Detecting galaxy clusters in the DLS and CARS: a Bayesian Cluster Finder

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- Vera Margoniner (Sacramento State University)
- Ian Dell' Antonio (Brown University)
- Will Dawson (UC Davis)
- Ami Choi (UC Davis)
- James Jee (UC Davis)
- … and the rest of the DLS team

OUTLINE

- Introduction: Galaxy cluster detection
- The Bayesian Cluster Finder
  - The method
  - Simulations
- Applications
  - DLS
  - CARS
- Work in progress

GALAXY CLUSTER DETECTION

- GEOMETRY: Voronoi Tessellation (*Kim et al. 2002, Ramella et al. 2001, Lopes et al. 2004*), Counts in cells (*Couch et al. 1991, Lidman & Peterson 1996*), Percolation FoF Algorithm (*Dalton et al. 1997*).

- MATCHED FILTER: (*Postman et al. 1996, 2002*), Adaptative Kernel (*Gal et al. 2000, 2003, 2006*), Hybrid Matched Filter (*Kepner et al. 1999*), Adaptative Matched Filter (*Kim et al. 2002*). High z: Spitzer (*Eisenhardt et al. 2008*)

- RED SEQUENCE: MaxBCG (*Hansen et al. 2005, Koester et al. 2007*), The Cluster Red Sequence Method (*Gladders & Yee 2000, López-Cruz et al. 2004, Gladders et al. 2005*), Cut-and-enhance (*Goto et al. 2002*), the C4 clustering algorithm (*Miller et al. 2005*). High z: SpARCS (*Wilson et al. 2008*)

THE BAYESIAN CLUSTER FINDER

- Motivation: to take advantage of all the characteristics of every algorithm.
- Each galaxy in the survey is assigned a Bayesian probability that the galaxy belongs to a cluster at a certain redshift.
- Likelihood: Based on a variation of the Matched Filter Algorithm including photo-z information.
- Introduction of a Bayesian prior: CMR – z relation and BCG magnitude –z relation.

Ascaso et al. 2010b,c, ApJ to be submitted

GALAXY CLUSTERS DETECTION

1. Redshift slices (z_s) from $0.1 \leq z_s \leq 1.2$ in steps of 0.1
2. Each galaxy (α_i, δ_i, $z_{s,i}$) -> prob
3. Each z_s -> background and σ probability. Only select 3σ detections.
4. Output:
   - Richness (Λ_{cl}; effective number of L^* galaxies in the cluster)
   - Position (α_c, δ_c)
   - Maximum probability redshift z_s
   - Mean redshift (z_m) from the photo-z's galaxy distribution
5. Only keep candidates that $|z_s - z_m| < 0.06(1+z_s)$
6. Clusters with $D<1.5$Mpc and $|z_{s,1} - z_{s,2}|<0.3$ are merged

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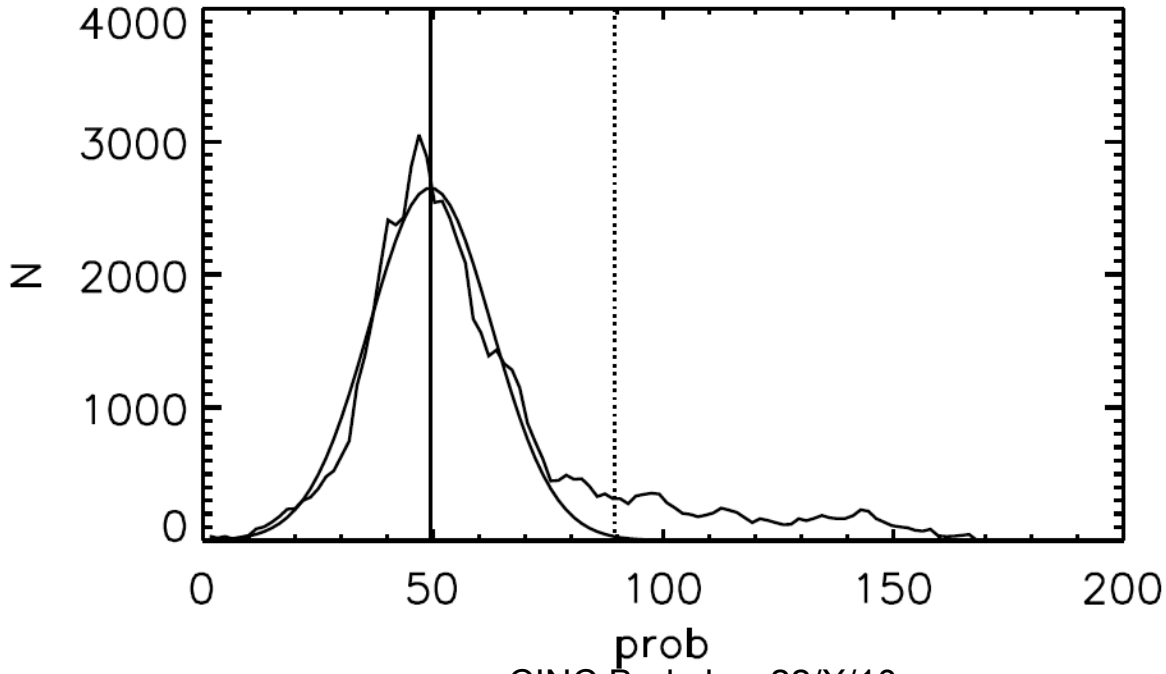

in the cluster)

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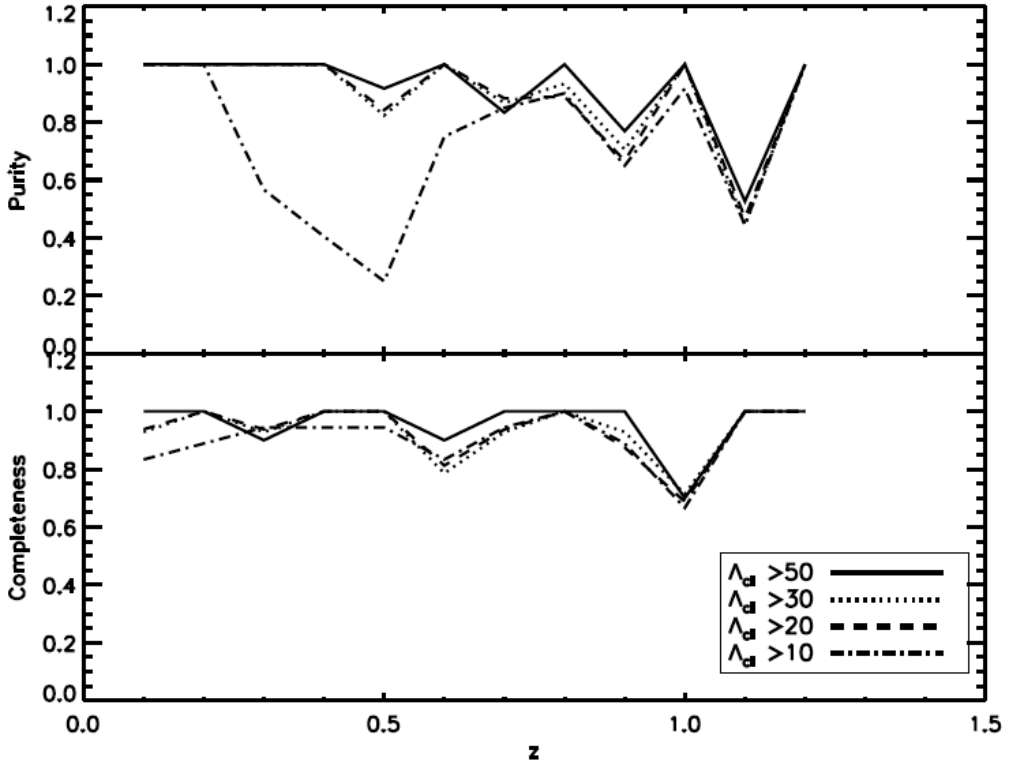
SIMULATIONS

- Clusters
  - Richness: $10 \leq \Lambda_{cl} \leq 250$ (equivalent to $0 \leq RA \leq 4$)
  - Redshifts: $0.1 \leq z_c \leq 1.2$
  - Magnitudes: Schechter LF model with α=-1.1 and M*= -21.
  - Positions: Plummer profile.
  - Galaxies redshift: spread as a normal function with $\mu=z_c$ and $\sigma=2(1+z_c)0.06$
  - Colors: Using spectra templates combined with a spread technique in order to match the observed CMR
- Field galaxies
  - Magnitudes, colors and photo-z distribution from the original data
  - Positions: Rayleigh-Levy two point correlation function

RECOVERY RATE

$$Purity = \frac{\#\{detected\ clusters \| simulated\}}{\#\{detected\ clusters\}}$$

$$Completeness = \frac{\#\{simulated\ clusters \| detected\}}{\#\{simulated\ clusters\}}$$



Both purity and completeness rates are over 80% for clusters richer than Λ_{cl} >20 and z<1.1

APPLICATION TO SURVEYS I: DLS

- The Deep Lens Survey (DLS)
  - *Wittman et al. 2002, 2006*
  - 20 □^{2} (5 x 4 □^{2}).
  - Four optical bands: BVRz, complete up to 26/26/27/26 mag/□^{2}
  - Pixel size: 0.257“
  - Best seeing in R band (<0.9”). For non-R images, seeing averages ~1.2”

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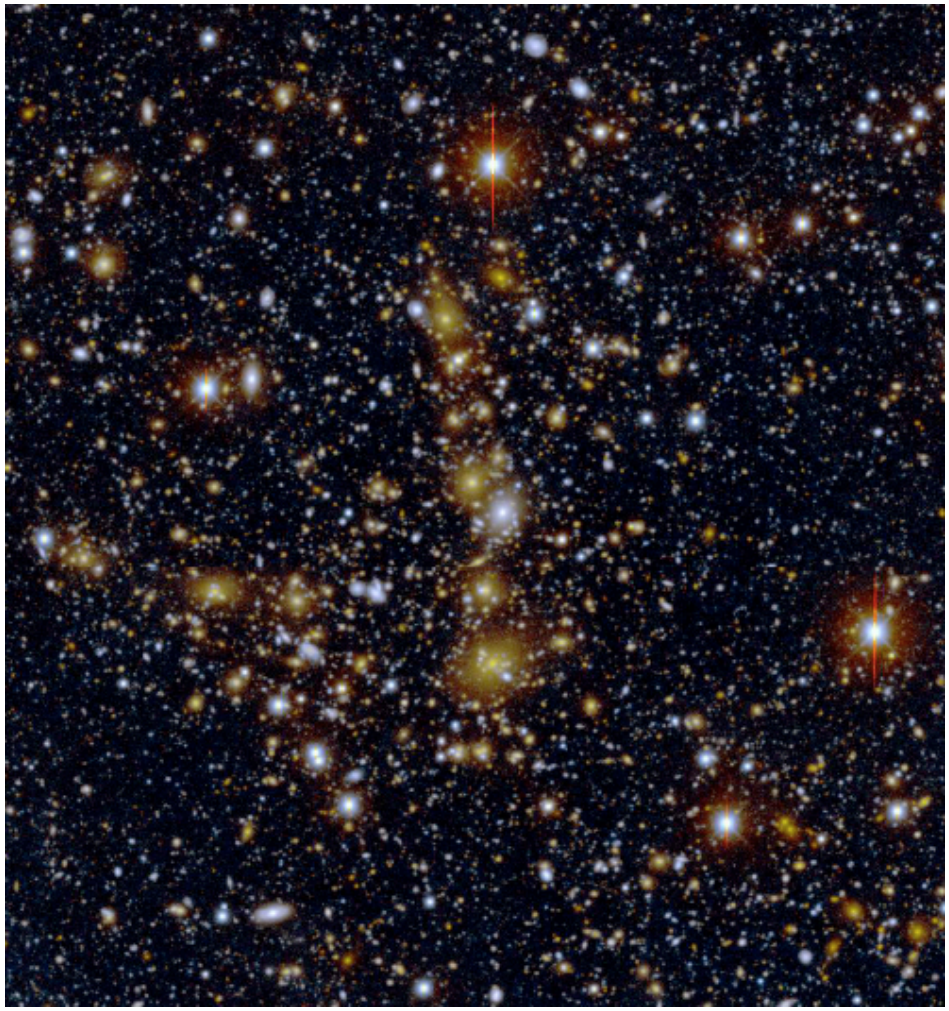
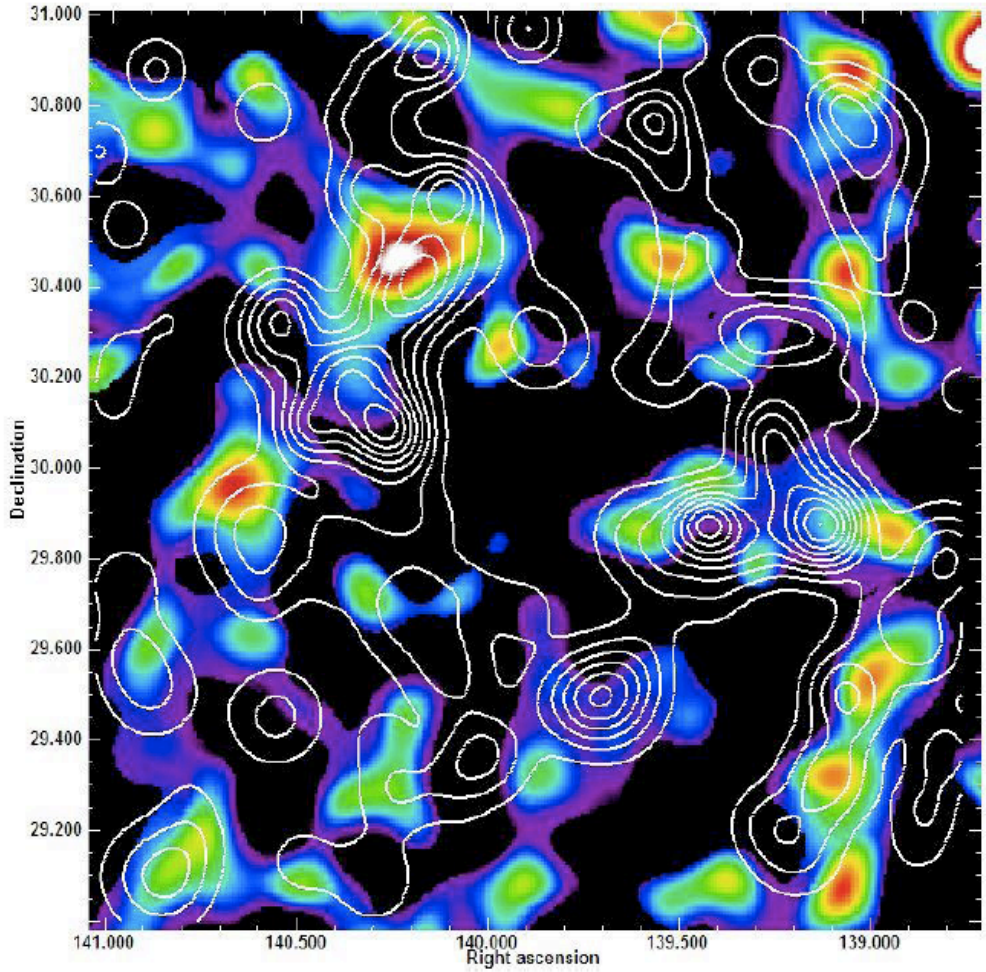


APPLICATION TO SURVEYS I: DLS

- More than 700 galaxy clusters detected up to z <1.2
- Detect 100% of the optical detections by MaxBCG and the spectroscopically confirmed clusters by *Wittman et al. 2006*
- Large Scale Structure
- Weak Lensing maps (Dawson et al. *2010 in prep)* correlations with optical detections



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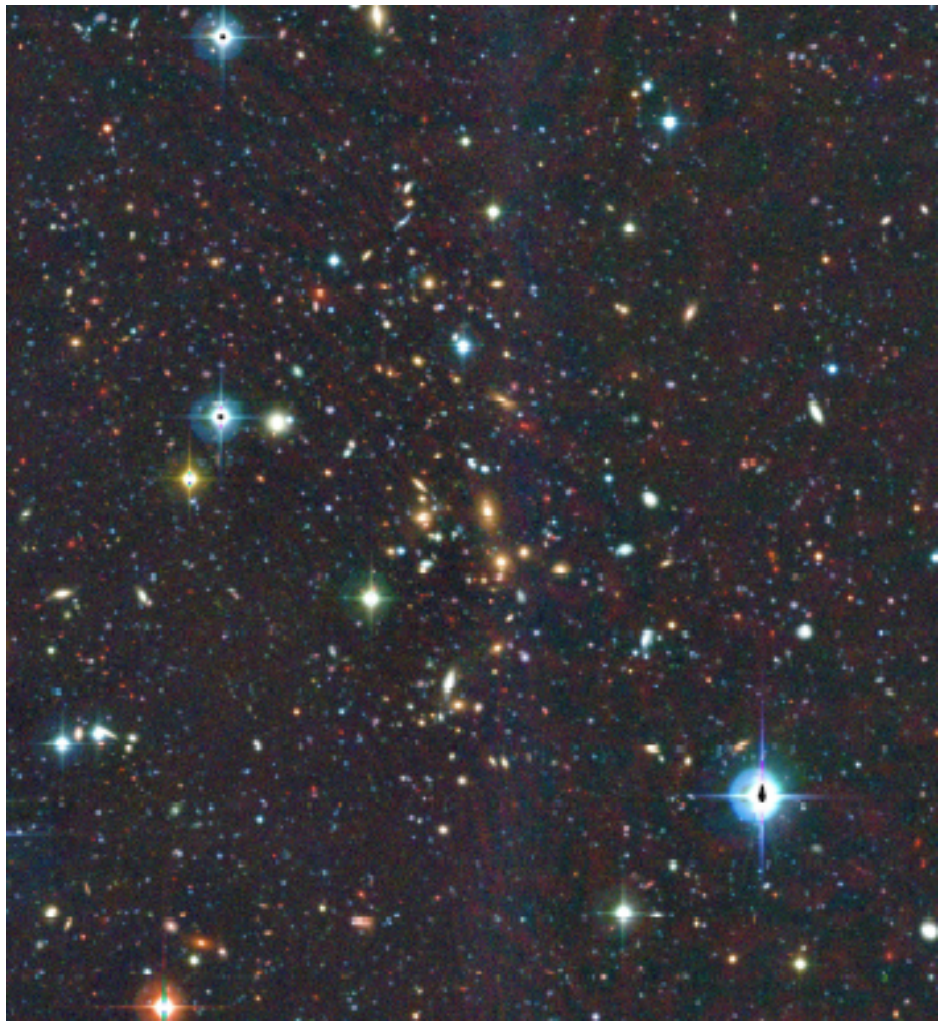
APPLICATION TO SURVEYS II: CARS

- The CFHTLS-Archive-Research Survey (CARS; *Erben et al. 2009*)
  - based on the public archive images from the CFHTLS-Wide (37 $\square^2$)
  - Five optical bands (ugriz)
  - Complete up to 24 in R band
  - Pixel size: 0.186‘’
  - BPZ photo-zs *(Benítez 2000)*



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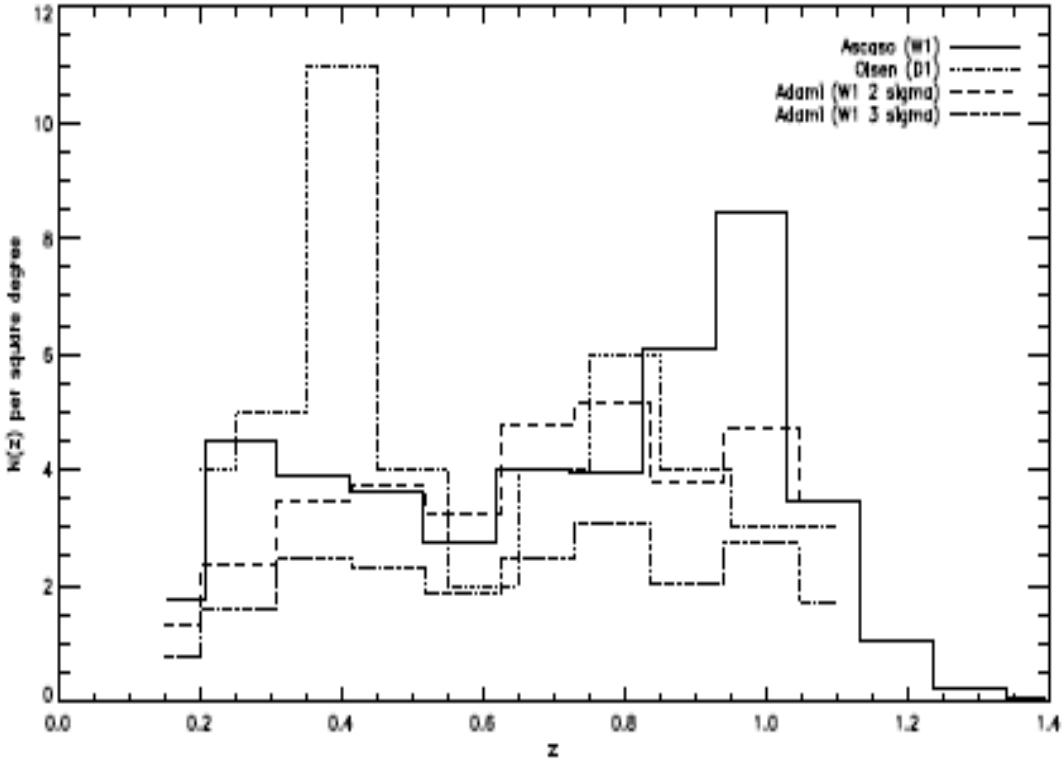
- *Adami et al (2010)*: We find an agreement of 81% and 74% over 3 and 2σ respectively



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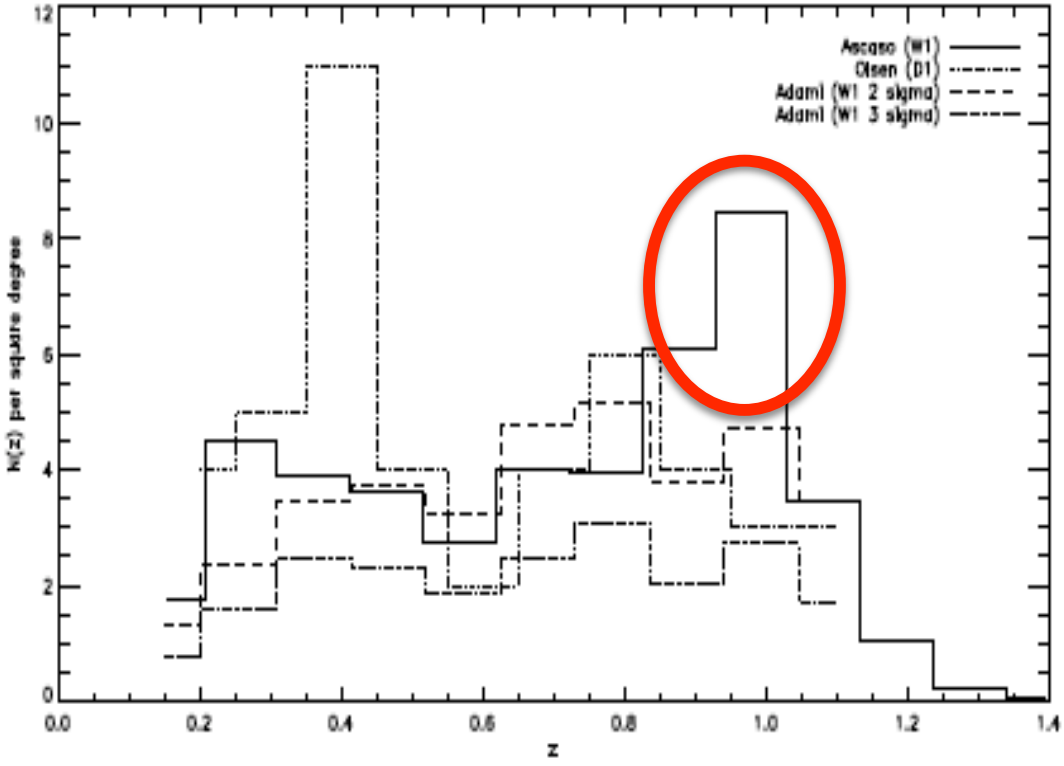

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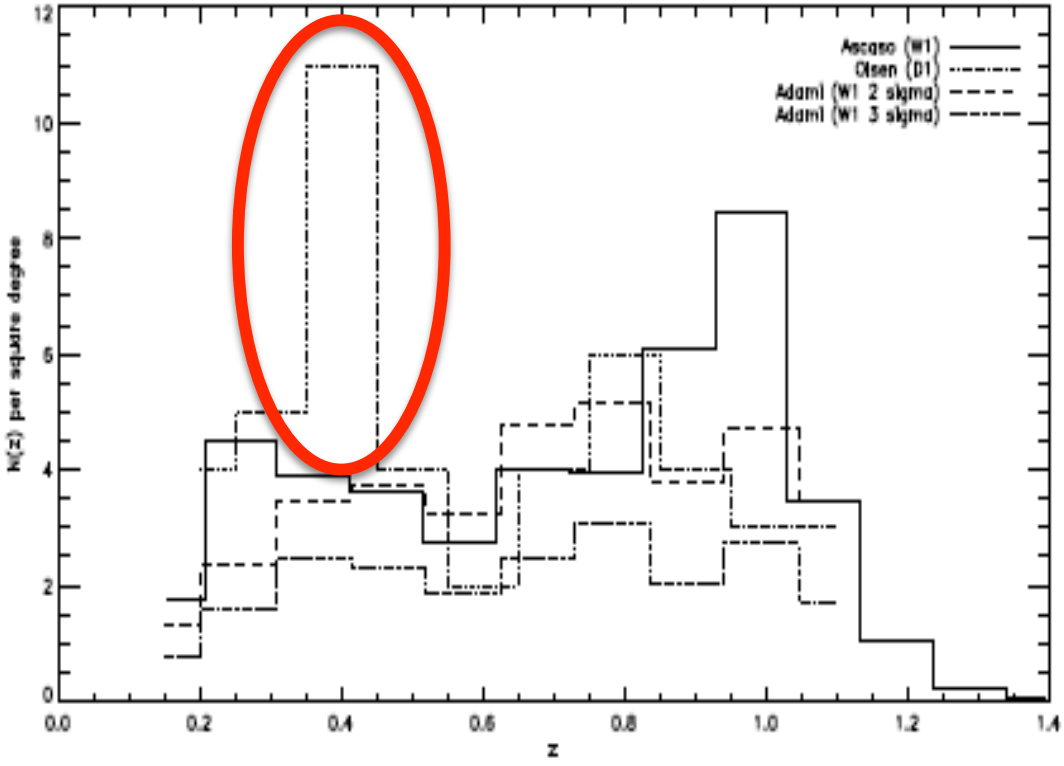

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WORK IN PROGRESS

- Extend the DLS detections to high redshift clusters (z>1) by using existing IR data.

- Developing telescope proposals to confirm the completeness and purity rates and to diminish the photometrical redshift errors.

Comments, suggestions or collaborations are welcome

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¡GRACIAS!

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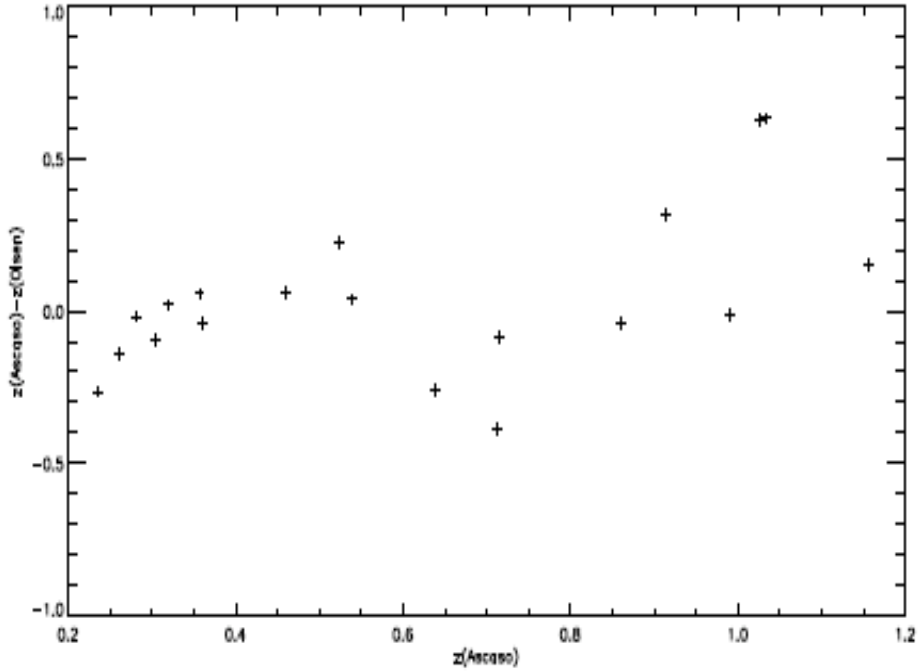
APPLICATION TO SURVEYS II: CARS

Detections and comparison with other works:
Olsen et al. 2007

- They detect 32 clusters in Deep 1 (one degree overlap with W1) excluding 14 C or D systems.
- We find 62 clusters in W1 (65% in common)
- We detect many more, in particular at z>0.9 in less deep fields



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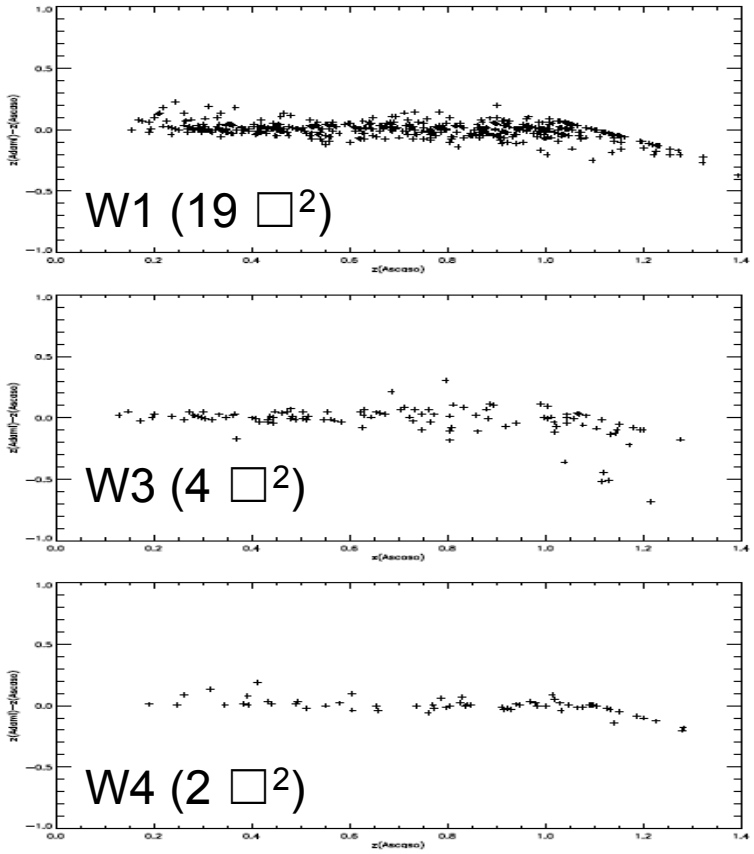
APPLICATION TO SURVEYS II: CARS

Adami et al. 2010

- They detect clusters in Wide and Deep fields.

- We obtain more than 1200 galaxy clusters in 25 $\square^2$ in common, while they find ~600 and 1000 over 3 and 2σ resp.

- We find an agreement of 81% and 74% over 3 and 2σ resp.



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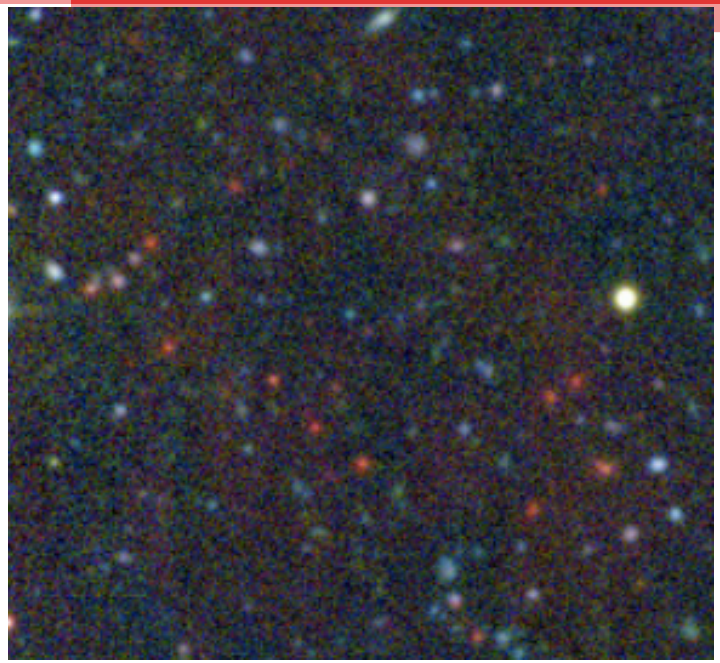
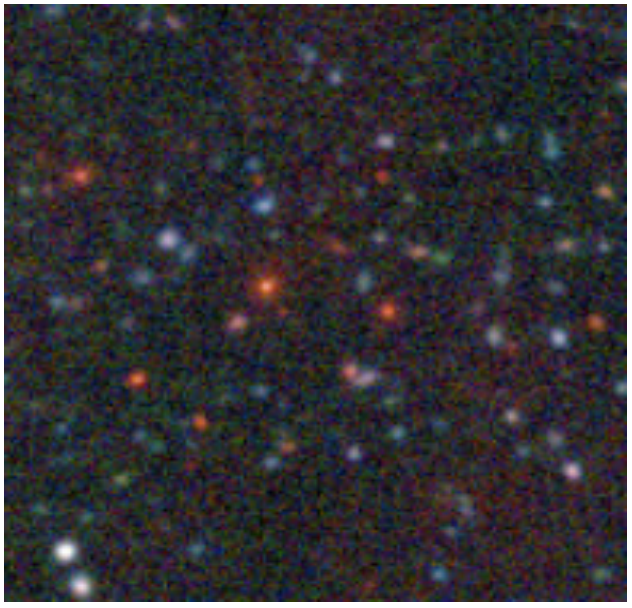
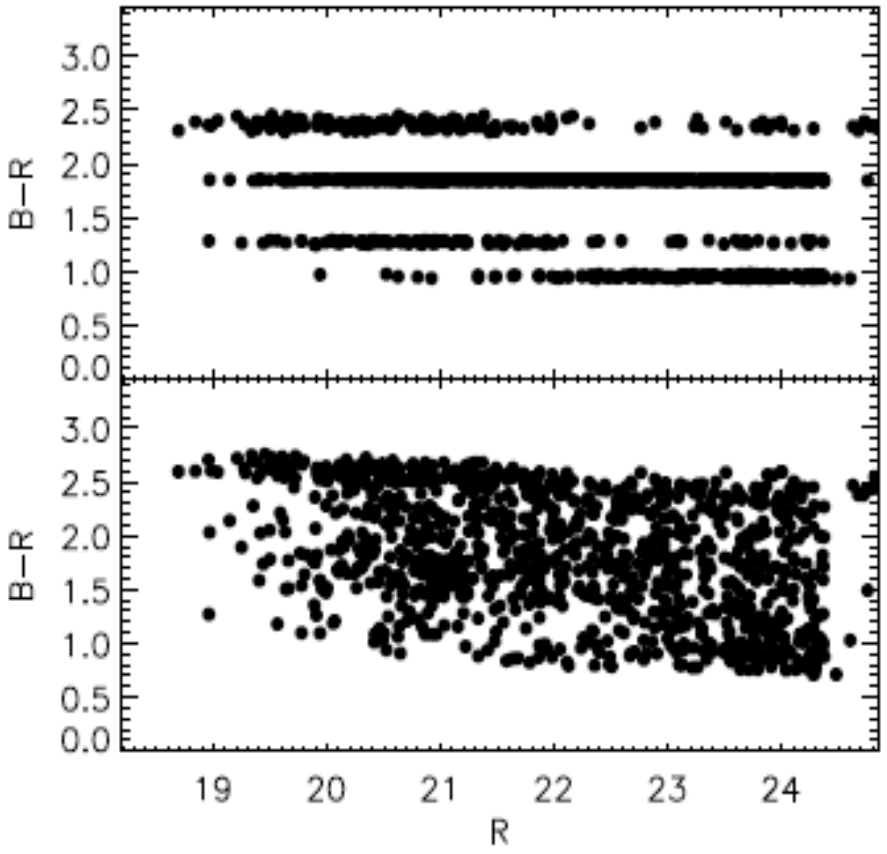




SIMULATIONS

Color-Magnitude simulation



THE LIKELIHOOD

- The likelihood models the probability that a galaxy with its position, photo-z, magnitude and morphological type belongs to a cluster at that position, with a given redshift and richness.
- It is the product of the model probability for
  - A cluster spatial profile: e.g., a Plummer profile.
  - A luminosity function: e.g. a Schechter function,
  - A redshift probability distribution: either from a photometric redshift software (e.g. from BPZ) or a Gaussian.

Density		Luminosity		Redshift	
Plummer		Schechter		Gaussian	
r_c (Kpc)	r_{cut} (Mpc)	α	M^*	$< z >$ z	σ
1.25	1.25	-1.05	-21.44	$0.1 - 1.2$	$0.06(1+z)$

THE PRIOR

- The prior enhances the probability that a cluster exists at a given position by including any a priori information about clusters. We have considered:

  - The cluster CMR at any redshift: obtained from a set of template spectra and a fix slope. We use B-R and R-z.

  - The BCG magnitude-redshift relation: obtained from the MaxBCG sample of 13823 BCGs (*Koester et al. 2007*)