# Clustering from high quality photometric redshifts: the case of ALHAMBRA

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&
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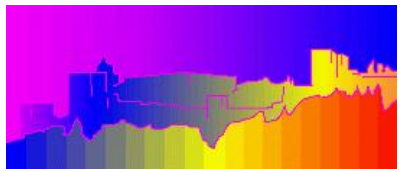


# ALHAMBRA

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

- A pencil-beam, multi-band photometric survey with the aim of providing a *cosmic tomography* to study cosmic evolution
  - Homogeneous and unbiased selection of objects over large $z$ range
  - Depth — Area compromise (to avoid cosmic variance)
  - Accurate $z$ determination

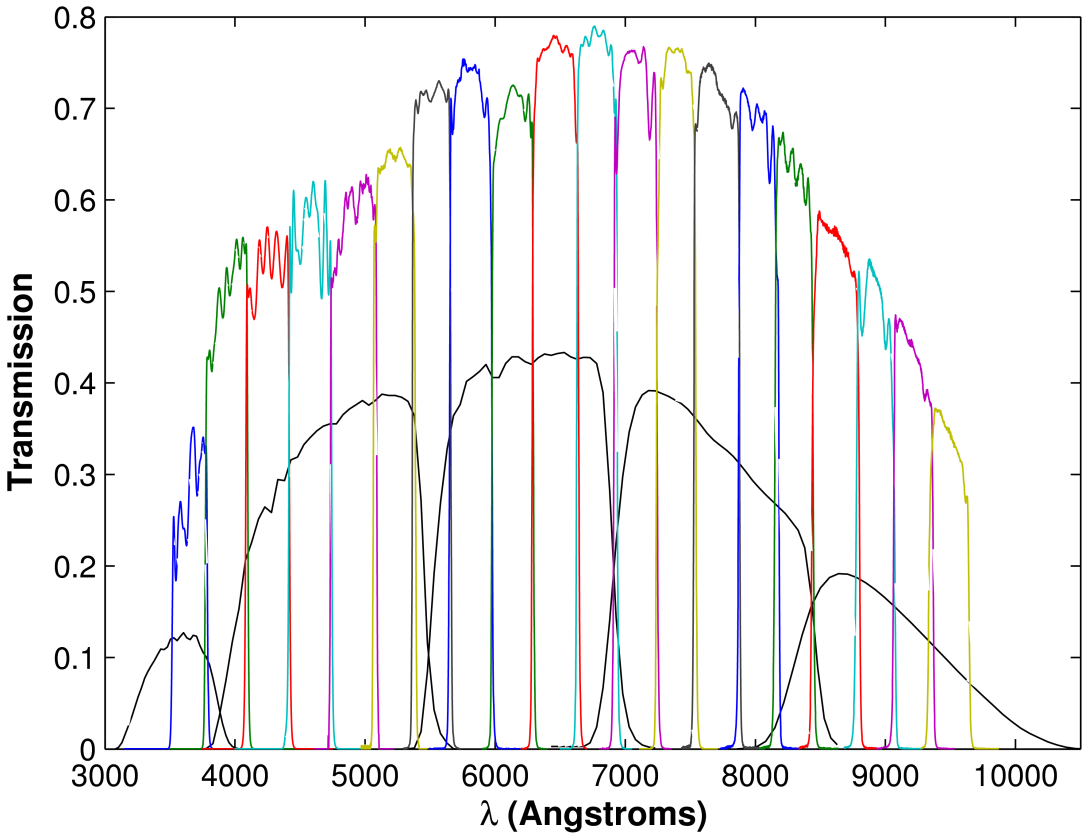
$$\Downarrow$$

Exploit photo-$z$ techniques at maximum

- Total area: $4\,\mathrm{deg}^2$, distributed in 8 separate fields (overlap with other surveys: SDSS, DEEP2, COSMOS, HDF-N, GROTH, ELAIS-N1)
- Survey uses 3.5-m Calar Alto telescope, with cameras LAICA (optical) + Ω-2000 (NIR)
- More info.: Moles et al. (2008), `http://www.iaa.es/alhambra`

# ALHAMBRA filter system

Filter system purpose-designed to minimise $\sigma_z/\sqrt{N_{good}}$ (Benítez et al., 2009b)



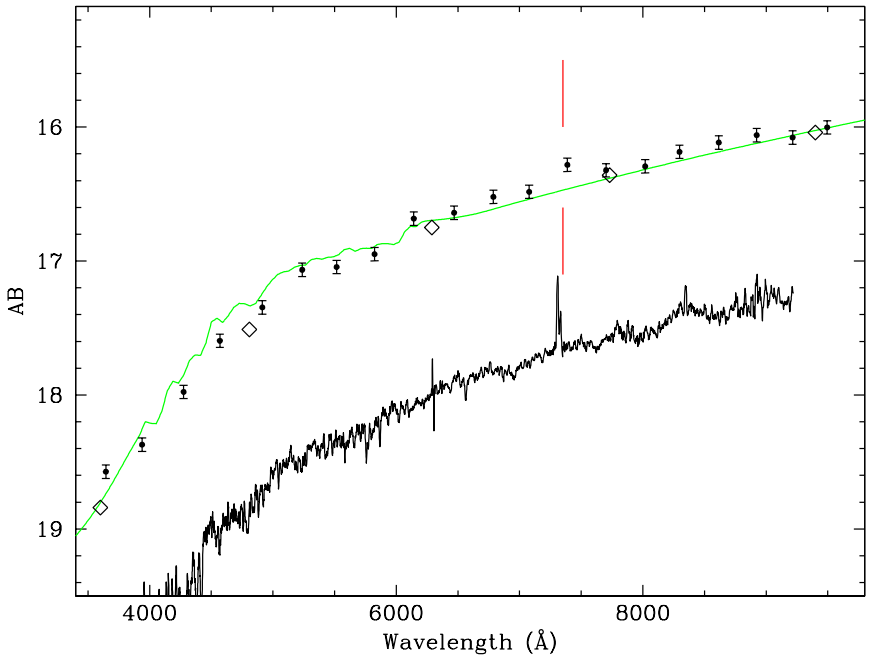

20 contiguous filters in the optical:

- Top hat filters
- Constant width (310 Å)
- Minimal overlap between filters

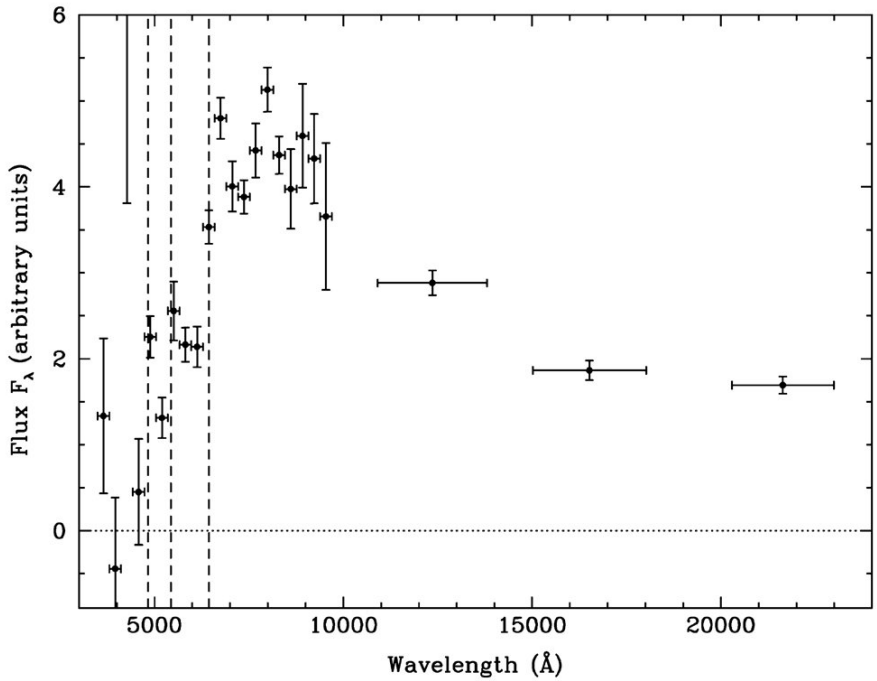
Add JHK$_s$ observations to break photo-z degeneracies

# Examples of "ALHAMBRA spectra"

Sab galaxy, $z_{ph} = 0.12$
Compared with SDSS spectrum




Starburst, $z_{ph} = 4.23$, $I_{AB} \simeq 23$




$\Rightarrow$ Expect $\sigma_z/(1+z) \leq 0.015$ for $I_{AB} \lesssim 24$ (survey's depht: $I_{AB} \simeq 25$)

# Future surveys

- Two PAU surveys will extend this technique (Benítez et al., 2009a):
  $\Rightarrow \sim$40–50 filters $\rightarrow$ expect $\sigma_z/(1+z) \simeq 0.003$ for LRGs ($i_{AB} \lesssim 22.5$)
- PAUS[1]: $\sim 200\,\mathrm{deg}^2$ using WHT (La Palma, Spain)
- J-PAS[2]: $\sim 8000\,\mathrm{deg}^2$ using new dedicated ACTUEL telescope (Teruel, Spain)
- Expected to start in 2012-2013
- Much larger volumes: suited for very large-scale cosmological studies: growth rate, (radial) BAO, ...

[1] http://www.pausurvey.org/

[2] http://w3.iaa.es/~benitez/jpas/main.html

# ALHAMBRA: Present status

- Observations finished in 2011
- Ongoing optimisation of object detection and photo-$z$ (using BPZ)
  $\rightarrow$ final catalogue in the next months
- Work with preliminary catalogue (IDR3) covering $\sim 60\%$ of total area
- Scientific explotation ongoing: galaxy clustering, luminosity functions, morphology, stellar populations, QSOs, EROs, Ly-$\alpha$ emitters, ...

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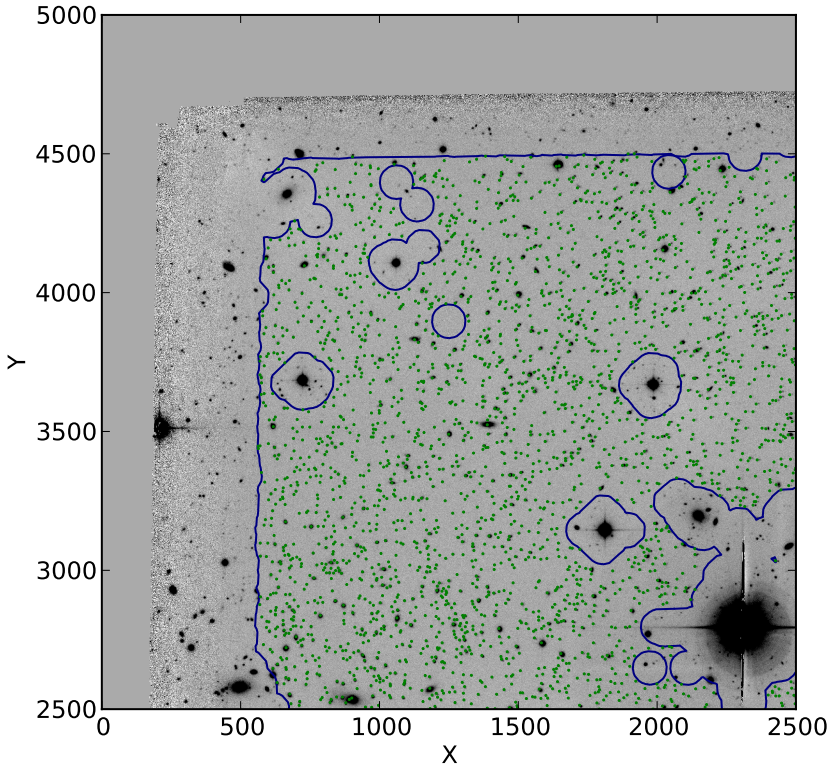
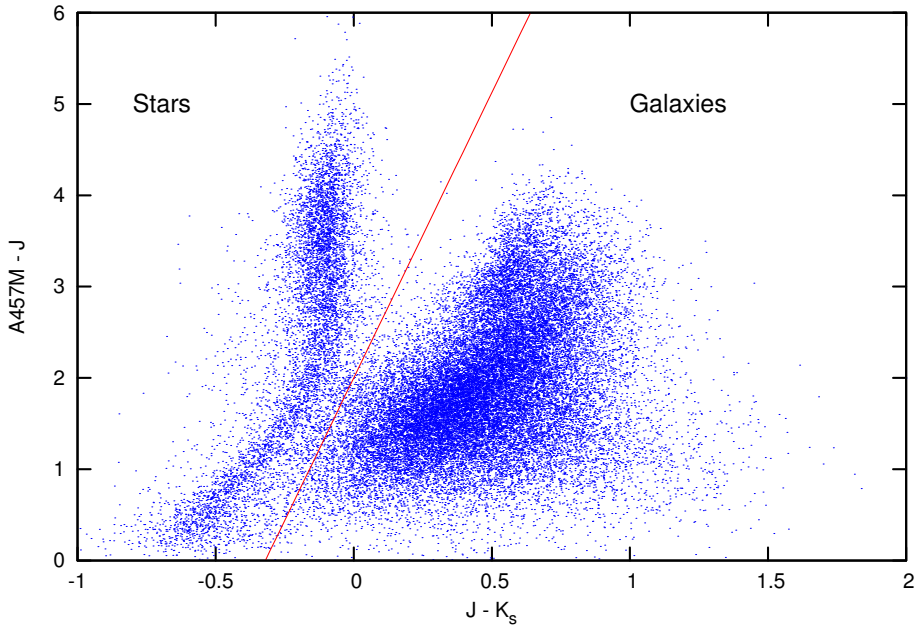
# Catalogue selection for LSS

Angular mask in detection image




Star – galaxy separation
($\sim$ *BzK* method)




$\Rightarrow$ Photo-$z$ quality cut ($p_{\rm odds} \geq 0.85$) $\rightarrow$ selects $\sim 40\%$ objects with best photo-$z$

# Characteristics of the catalogue (after selection)

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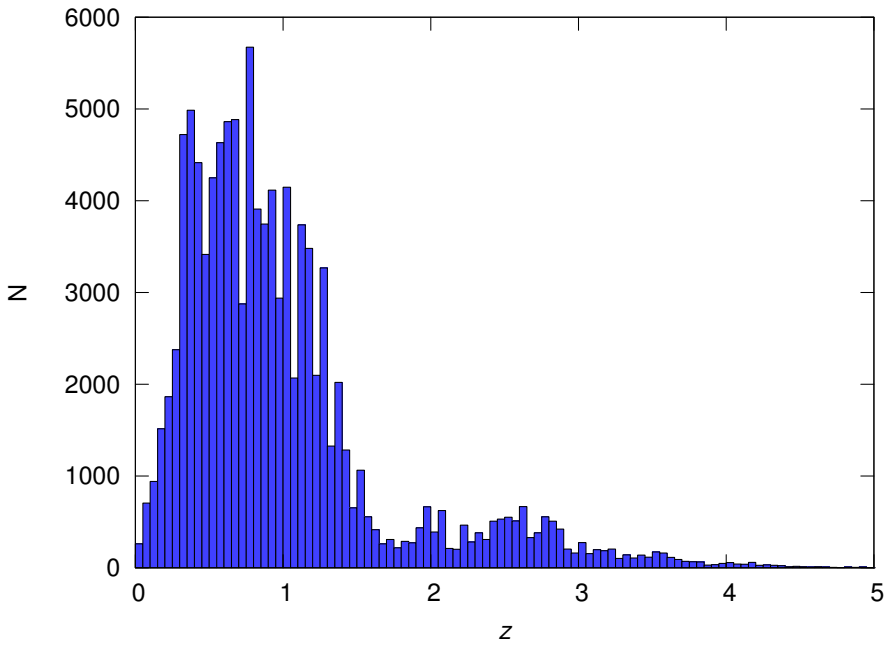

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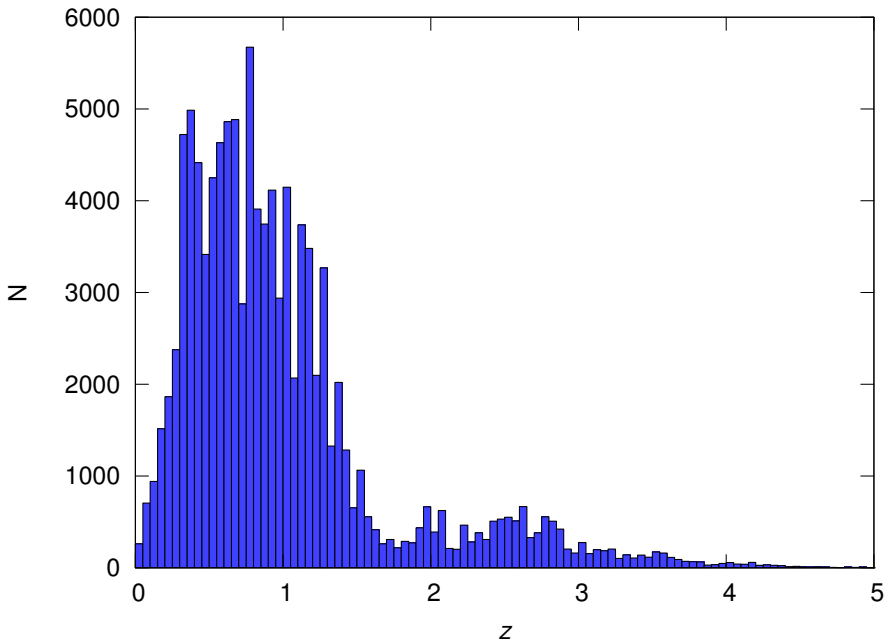
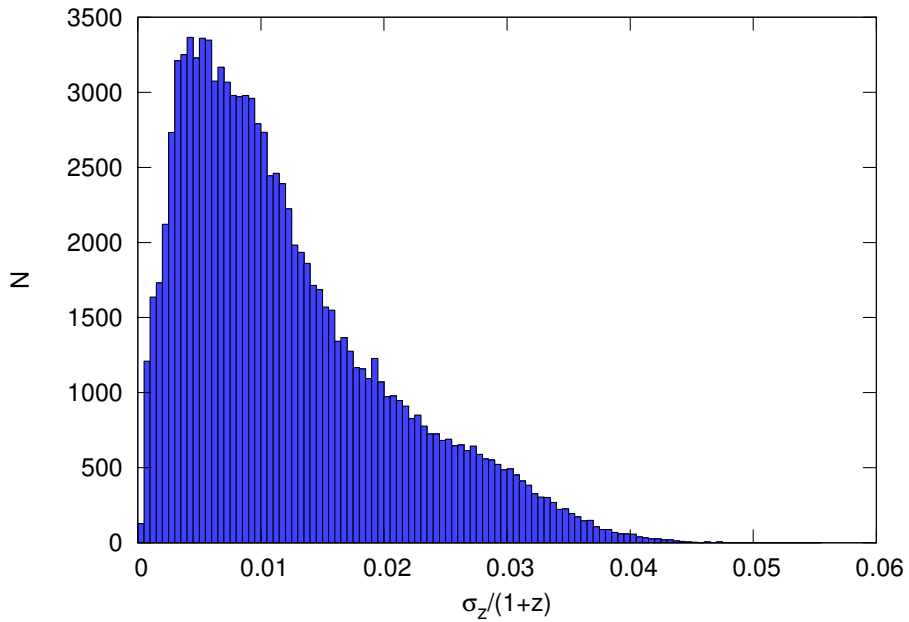
- $z_m = 0.81$, bulk on $N(z)$ in $z \in [0.3, 1.5]$
- Photo-$z$ accuracy:
  - Estimated: $\left\langle \frac{\sigma_z}{1+z} \right\rangle = 0.012$
  - Comparison with $\sim 3,600$ spectra: $\sigma_z \simeq 0.014(1+z)$

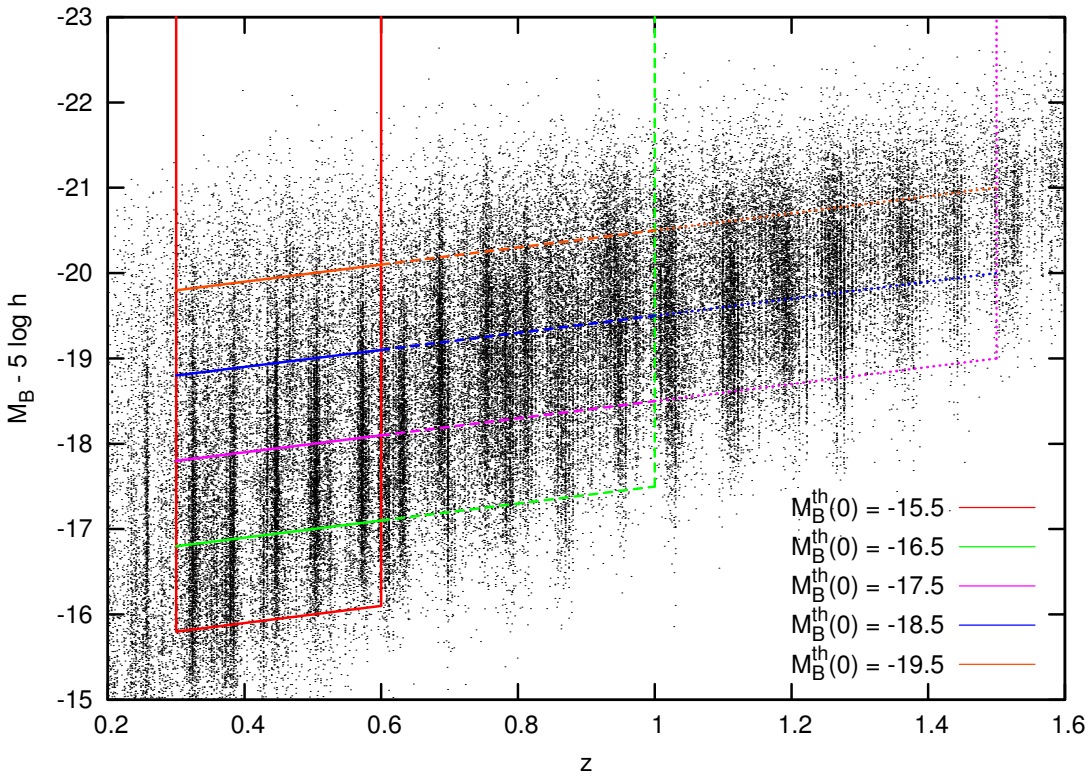


# Sample selection for galaxy clustering

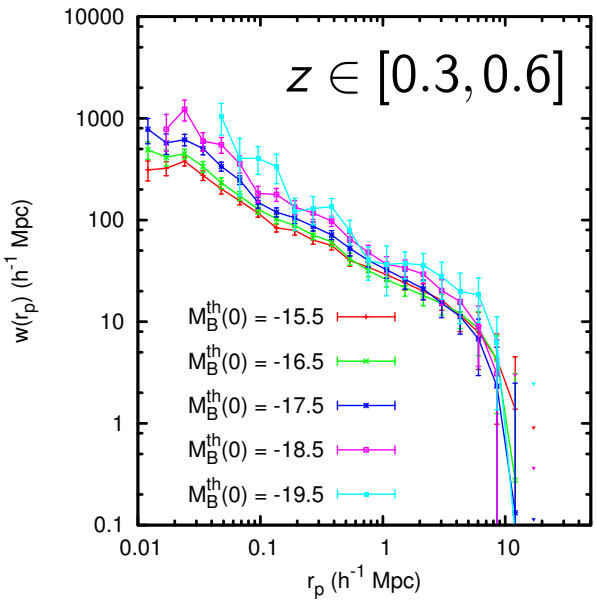
Study clustering as function of $z$ and $L \rightarrow$ selection of samples in $z$—$M_B$ plane:

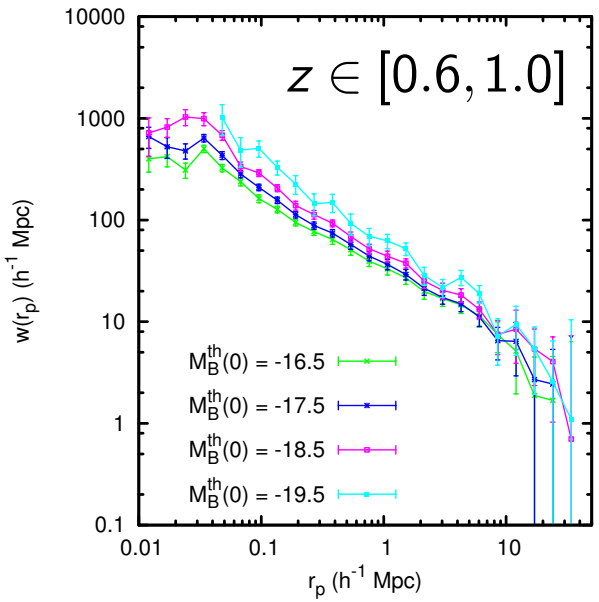
- 3 bins in $z$: $[0.3, 0.6]$, $[0.6, 1.0]$, $[1.0, 1.5]$
- "Threshold samples" in luminosity: impose faint limit $M_B \leq M_B^{th}$

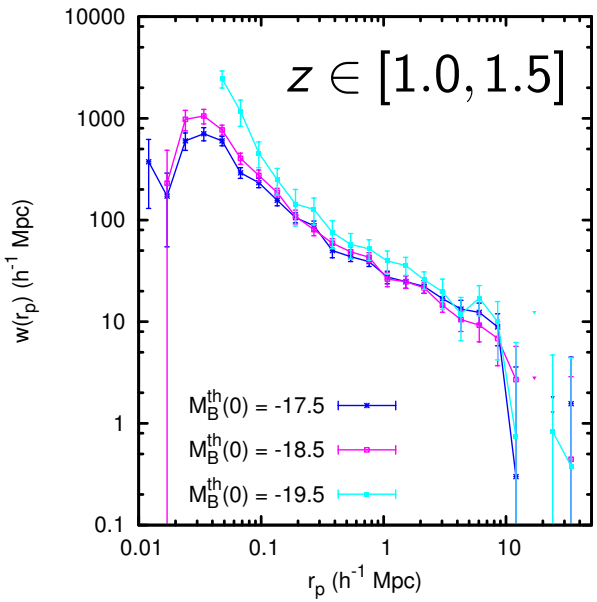


# Projected correlation functions

- Photo-$z$ $\rightarrow$ large uncertainty in LOS distance ($\pi$) $\rightarrow$ measure *projected correlation function* $w(r_p)$ (with long integration along $\pi$)
- Measure $w(r_p)$ for each of the selected samples:



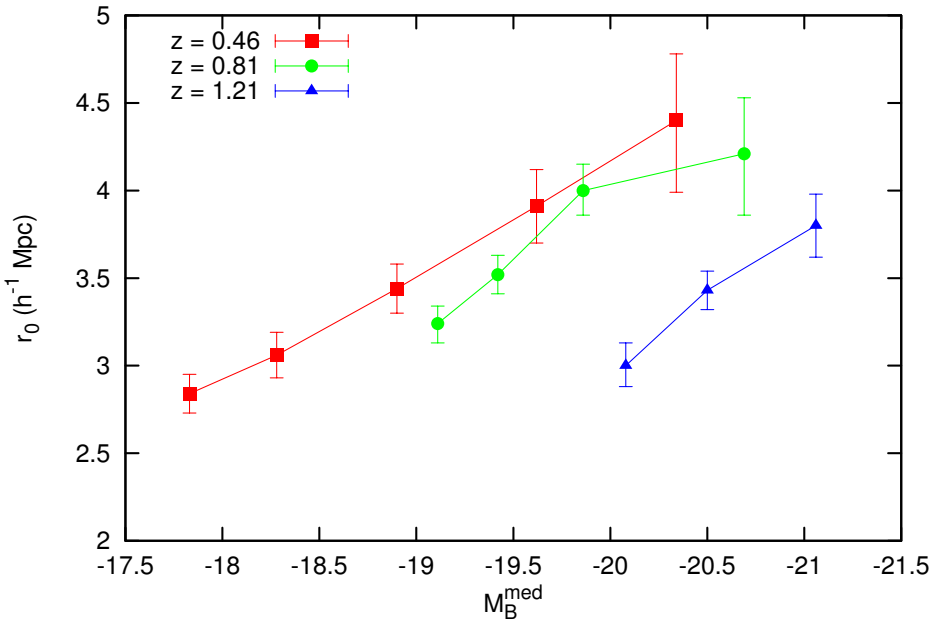



# Simple fits to data

$\Rightarrow$ fits in range $r_p \in [0.2, 15]\, h^{-1}\,\mathrm{Mpc}$

**Power-law fit:**

- $\xi(r) = \left(\frac{r}{r_0}\right)^{-\gamma} \rightarrow$ power law for $w(r_\perp)$
- Fits with fixed $\gamma = 1.7$



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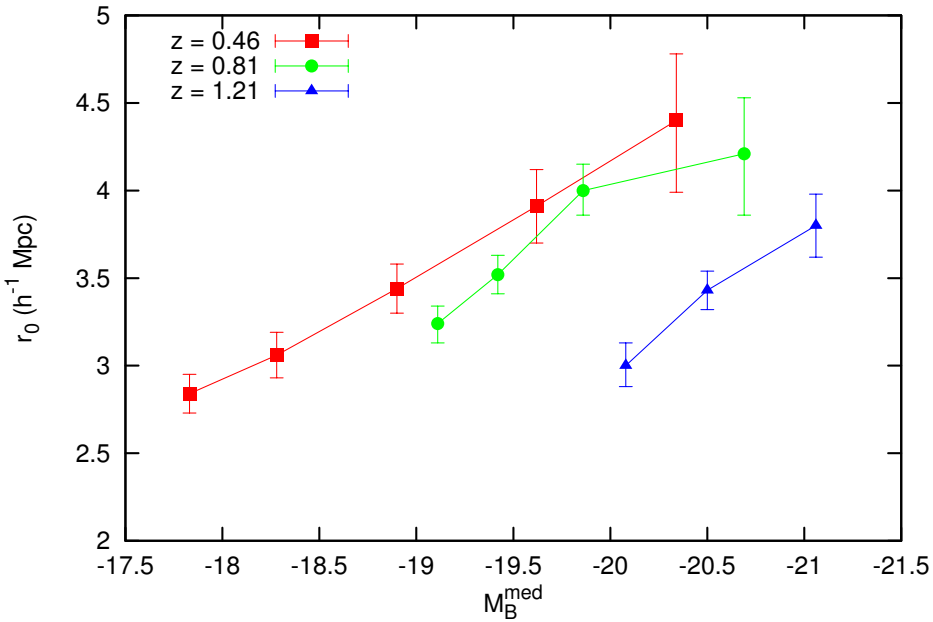
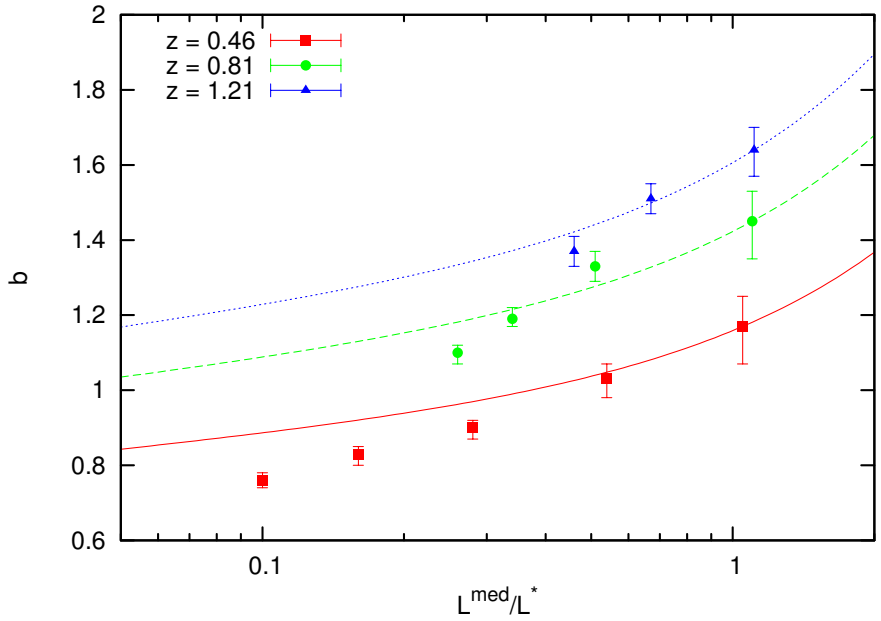



**CAMB (+ HaloFit) model:**

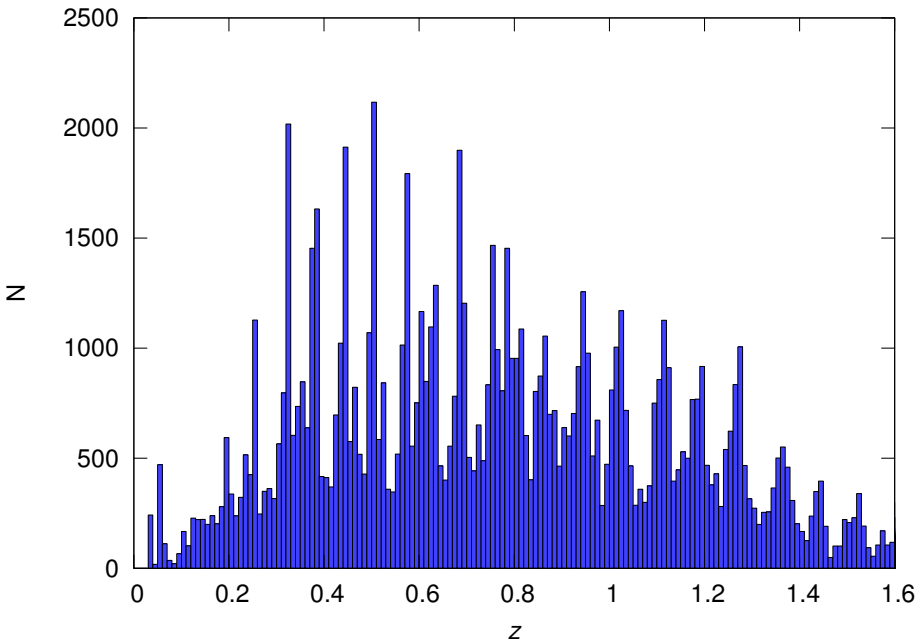
- Fixed parameters, only change is amplitude $\rightarrow$ bias
- Compare with $b(L)$ dependence in SDSS & 2dFGRS



# Several issues (work in progress)

- Definition of catalogue:
  - Photometric depth (magnitude limit) in different bands
  - Photo-$z$ (possible biases?)
- Photo-$z$ quality depends on type, $z \rightarrow$ How to deal with it?

- Possible systematics/artifacts coming from photo-$z$ technique (radial bumps)




- Develop clustering analysis methods to use all the available information: $p(z)$ for each galaxy

# Conclusions

- ALHAMBRA provides a deep catalogue covering a significant area with high quality photo-$z$
- Can study evolution of contents of the universe for a large range in $z$
- Will work as test bench for larger surveys using similar multi-band concept: PAU surveys
- Preliminary calculations of $w(r_p)$ for several samples in $(z, L) \rightarrow$ show the capabilities of ALHAMBRA for these clustering studies, but many issues still to be tackled