Quasar pairs as beacons to high redshift clusters

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Motivation

Relevance of the detection of clusters at high redshifts:

- **Cosmology:** ω, power spectrum amp, dark matter, etc.
- **Cluster physics:** evolution of the scale relations
- **Environ. effects:** galaxy formation and evolution

Most cluster detection methods (e.g. X-rays, optical/NIR, lensing) struggle at very high redshifts ($z>1.5$)

The use of quasar associations (pairs, triplets or +) can be a powerful tool to indicate the presence of clusters in those redshifts

Method: quasar associations

Quasars are rare objects whose activity seems to be triggered by galaxy interactions →

A physically close pair (or triplet or +) of quasars is likely be related with a galaxy overdensity

<u>Concept proof</u>: Study of 4 fields with quasar pairs

Boris et al. (2007)

Sample

Catalog: Véron-Cetty & Véron (2001)

Association criteria: $\Delta z < 0.01$

$15'' < \Delta\theta < 300''$

Redshift range: $0.9 < z < 1.0$

Quasar Names	α (J2000)	δ (J2000)	z	$\Delta\theta$ (arcsec)	Quasar Pair Name
J131046+0006[a]	13 10 46.2	00 06 33	0.925	177	QP 1310+0007
J131055+0008	13 10 55.9	00 08 14	0.933	...	...
J135457−0034	13 54 57.2	−00 34 06	0.932	252	QP 1355−0032
J135504−0030[a]	13 55 04.7	−00 30 20	0.934	...	...
Q0107−0235	01 10 13.2	−02 19 53	0.958	77	QP 0110−0219
PB 6291[a]	01 10 16.3	−02 18 51	0.956	...	...
J011441−3139[a]	01 14 41.8	−31 39 25	0.974	144	QP 0114−3140
J011446−3141[a]	01 14 46.4	−31 41 31	0.968	...	...

Observations: imaging

GMOS North and South: g', r', i', z'

(exp: ~ 50, 20, 45, 55 min. respectively)

		t_{exp} (s)			
PAIR	TELESCOPE	g'	r'	i'	z'
QP 1310+0007.....	Gemini N	9 × 300.0	6 × 200.0	11 × 350.0	8 × 450.0
QP 1355−0032.....	Gemini N	13 × 300.0	6 × 200.0	6 × 350.0	7 × 450.0
QP 0110−0219.....	Gemini N	10 × 300.0	6 × 200.0	8 × 350.0	8 × 410.0
QP 0114−3140.....	Gemini S	7 × 300.5	6 × 200.5	7 × 350.5	7 × 410.5

Photometric redshifts

Method LRW: Locally Weighted Regression

Santos, Sodré et al. (in prep.)

$$z(\boldsymbol{x}) = a_0 + \boldsymbol{a}^T \cdot \boldsymbol{x} = a_0 + \Sigma_{i=1}^{n} a_i x_i$$

$$\chi^2 = \Sigma_{j=1}^{N} \omega_j^2 \left(y_j - a_0 - \boldsymbol{a}^T \cdot \boldsymbol{x}_j \right)^2$$

$$\omega_j = \exp\left[\frac{-d^2(\boldsymbol{x}, \boldsymbol{x}_j)}{2K^2} \right]$$

HHDFN (Capak et al. 04) data were used optimize the parameters: 2/3 of the sample used for training and 1/3 for validation

Photometric redshifts

z'< 22

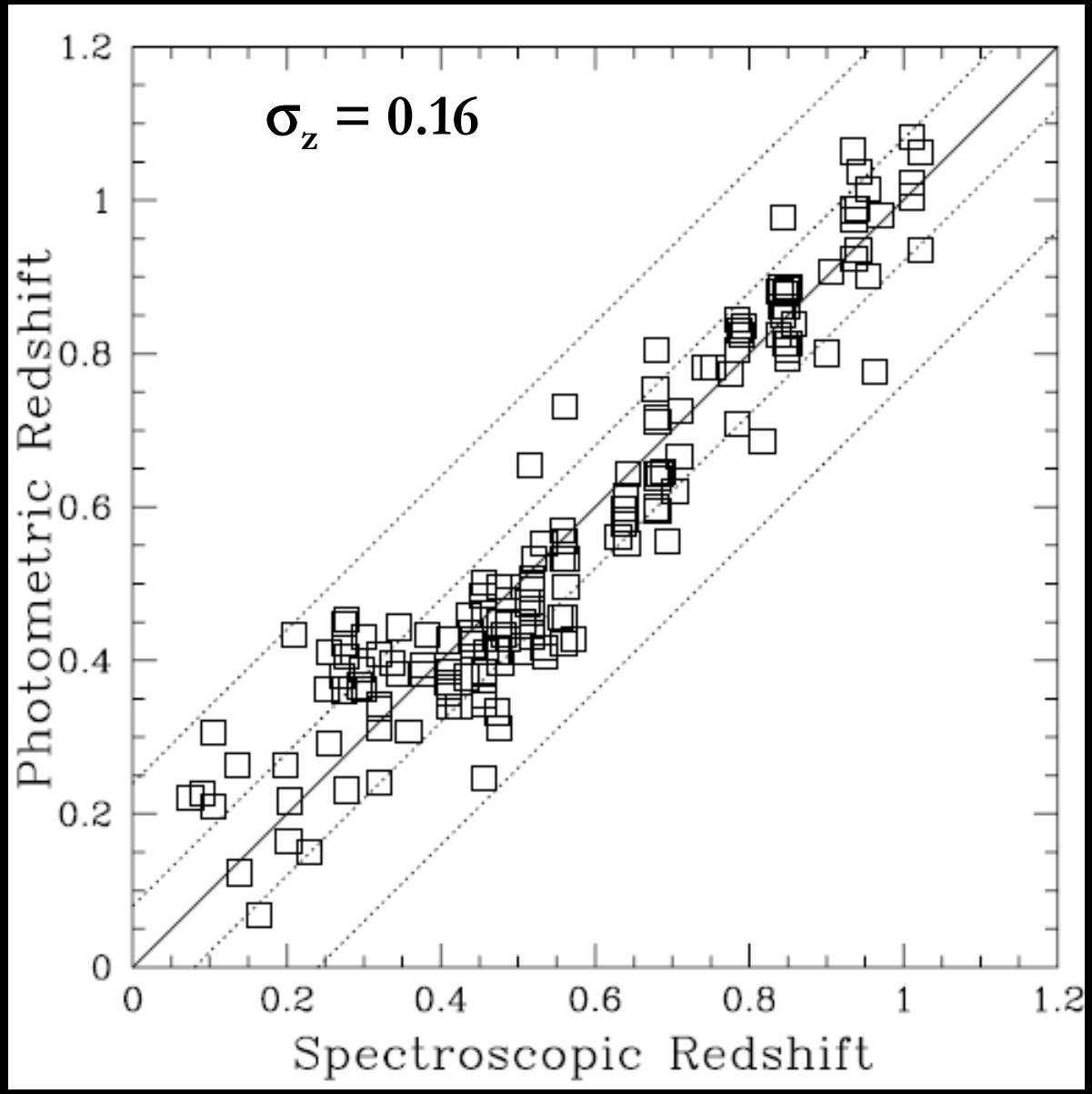
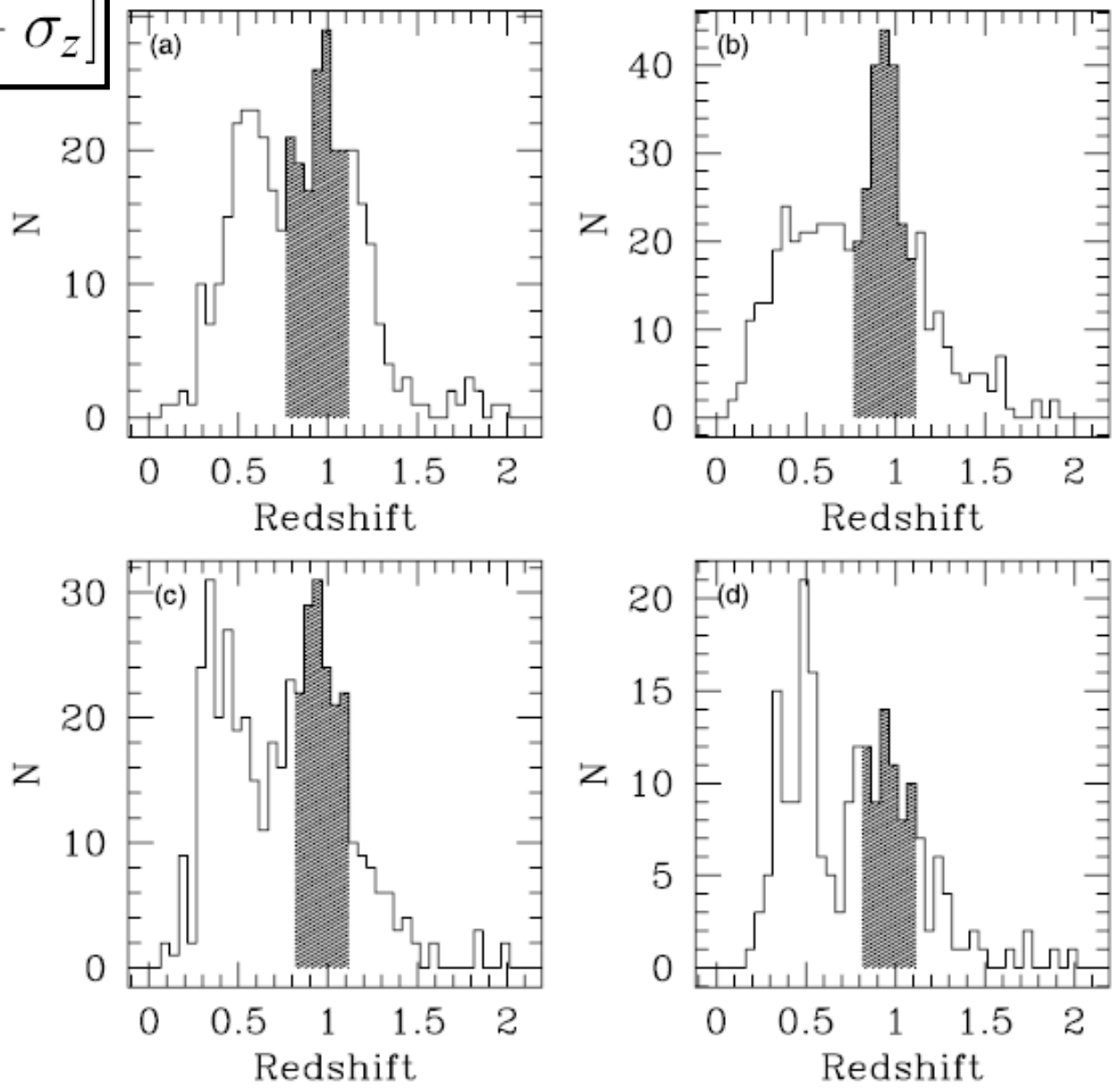


Photo-z distribution

$$z \in [z_{\rm pair} - \sigma_z, z_{\rm pair} + \sigma_z]$$



Tests

$$z \in [z_{\rm pair} - \sigma_z, z_{\rm pair} + \sigma_z]$$

Overdensity: $\delta = \dfrac{n_{\rm pair} - n_{\rm H}}{n_{\rm H}}$ — Density over the field (HHDFN)

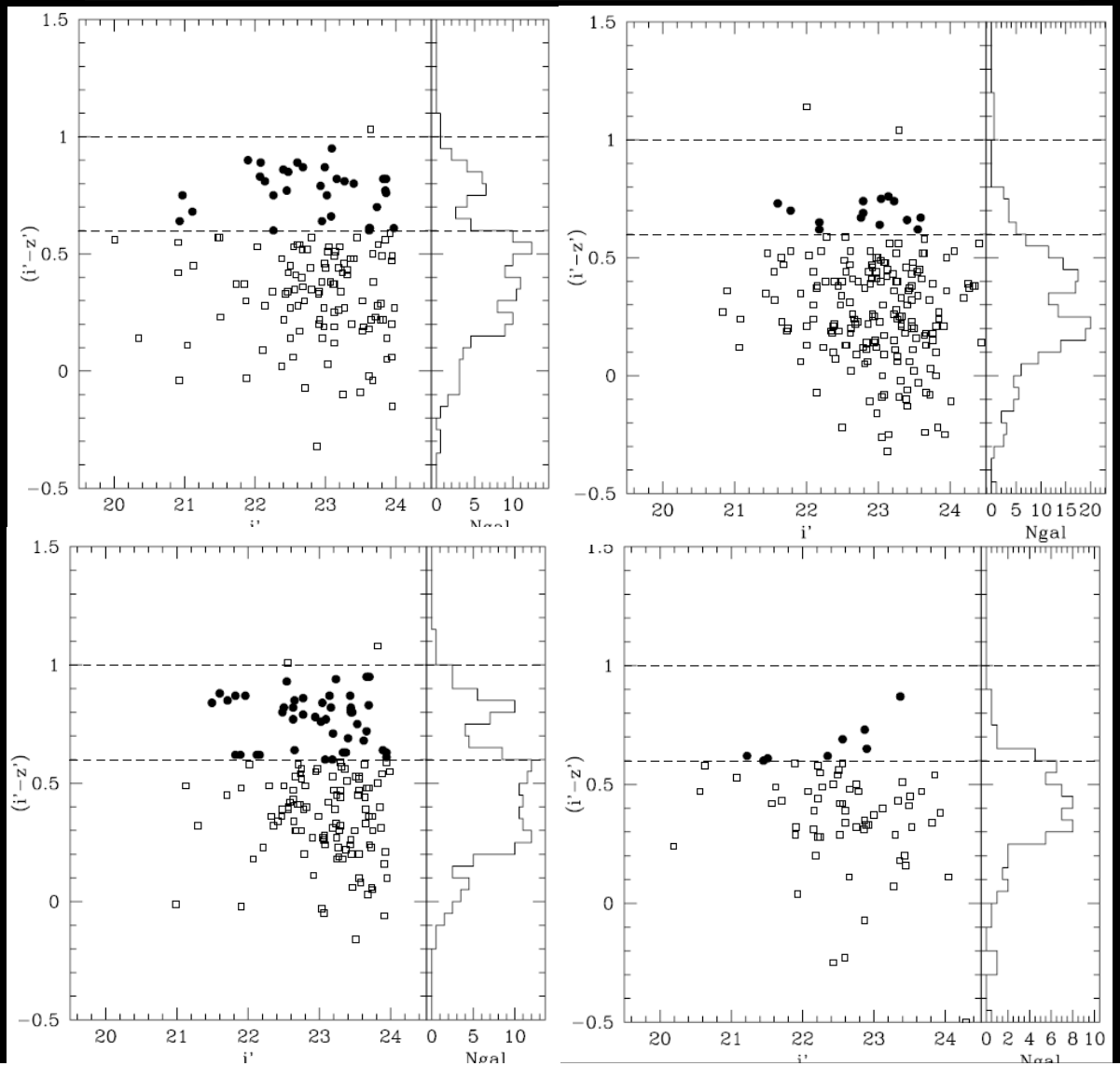
Clustering: $\mathrm{CL} = \dfrac{N(\Delta\theta > \Delta\theta_f)}{N_s}$ — Average distance between members compared to random

Richness: $N(i' < i'_3 + 2)$ — The Abell criteria

Pair	δ	$\Delta\theta_{\rm median}$ (arcmin)	$\mathrm{CL}_{\rm median}$ (%)	i'_3	$N(i' < i'_3 + 2)$	$N^{\rm esc}(i' < i'_3 + 2)$
QP 1310+0007.....	0.58 ± 0.14	2.7	67.0	20.35	6 ($R < 0$)	13 ($R < 0$)
QP 1355−0032.....	1.59 ± 0.19	2.6	98.5	21.06	95 ($R = 2$)	203 ($R = 4$)
QP 0110−0219.....	0.70 ± 0.14	2.4	100.0	21.29	35 ($R = 0$)	72 ($R = 1$)
QP 0114−3140.....	0.86 ± 0.23	2.8	0.5	20.63	34 ($R = 0$)	95 ($R = 2$)

Tests

Presence of a red cluster sequence



Test results

SUMMARY OF THE QUASAR PAIR PROPERTIES

Pair	δ	CL	N_A	RCM	C/F[a]	X-Rays
QP 1310+0007	ok	ok	x	ok	ok	...
QP 1355−0032	ok	ok	ok	x	x	...
QP 0110−0219	ok	ok	ok	ok	ok	ok
QP 0114−3140	ok	x	ok	x	x	...

[a] Cluster-like or filament-like distribution.

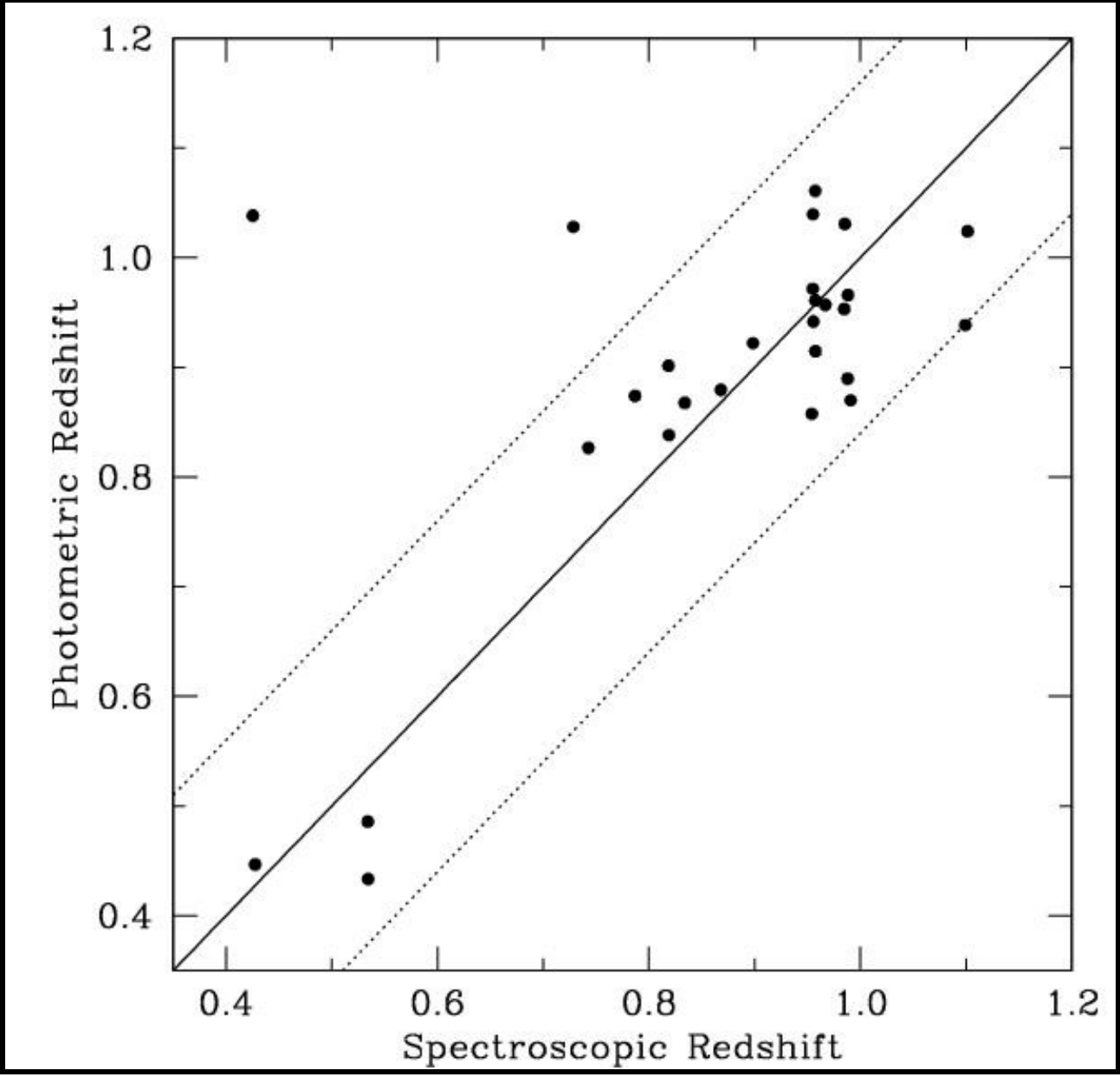
QP 0100-0219: Spectroscopy

GMOS @ Gemini North:

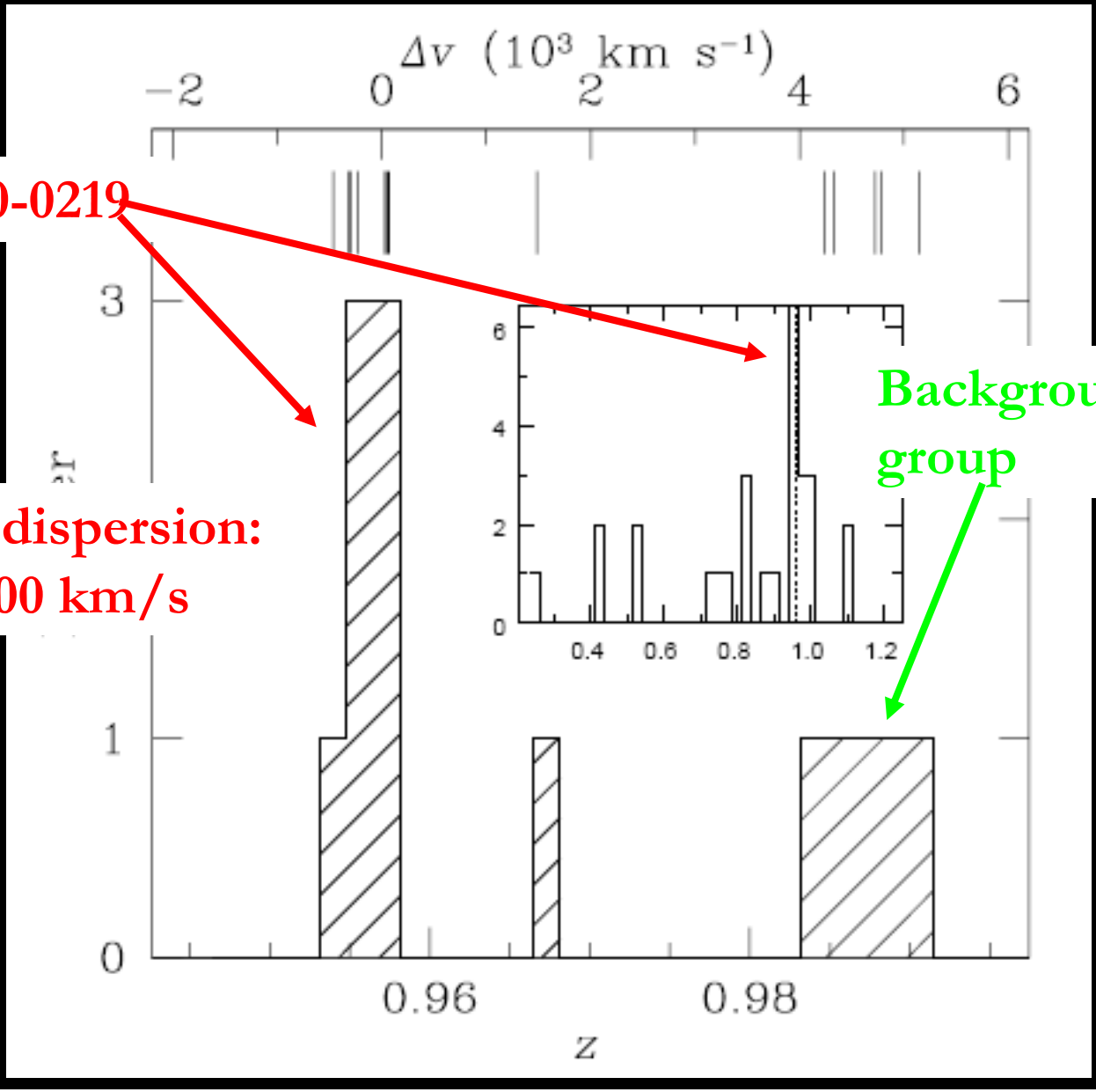
- R400+1.5”slits $\lambda \in$ [~5500Å, ~9700Å]
- 2.4h on target (Nod & Shuffle technique)
- Targets selected by photo-z’s
- One mask (32 slits) → 27 redshifts

Cypriano et al. in prep.

Spec. *versus* phot. redshits



Redshift distribution



CL 0110-0219

Background group

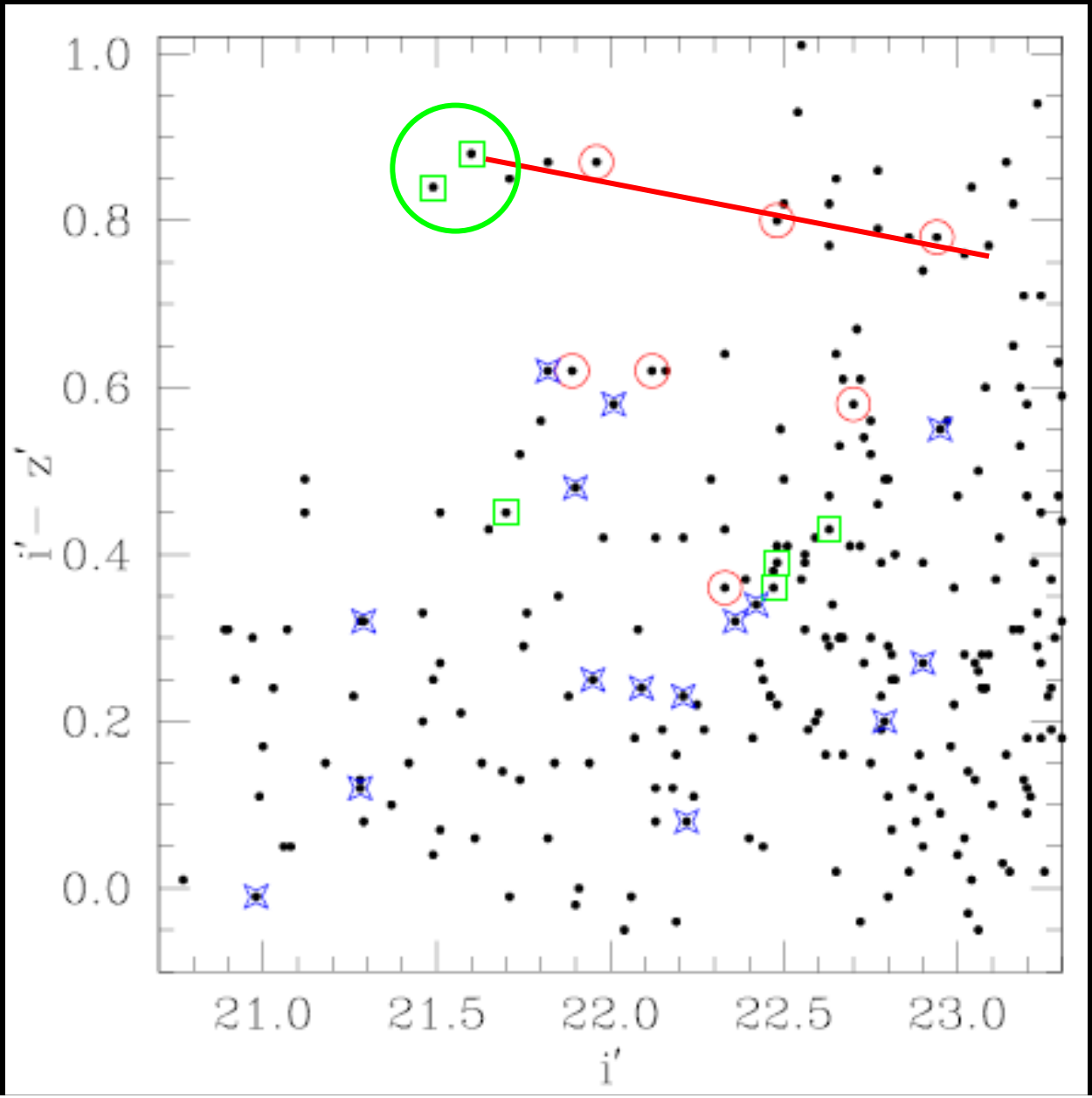
Velocity dispersion:
σ ~ 300 km/s

Color-magnitude diagram

CL 0110

Back. group

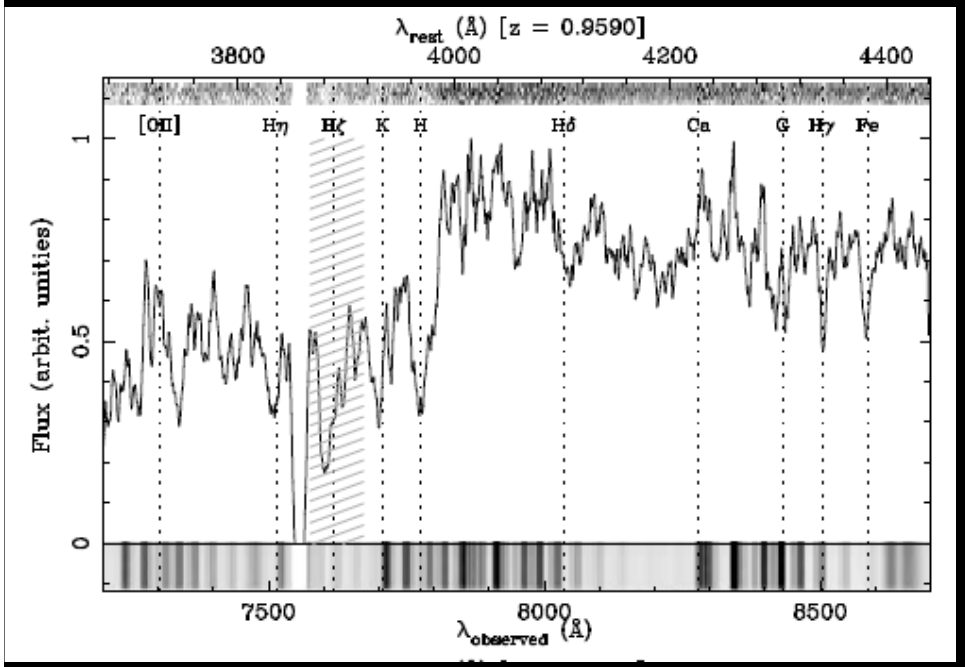
Line-of-sight

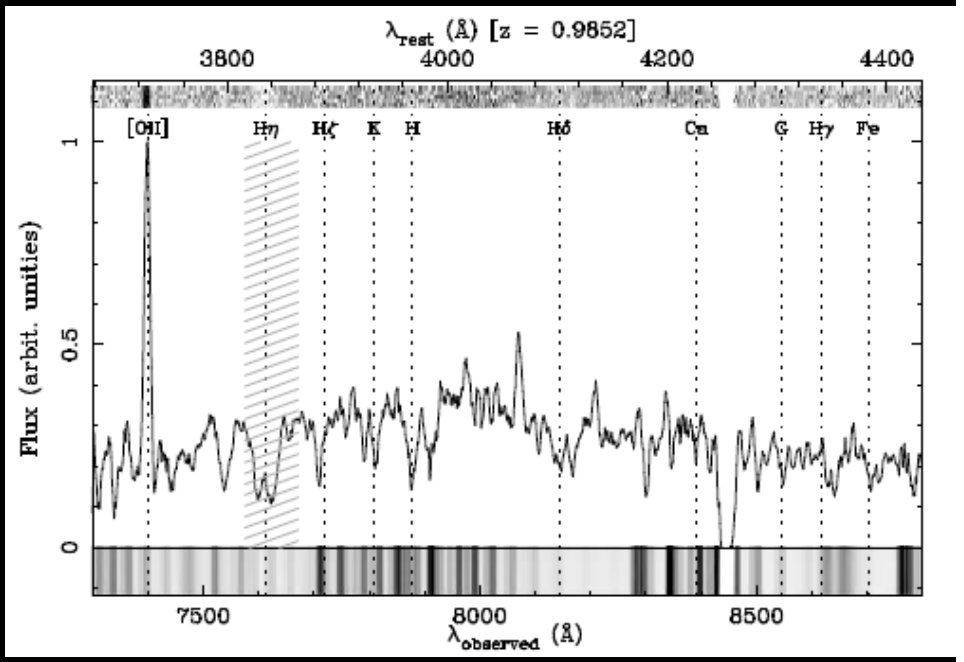


Galaxy populations

Passive

Star forming





3/7	CL 0110-0219	4/7
1/6	Back. group	5/6

Discussion

Quasar pairs at high z actually seems to belong to galaxy clusters or groups (3 out of 4; one spec. confirmation): Concept is viable

Similar results were obtained for quasar triplets (Soching et al. 2008 & Alonso et al. 2008): Most triplets at low and high z reside at the periphery of rich clusters

Low mass systems such as CL 0110 would probably be missed by most other cluster detection methods:

Good for extending the baselines of scaling relations

The downside: no complete samples

Discussion

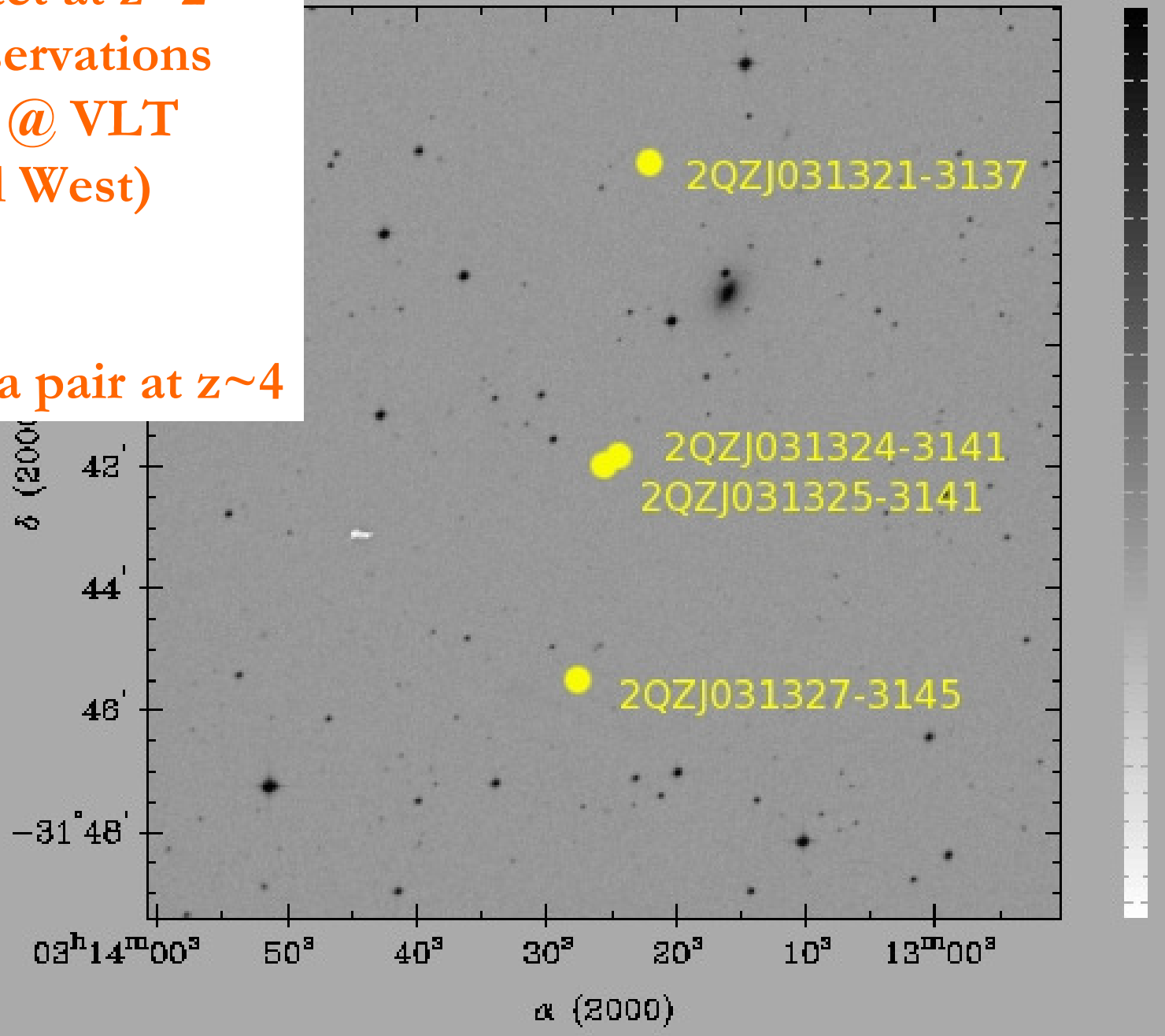
Probably the greater potential of this method is to detect clusters at redshifts greater than 1.5 →

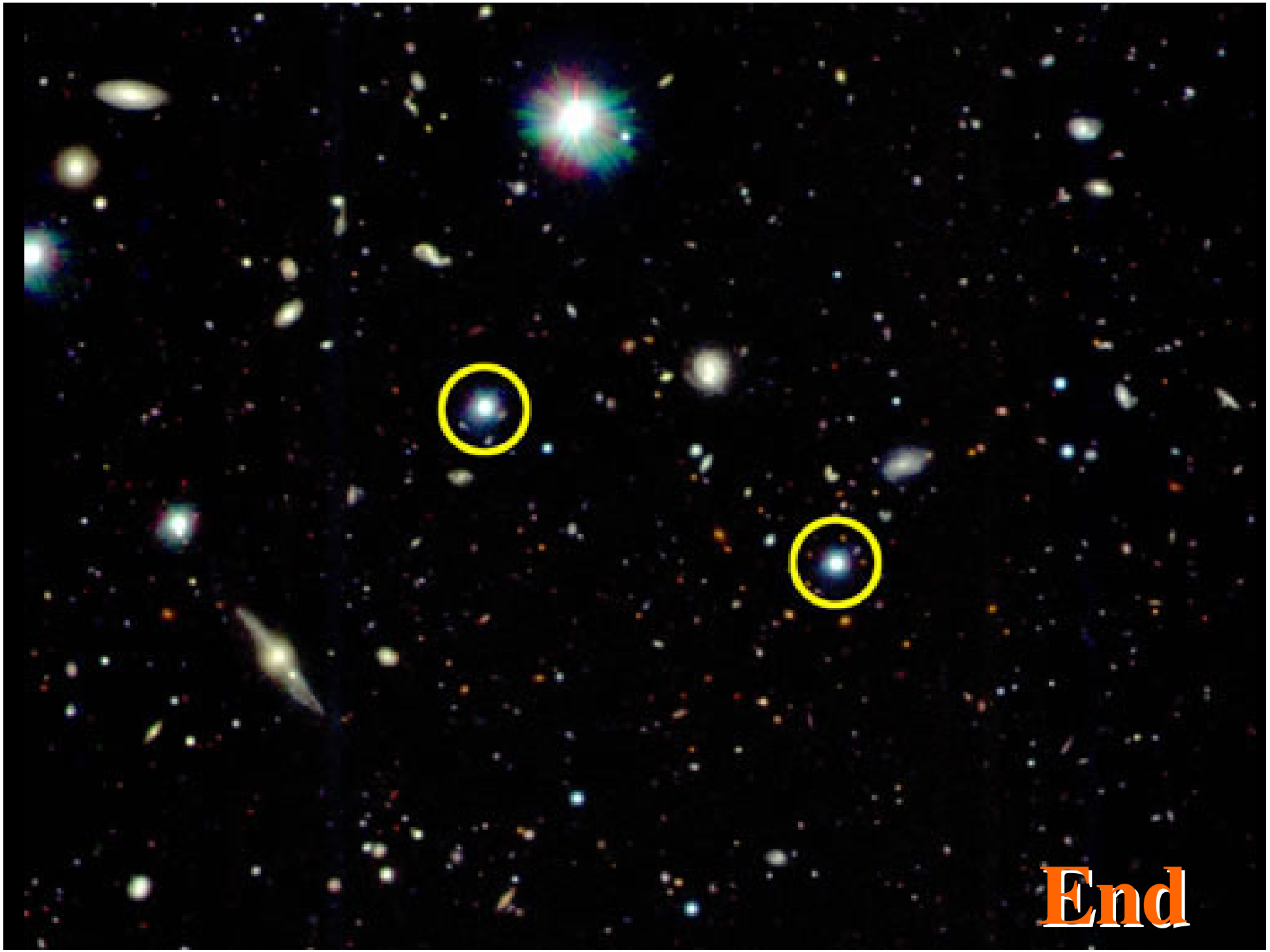
Near infrared instruments at large telescopes are needed

Quasar quartet at z~2
Ongoing observations
with Hawk I @ VLT
(P.I. Michael West)

+

Proposal for a pair at z~4

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