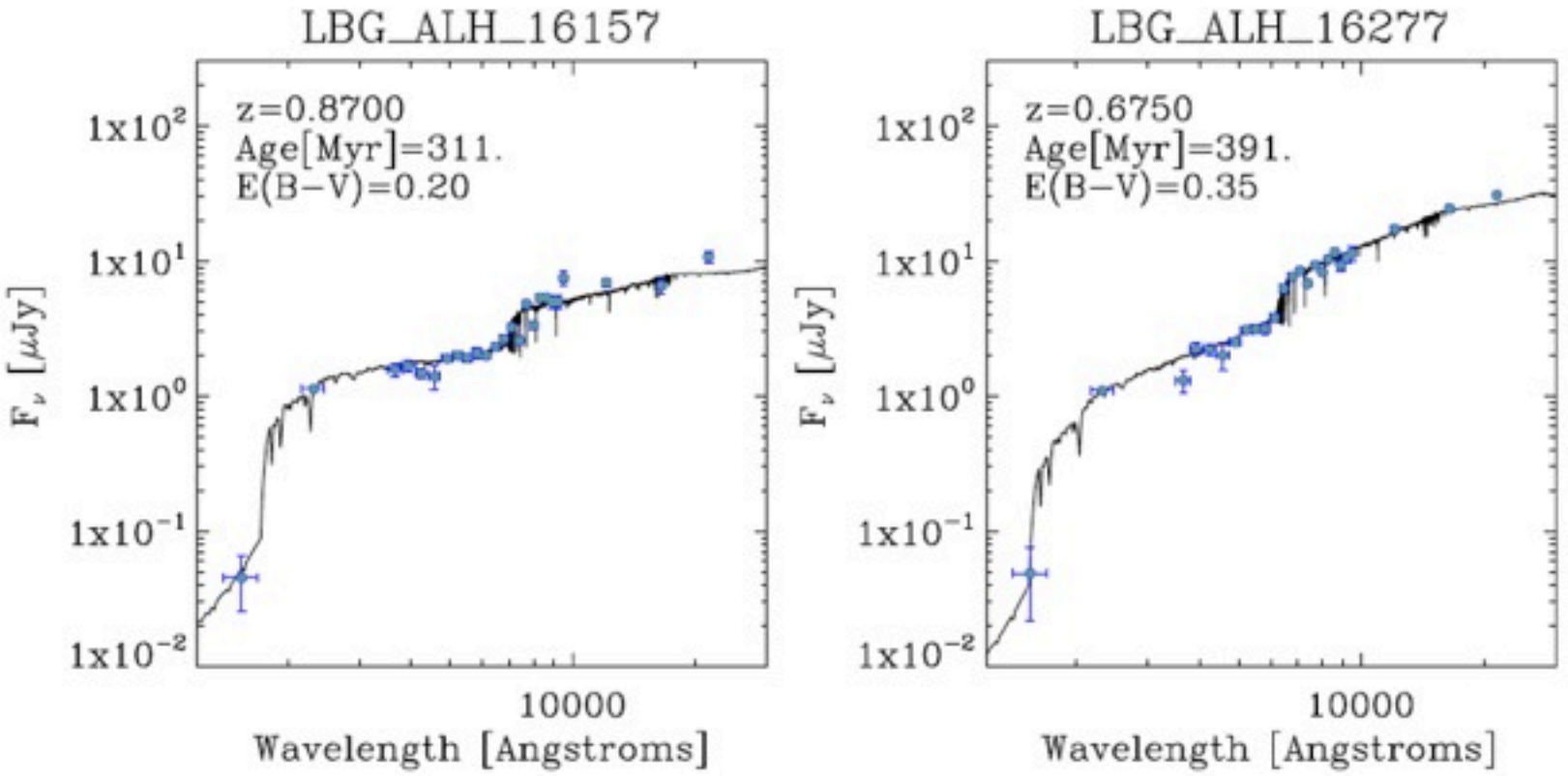


Fig. 4. Examples of SED fittings results with GALEX+ALHAMBRA data for four LBGs from the total sample. Blue points are the observed GALEX and ALHAMBRA fluxes and the black curves are the BC03 templates that fit the photometry of each object best.

Oteo et al. 2013, MNRAS 433, 2706

UV Selected galaxies at z~1 (+Herschel)

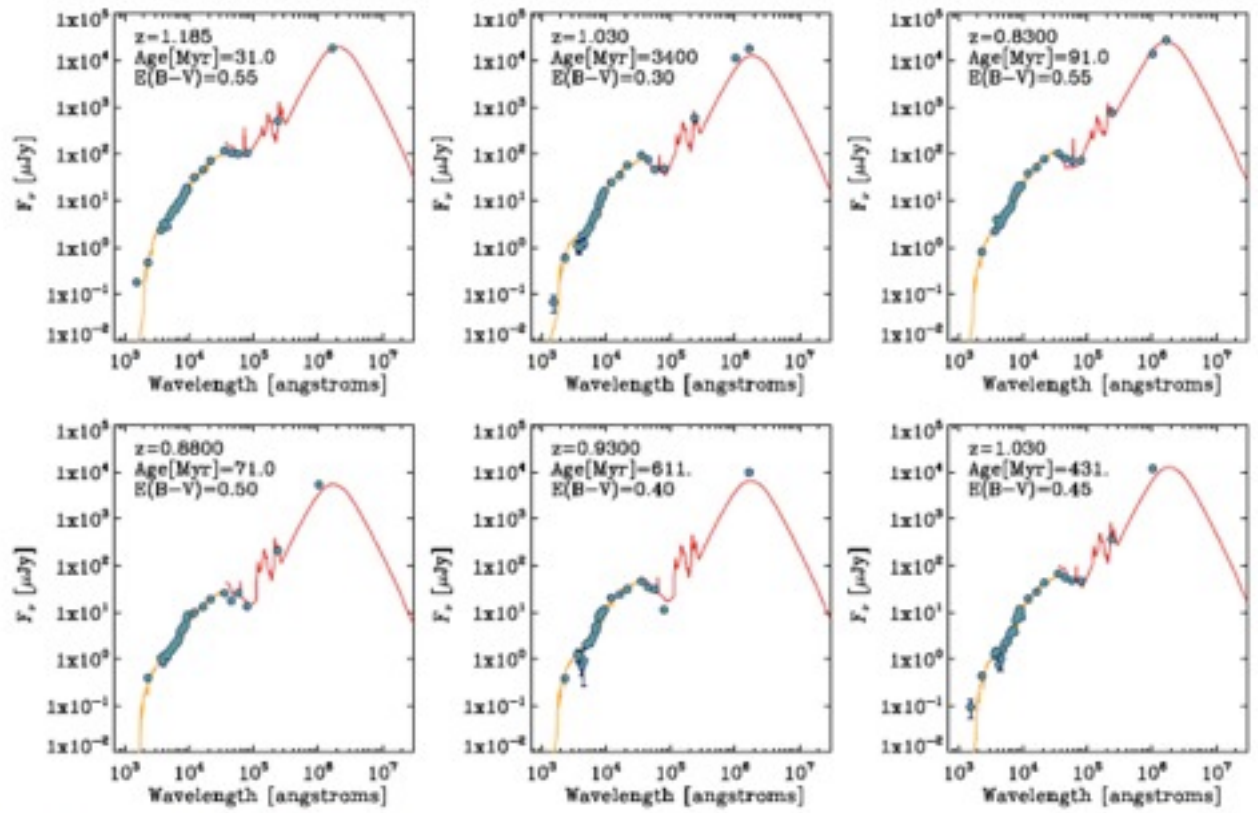
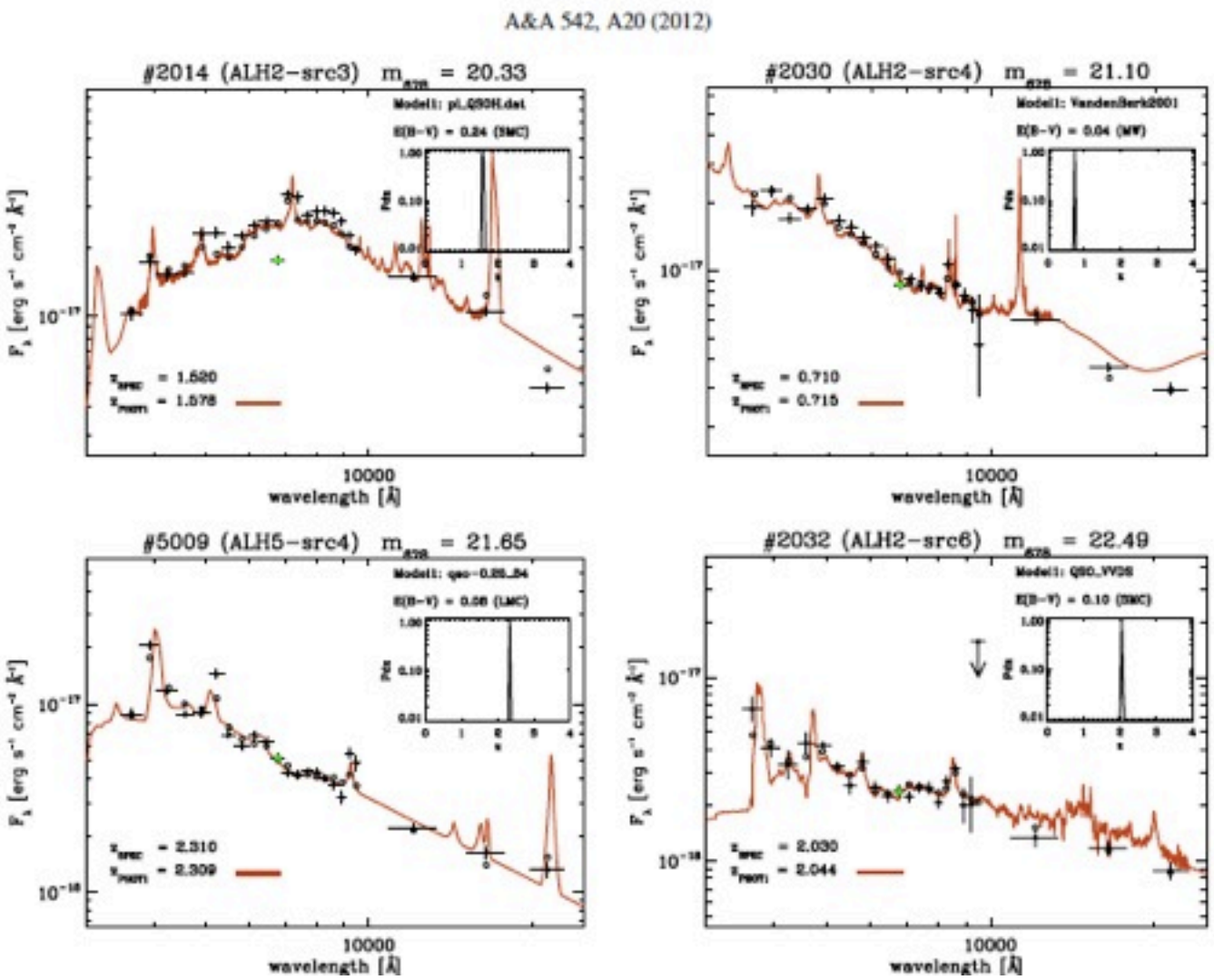


Figure 1. Rest-frame UV-to-FIR SED of nine PACS-detected LBGs (*top*). These examples are representative of the SED-fitting results for our whole sample of our PACS-detected galaxies. Blue points are the observed UV to FIR fluxes of the galaxies. Orange curves are the BC03 templates which fit the UV to IRAC-4.5μm fluxes best for each source. The BC03 templates considered in the representations and fits are associated to time-independent SFH and fixes sub-solar metallicity $Z = 0.4Z_{\odot}$ (see Oteo et al. (2013) for more details). SED-derived redshift, age and dust attenuation associated to the represented BC03 templates are also indicated. Red curves are the CE01 templates which fit the IRAC-5.8μm to PACS fluxes best for each galaxy.

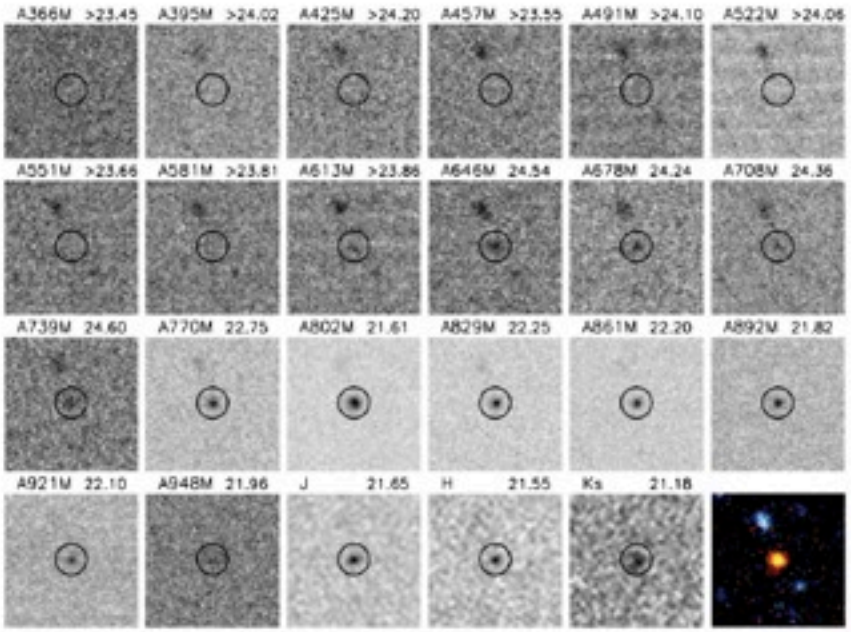
Oteo et al. 2013, MNRAS 435, 158

ID and Photometric Redshifts for QSOs



Matute et al. 2012, A&A 542, A20

Discovery of High Redshift Objects



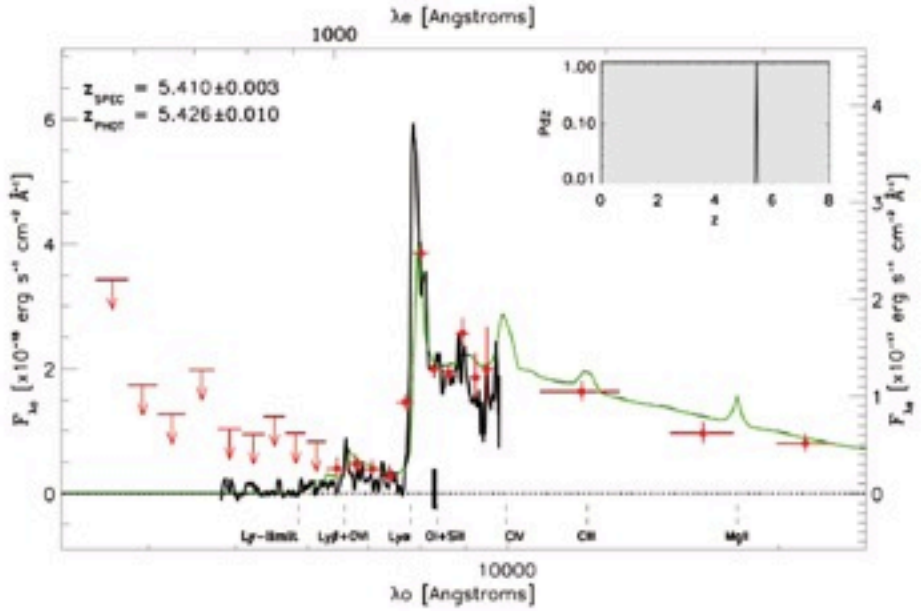


Fig. 1. *Left)* Cutouts (15"×15") in all the ALHAMBRA optical/NIR filters for the discovered QSO (highlighted by an open circle). Above each cutout we indicate the filter name and measured magnitude (or 5-σ upper limit). The final image is a color composite of all bands, where the contrast has been increased in order to make all objects clearly visible. Images are oriented with north up and east to the left. *Right)* Optical–NIR spectral energy distribution of the discovered QSO. ALHAMBRA photometric detections are indicated as circles with associated error bars (arrows indicate 5σ upper limits). The reference magnitude in the m_{830} filter is indicated by a vertical thick line. The best photo-z template solution (QSO with optical slope index $\alpha = -0.25$ at $z_{PHOT} = 5.426 \pm 0.010$) is shown as a green line while the OSIRIS/GTC spectra (smoothed with a 7 pixel box) is shown as a thick black line, with the redshift probability function in the inset. The agreement found between the spectro-z and the photo-z is remarkable. The most important emission lines for QSOs at the redshift of the source are also indicated.

Matute et al. 2013, A&A 557, 78

Reliable morphological classification

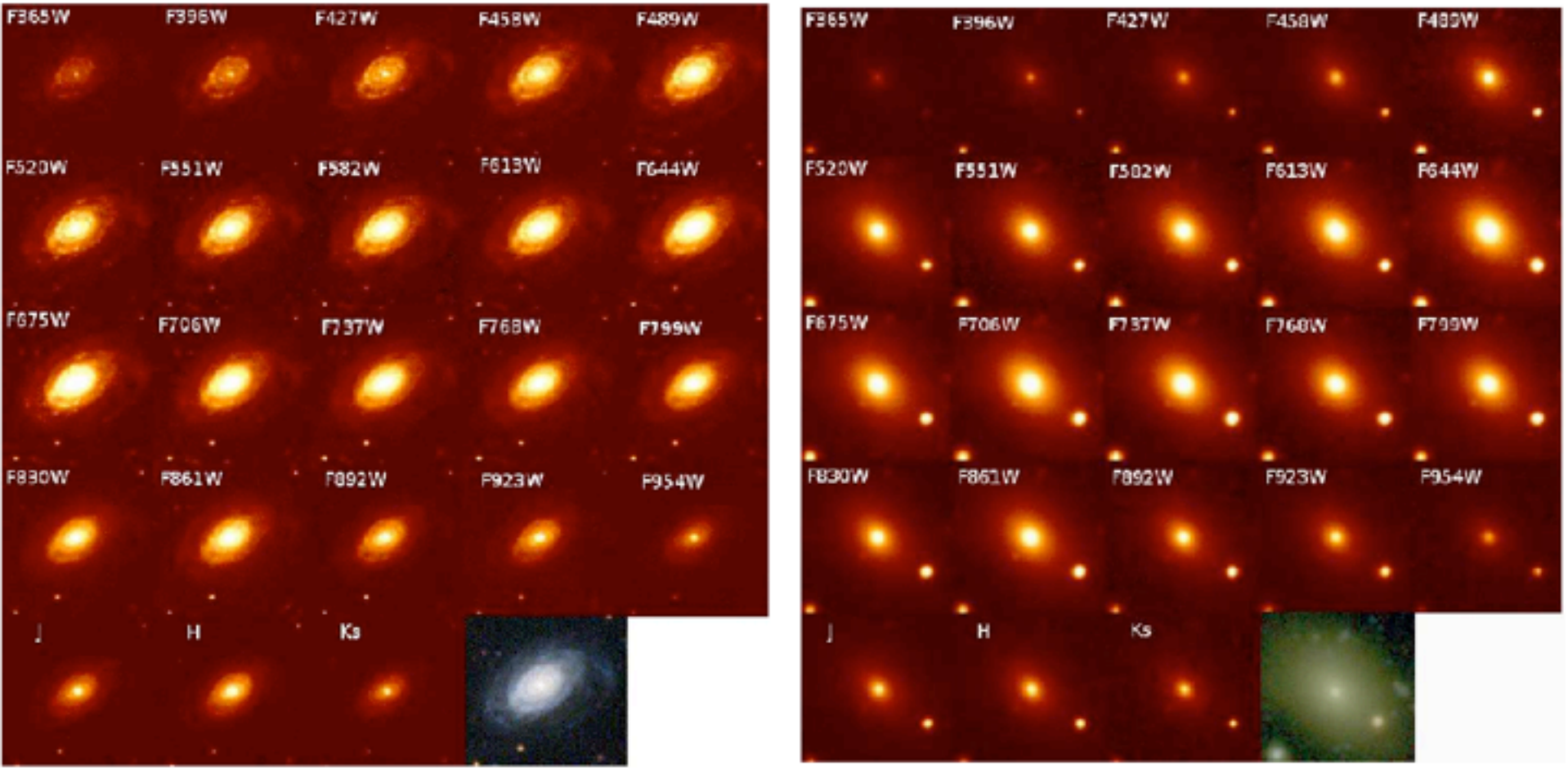


Figure 1. Example of two galaxies observed with 20 optical and 3 near-infrared ALH filters.

Povic et al. 2013, MNRAS 435, 3444

Cosmic variance for merger fraction studies

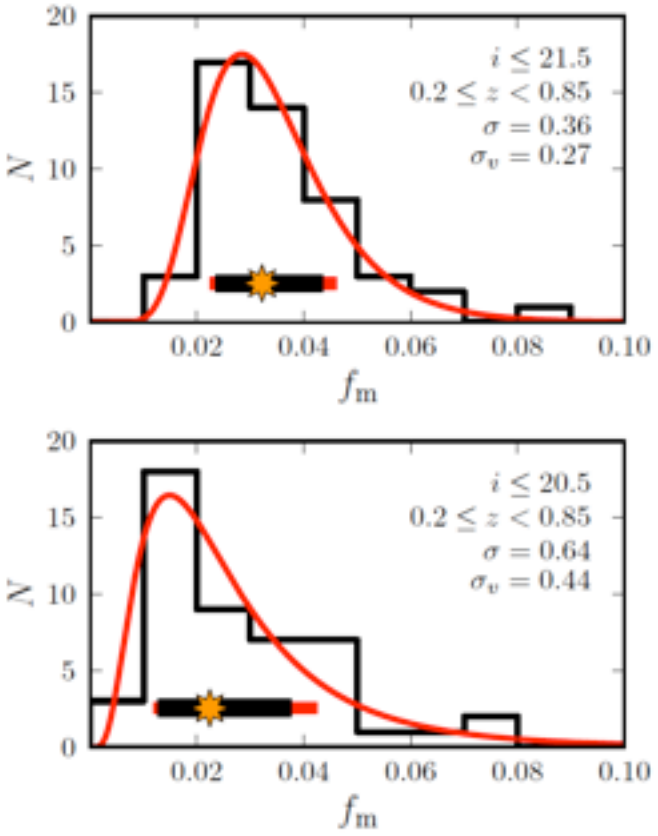


Fig. 3. Distribution of the merger fraction of $i \leq 21.5$ (*top panel*) and $i \leq 20.5$ (*bottom panel*) galaxies in the 48 ALHAMBRA sub-fields, measured from close pairs with $10h^{-1}$ kpc $\leq r_p \leq 30h^{-1}$ kpc. In each panel, the red solid line is the best least-squares fit of a log-normal function to the data. The star and the red error bar mark the median and the 68% confidence interval of the fit, respectively. The black error bar marks the confidence interval from the maximum likelihood analysis of the data and is our measurement of σ_v. [*A colour version of this plot is available at the electronic edition*].

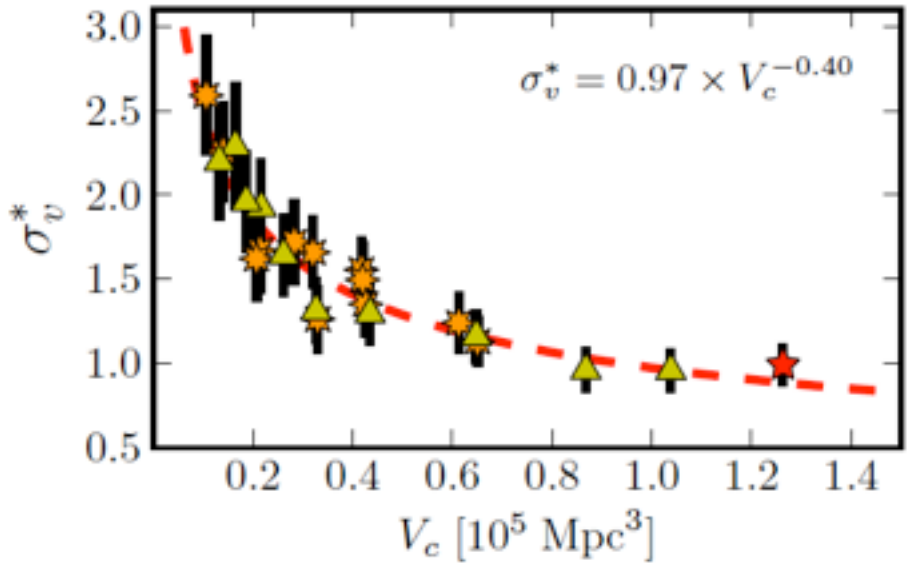
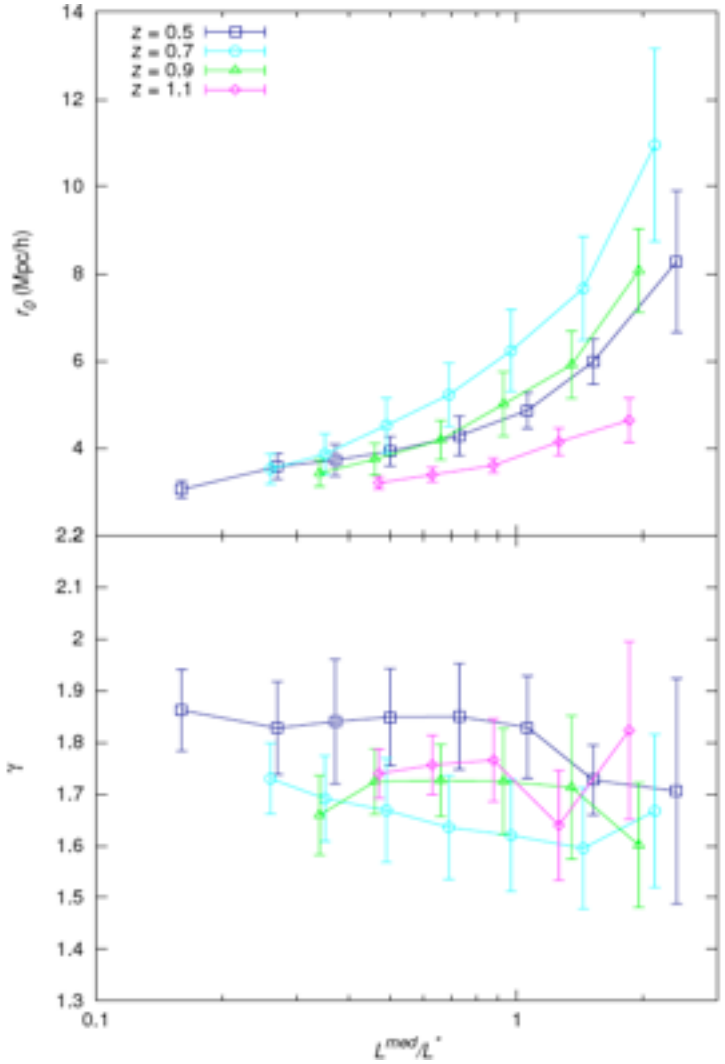
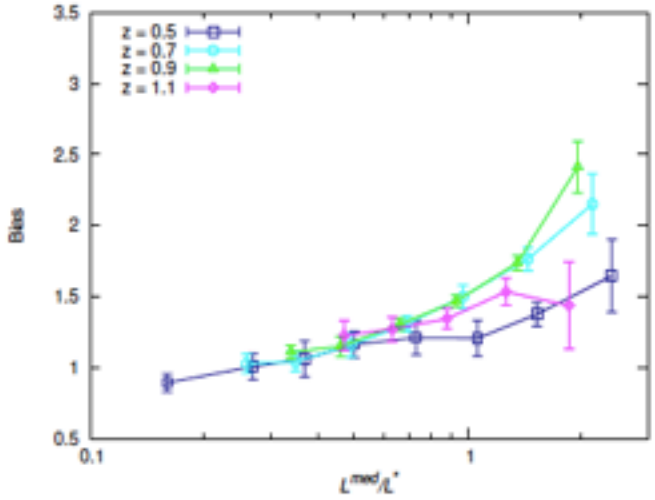


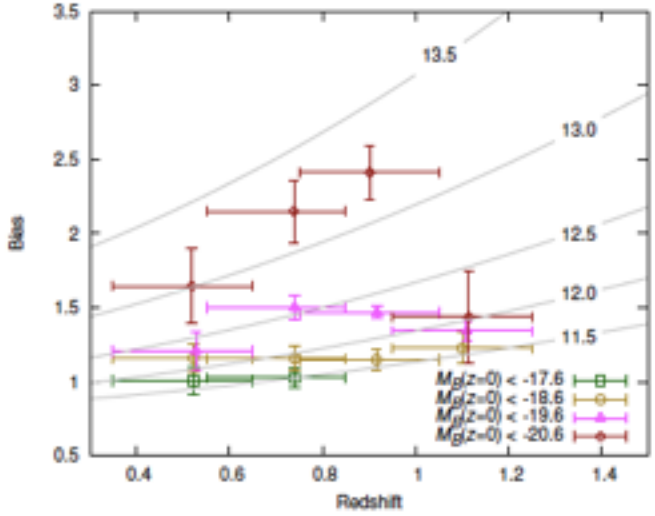
Fig. 8. σ_v^* as a function of the probed cosmic volume V_c for galaxies with $i \leq 23$. The red star is the same data point than in Fig. 7. The orange stars probe different redshift intervals, while triangles probe sky areas smaller than the fiducial ALHAMBRA sub-field. The red dashed line is the error-weighted least-squares fit of a power-law to the data, $\sigma_v^* \propto V_c^{-0.40}$. [*A colour version of this plot is available at the electronic edition*].

López-Sanjuan et al. 2014, A&A 564, 127

Evolution of galaxy clustering

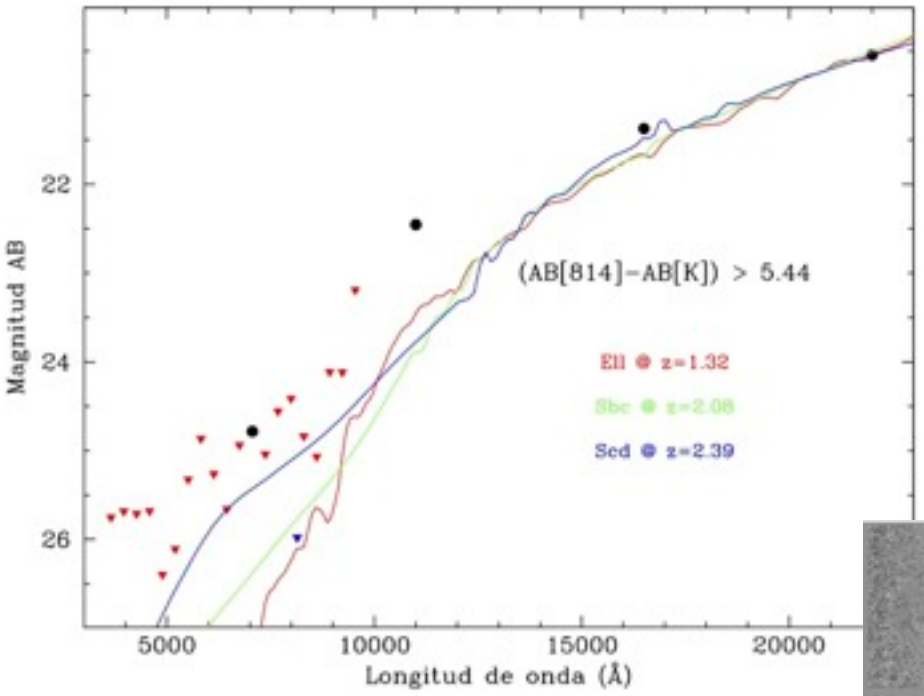




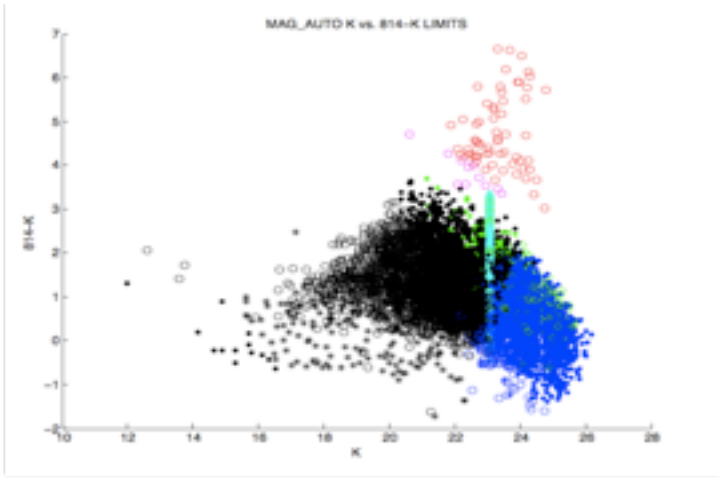


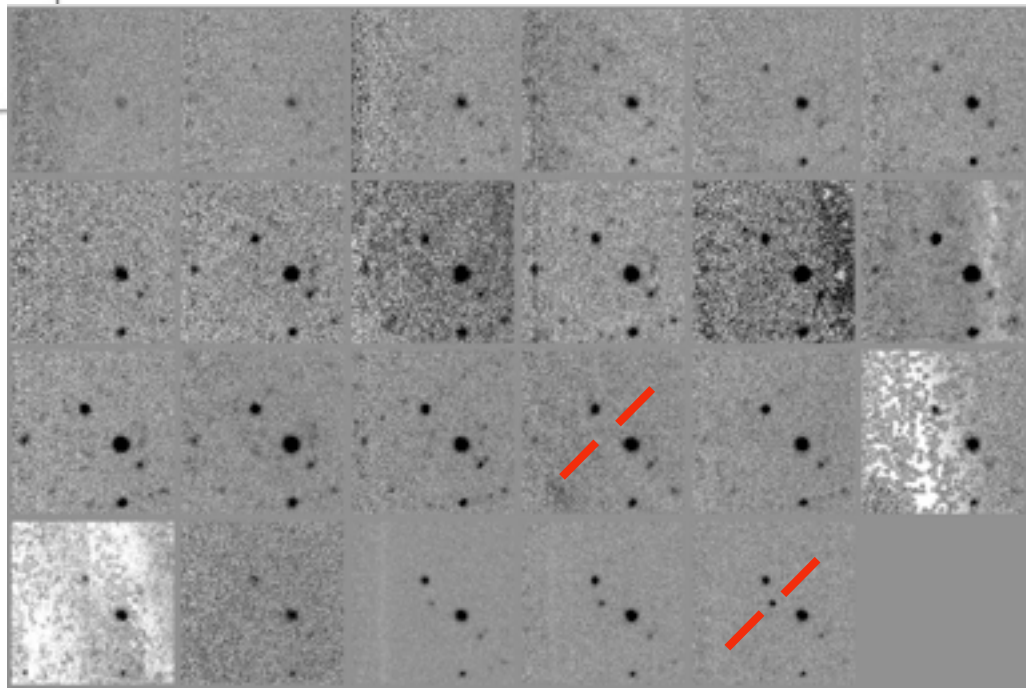
Arnalte-Mur et al. 2014, MNRAS 441, 1783

ALHAMBRA K-Band selected catalogue



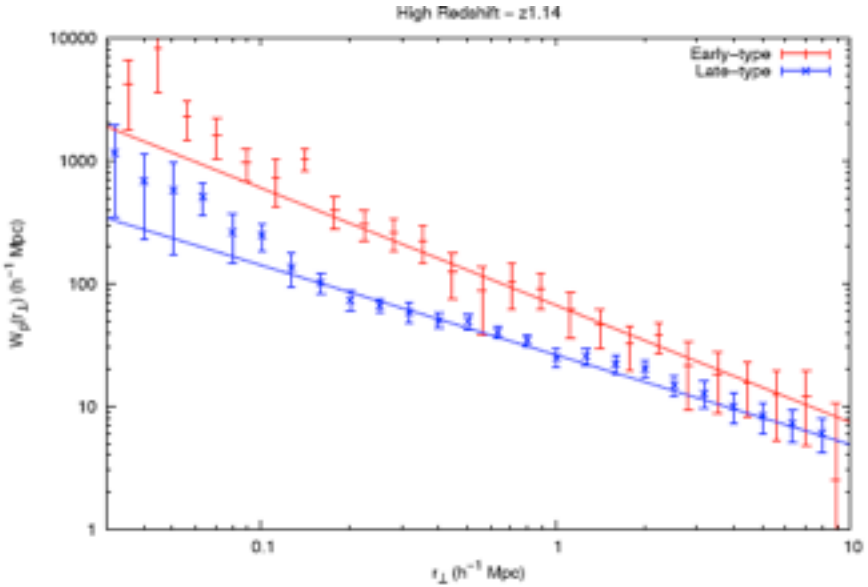
Nieves-Seoane
et al. (in prep.)

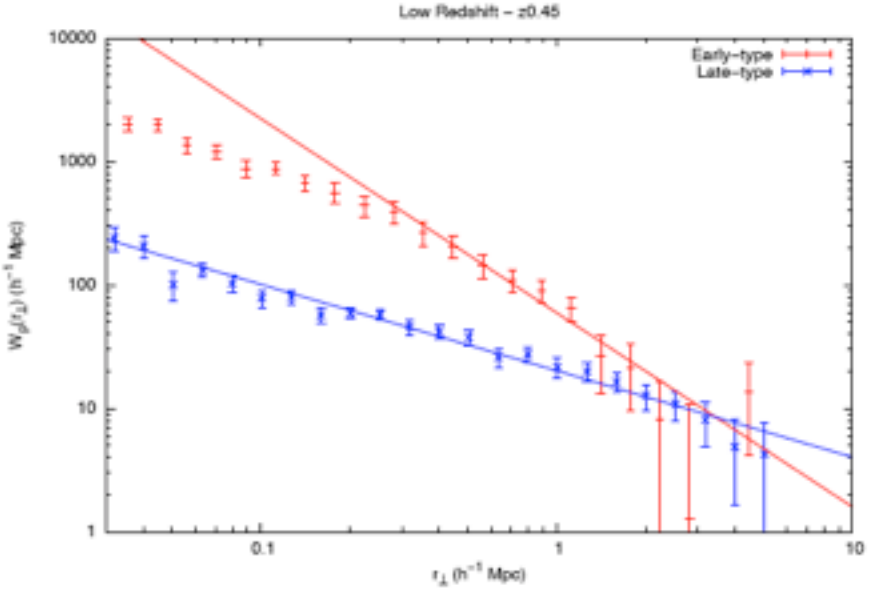


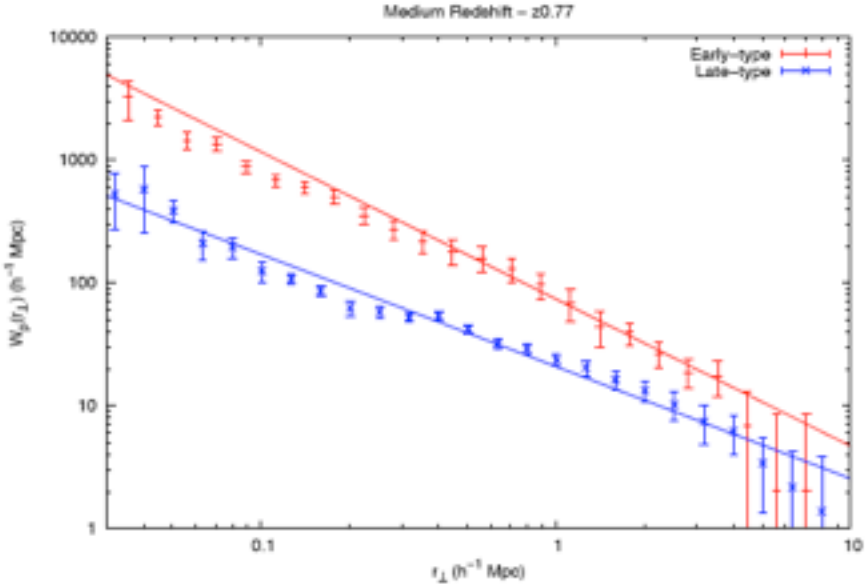


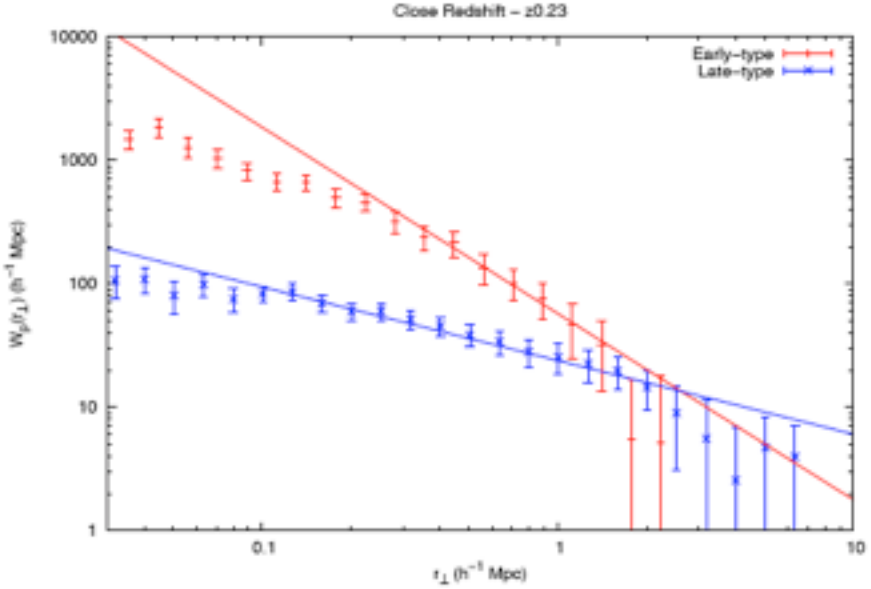
Evolution of galaxy segregation

Hurtado-Gil et al (in prep.)

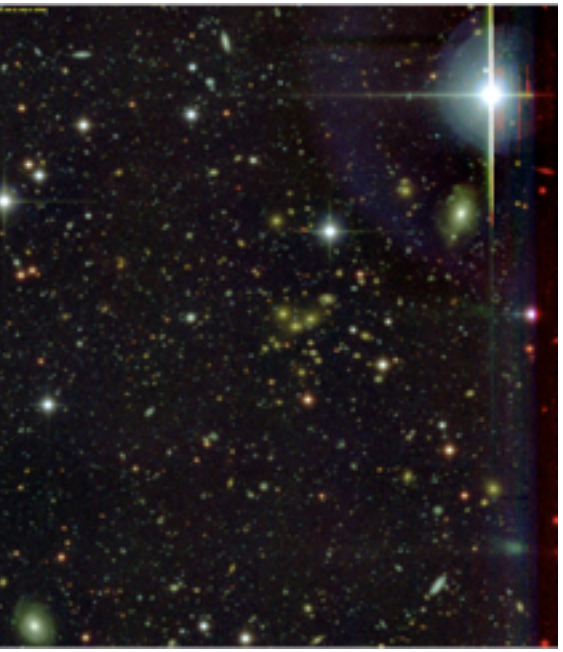


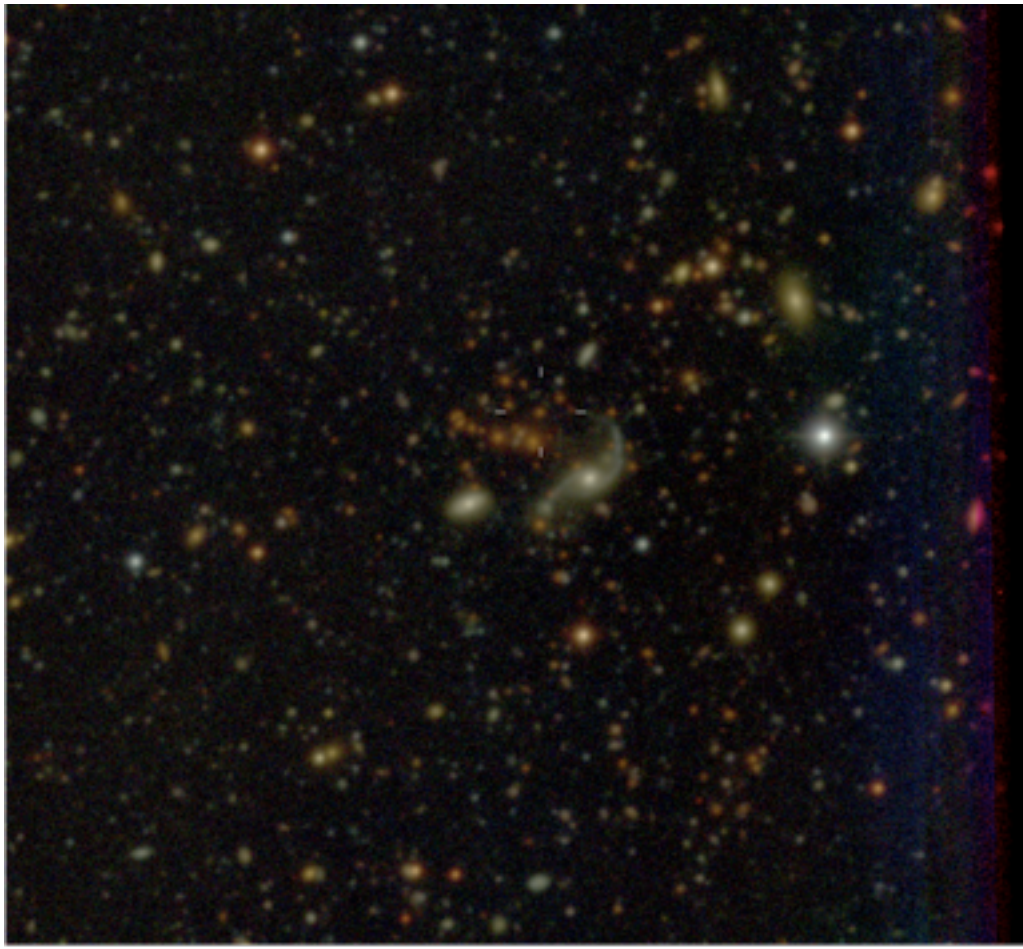






Galaxy clusters in ALHAMBRA images

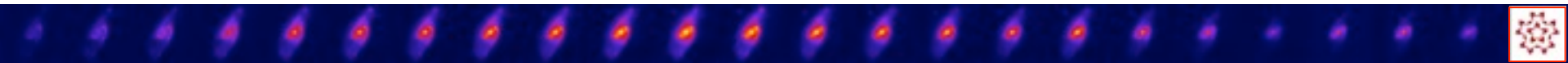




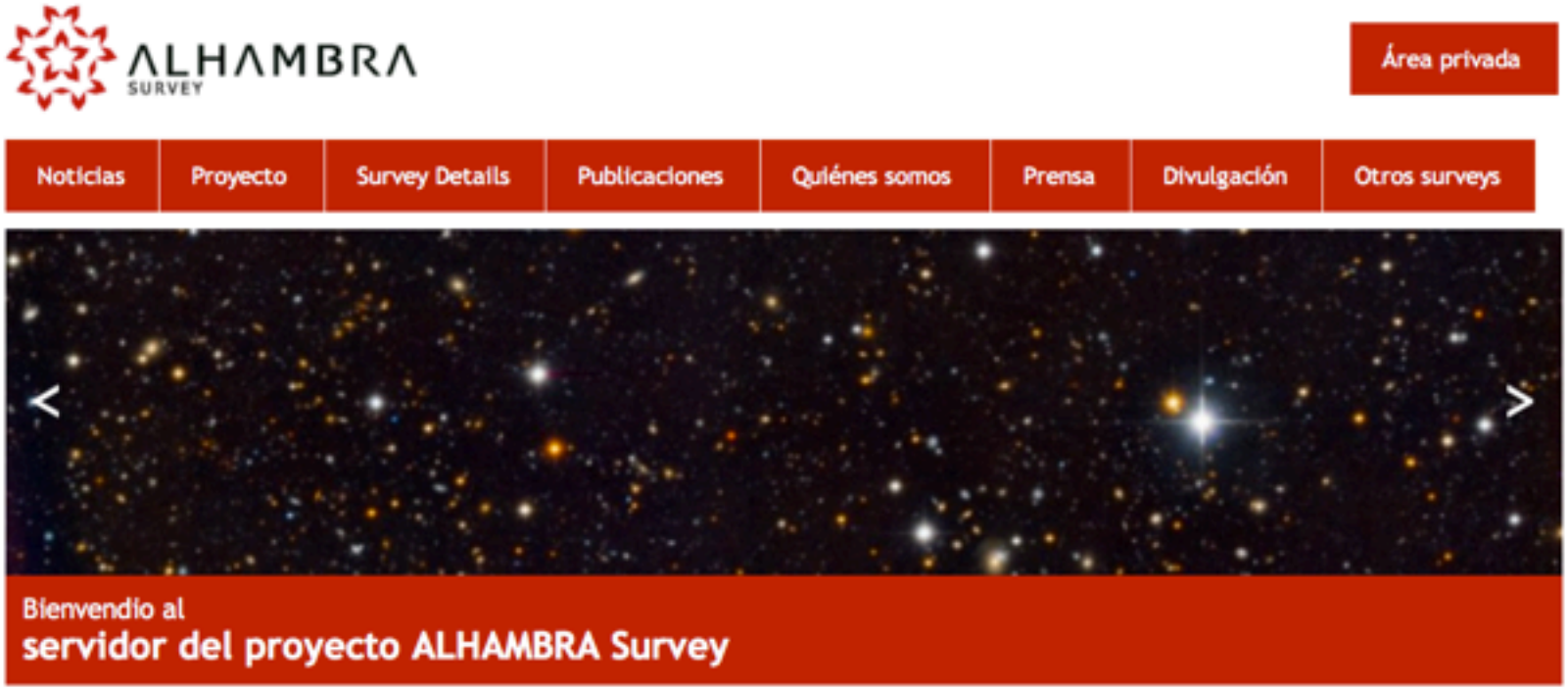
~200 clusters at $0.2 < z < 1.0$

Ascaso et al. 2014 (in prep.)

Access to ALHAMBRA Data

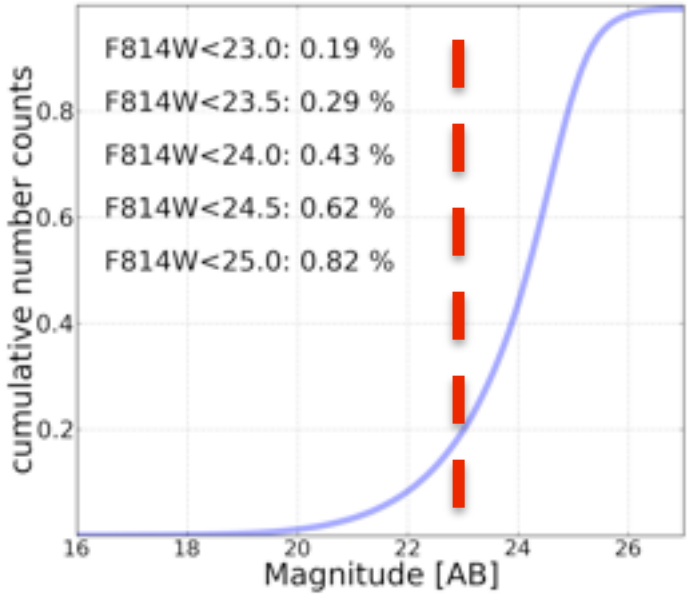


Survey website & Data Access



www.alhambrasurvey.com

The ALHAMBRA Gold Catalogue



- The catalogue provides PSF-corrected photometry for ~100.000 galaxies with a $dz/1+z<0.012$ and P(z) well described by a single Gaussian peak.
- Photometrically complete down to I=23AB
- ~20.000 stars identified in the galactic halo
- ~1000 AGN candidates.

Magnitude F814W	σ_z (Odds>0.0)	# (%)	η_1 (%)	η_2 (%)	σ_z (Odds>0.5)	# (%)	η_1 (%)	η_2 (%)	σ_z (Odds>0.9)	# (%)	η_1 (%)	η_2 (%)
$18.0 < m < 19.0$	0.0081	0.8	0.0	0.1	0.0073	0.6	0.0	0.0	0.0055	0.1	0.0	0.0
$19.0 < m < 20.0$	0.0083	2.2	0.1	0.3	0.0077	1.7	0.1	0.1	0.0056	0.3	0.1	0.1
$20.0 < m < 21.0$	0.0095	5.3	0.3	0.7	0.0085	4.1	0.1	0.3	0.0059	0.7	0.0	0.0
$21.0 < m < 22.0$	0.0101	11.9	0.4	1.1	0.0093	9.0	0.2	0.5	0.0058	1.3	0.0	0.0
$22.0 < m < 23.0$	0.0140	26.0	0.7	2.1	0.0111	16.0	0.3	0.9	0.0065	1.5	0.0	0.0
$23.0 < m < 23.5$	0.0182	22.8	0.6	2.1	0.0129	9.4	0.2	0.6	0.0045	0.5	0.0	0.0
$23.5 < m < 24.0$	0.0263	30.7	0.9	2.3	0.0118	7.4	0.2	0.4	0.0038	0.3	0.0	0.0

Survey website & Data Access

Observational Cosmology Group

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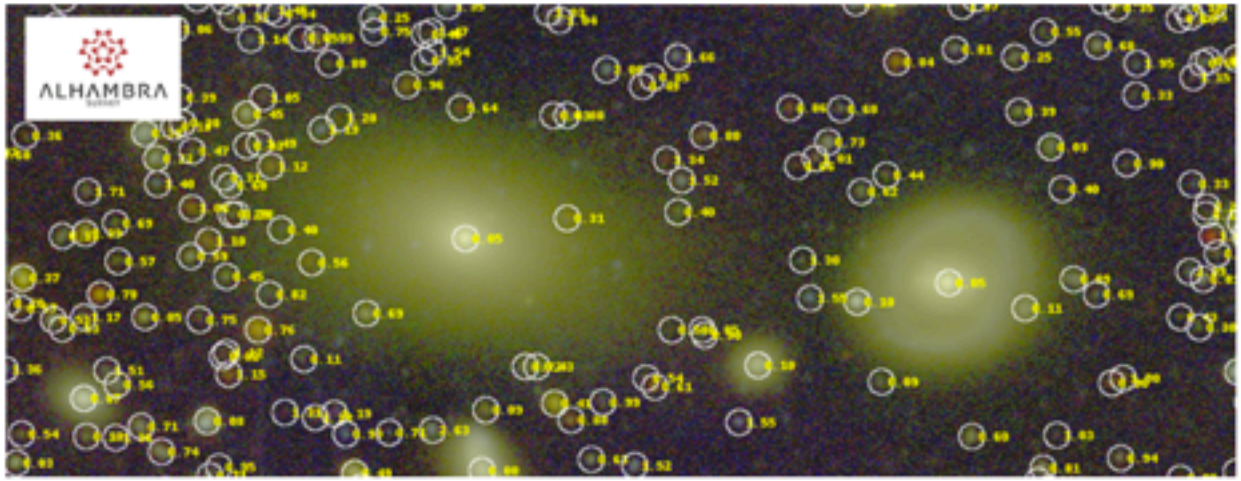
Research Products

www.cosmo.iaa.es

The ALHAMBRA Gold catalog

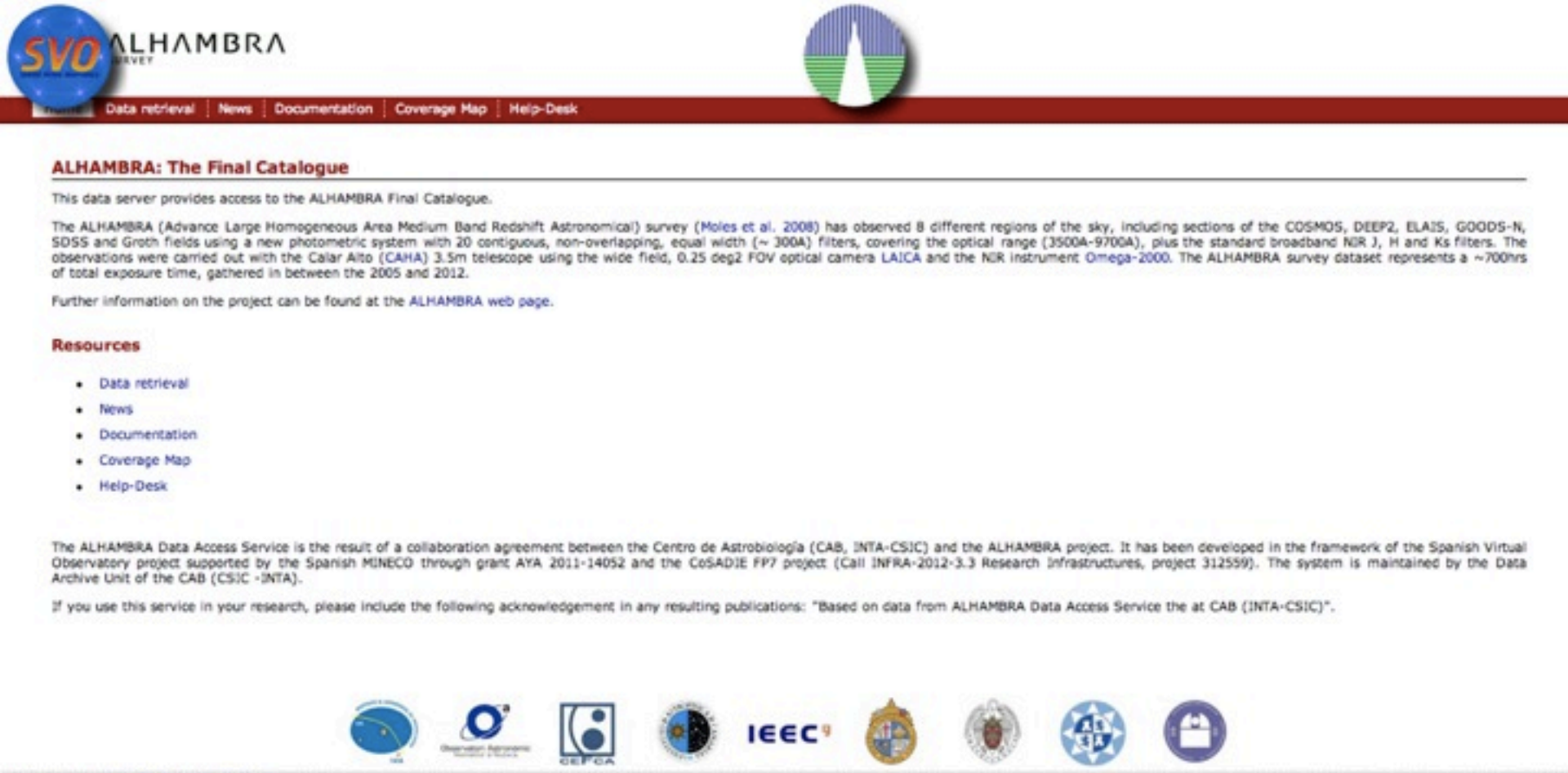
The ALHAMBRA Gold Catalogue (Molino et al. 2013) corresponds to a subsample of ~100k galaxies, photometrically complete down to a magnitud I=23 AB, covering a total area of 3 deg2, spread over 7 non-contiguous regions of the sky, with an on-target exposure time of ~32hrs.

The catalogue provides PSF-corrected photometry for 20+4 bands and accurate photometric redshift estimations, with an expected error dz/1+z<0.012 and redshift probability distribution functions P(z) well described by a single Gaussian peak.



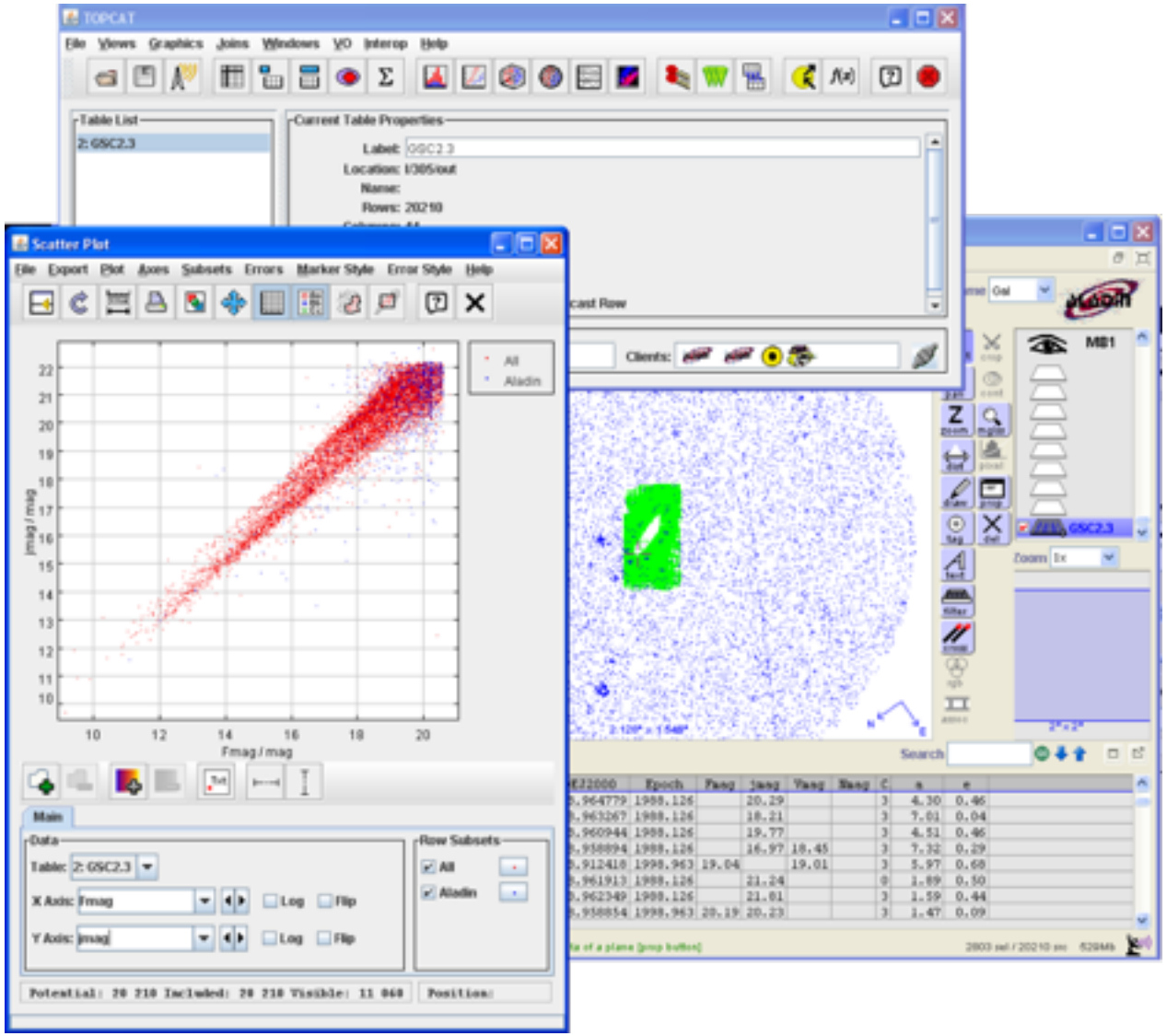
For a detailed explanation of the catalog and download instructions, please visit The ALHAMBRA Gold catalog page.

The ALHAMBRA catalogues and F814W images are accessible via SVO

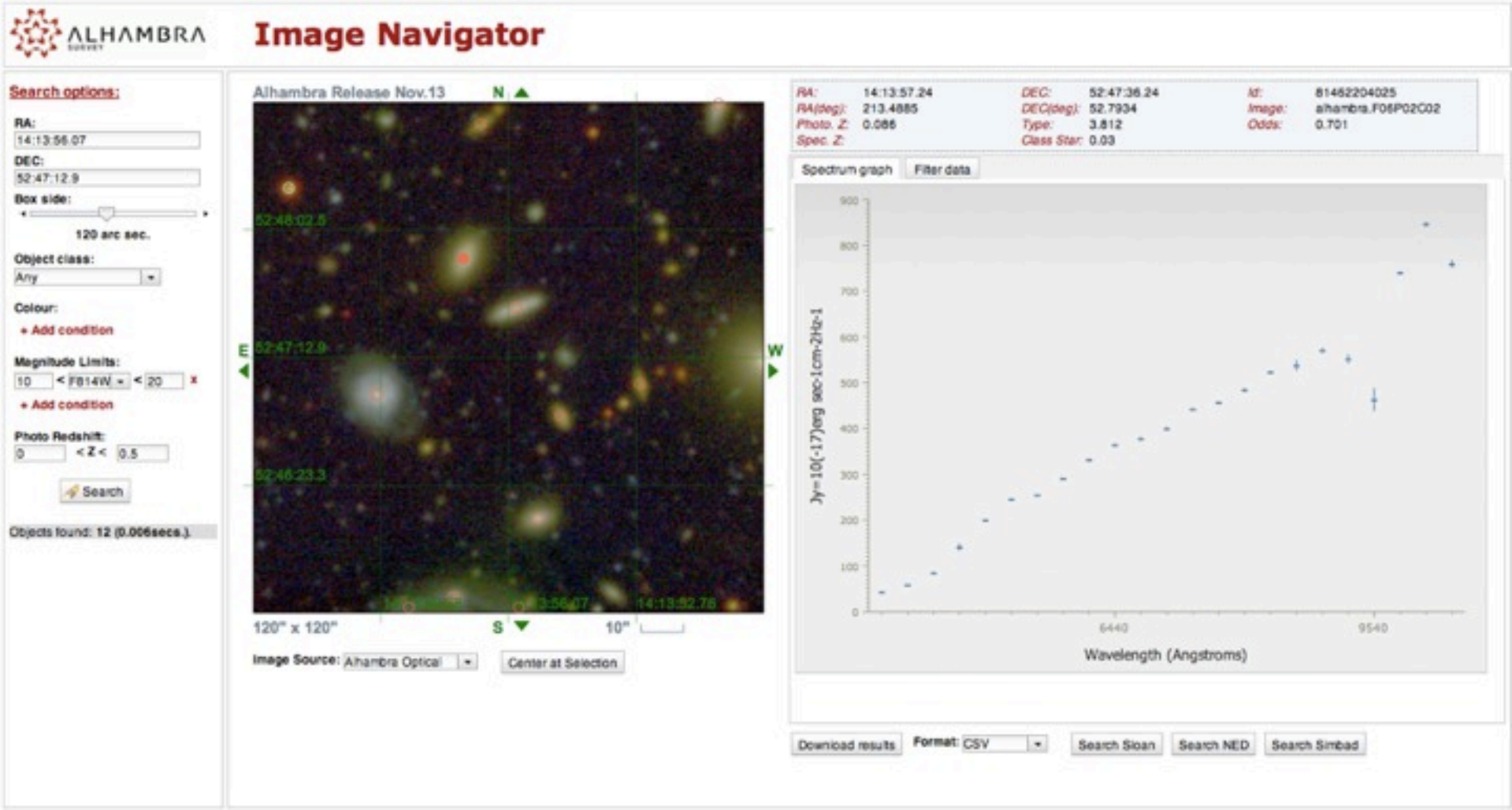


http://svo2.cab.inta-csic.es/vocats/alhambra/index.php

The full ALHAMBRA catalogues are also available via VO Tools: Topcat, Aladin,...



A data discovery tool is in a test phase



At the end of the day...

- ALHAMBRA is in its exploitation phase
- You are invited to use the data
- Catalogues available to the community
  - VO Compliant (Topcat, Aladin)
  - Gold sample (I<23) catalogues on the web
  - Navigator under tests
- Full dataset coming

Please contact your local ALHAMBRA expert!

!Gracias!