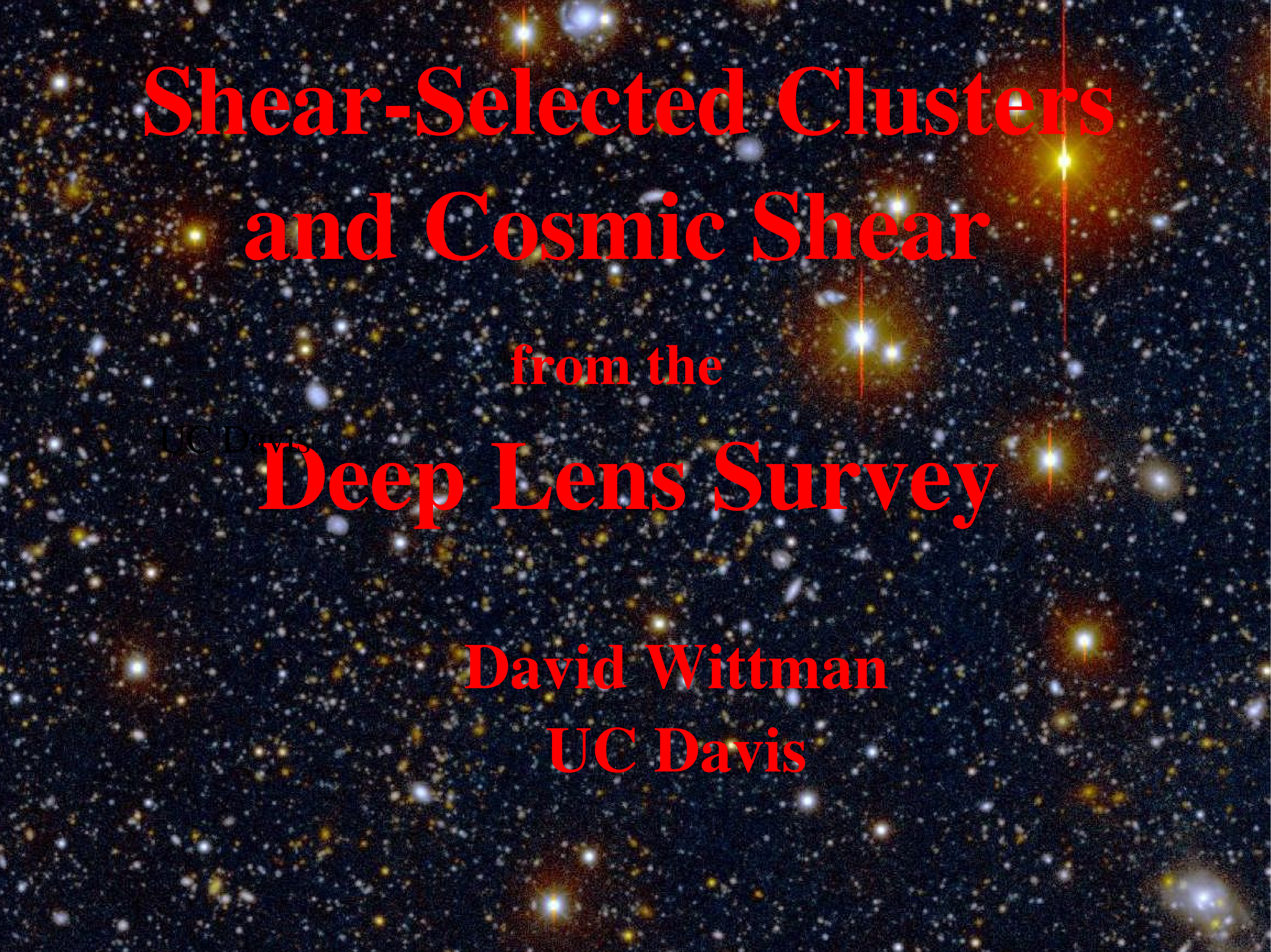


Shear-Selected Clusters and Cosmic Shear

from the

Deep Lens Survey

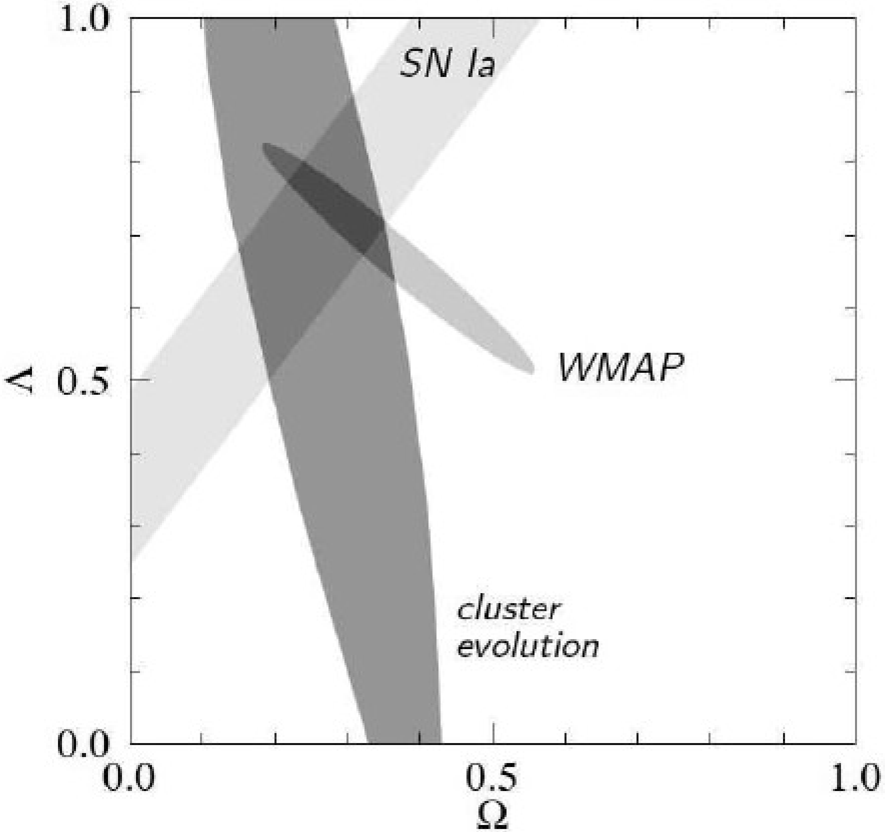
UC Davis

David Wittman
UC Davis

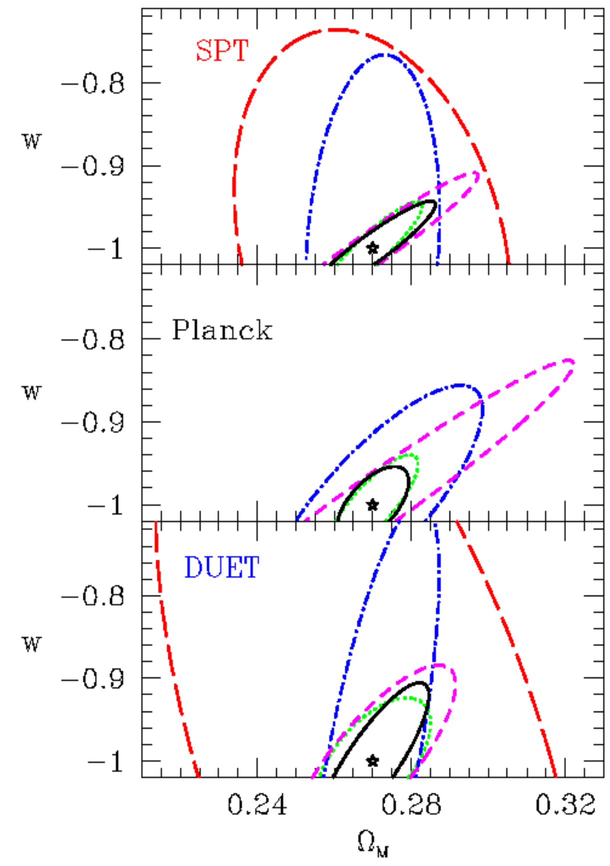
<Motivation>

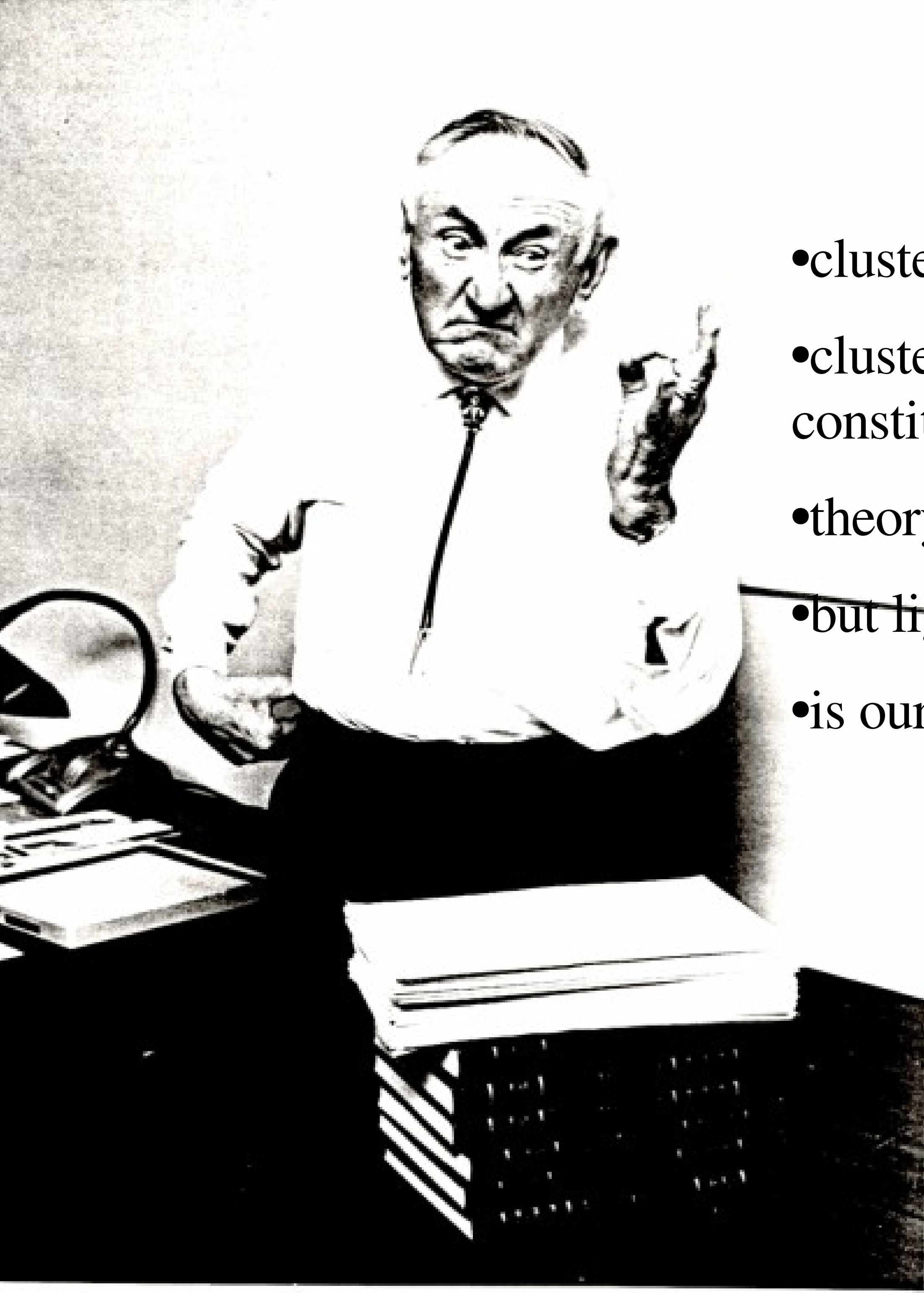
Clusters as Cosmological Probes

Present: Vikhlinin et al 2003



Future: Majumdar & Mohr 2004





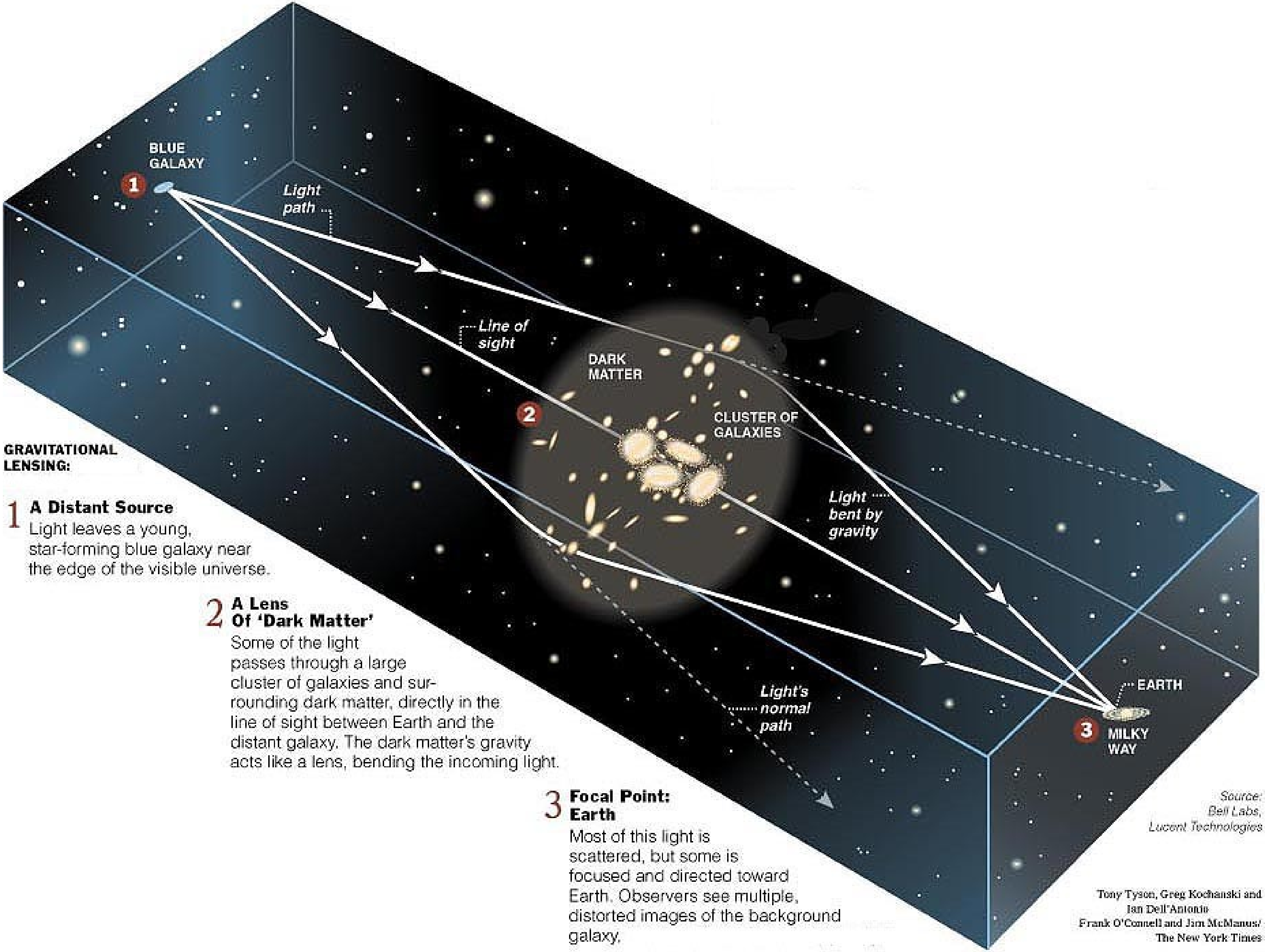
- clusters are important cosmological probes*
- cluster detection to date depends on trace constituents
- theory predicts mass, not light
- but light is used to compile samples
- is our view biased?

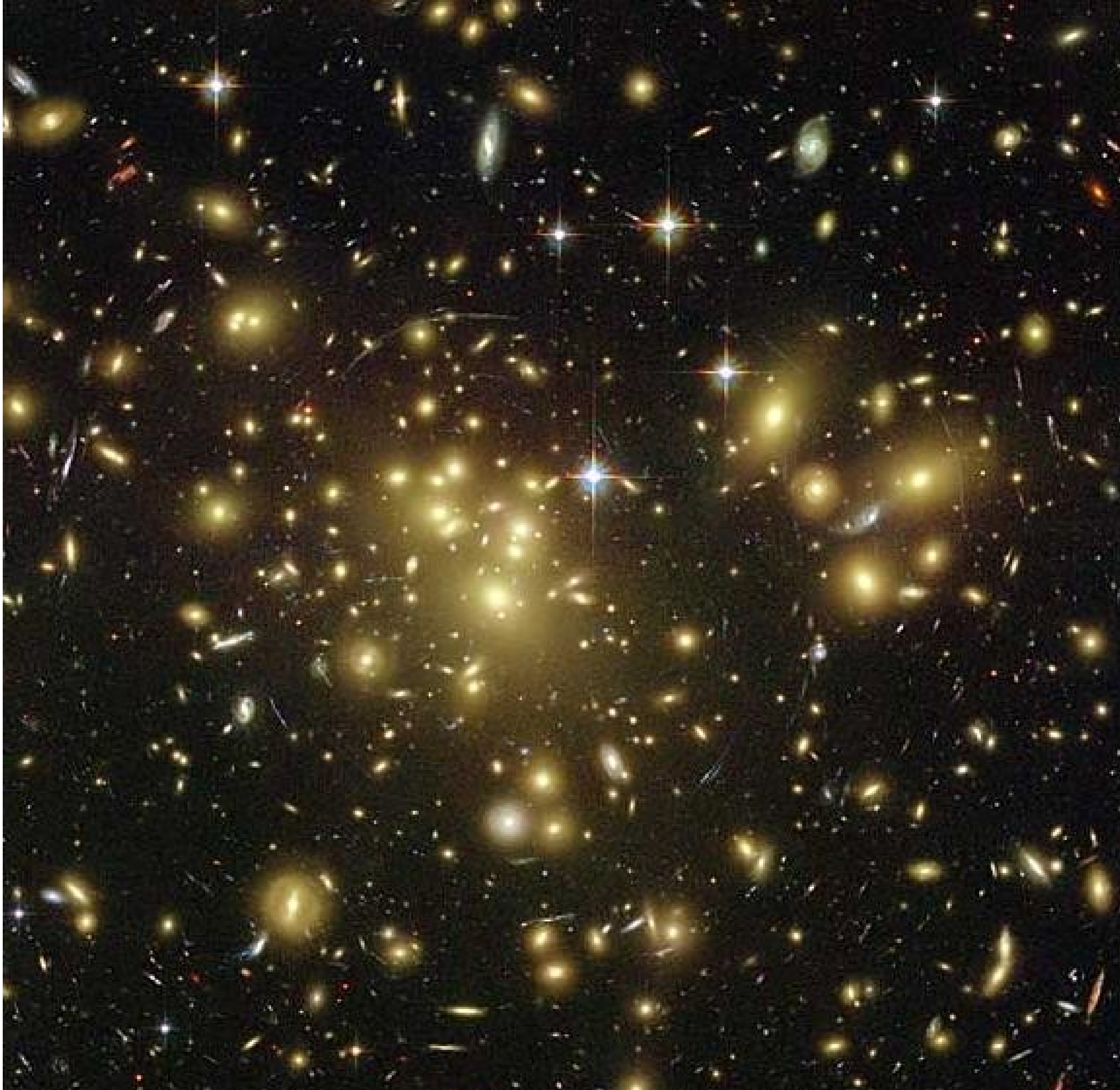
*and interesting astrophysical laboratories in their own right

Lensing: *independent of* dynamics, baryon content, star formation history

Strong lensing: on axis, high resolution, *densest* regions of universe

Weak lensing: off axis, low resolution, *all* regions of universe, statistical



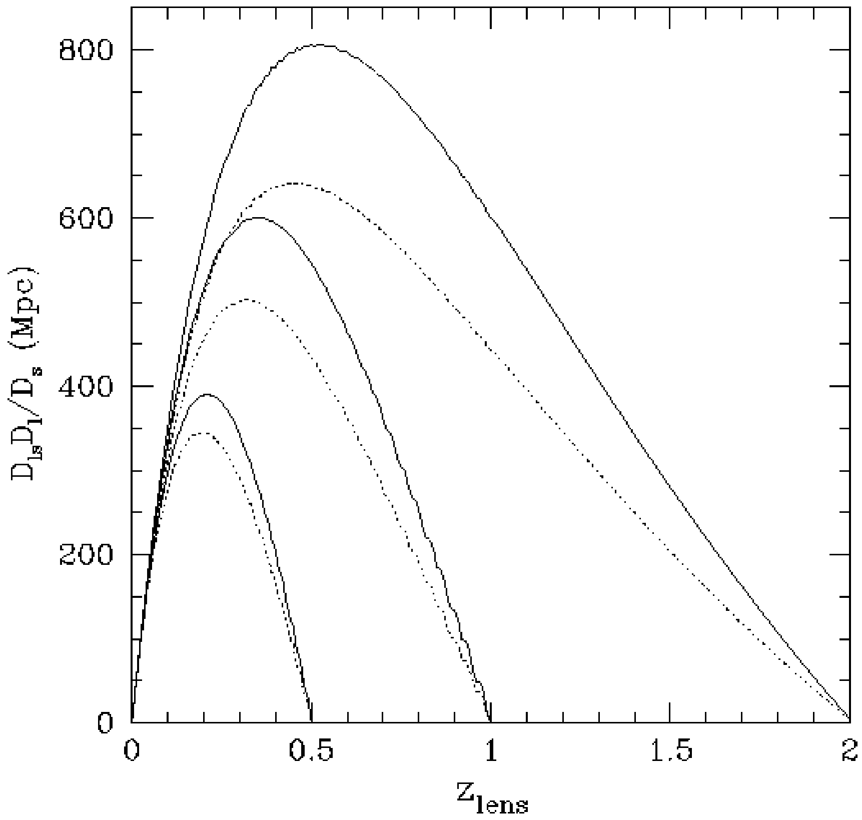


Shear Selection ≠ Mass Selection

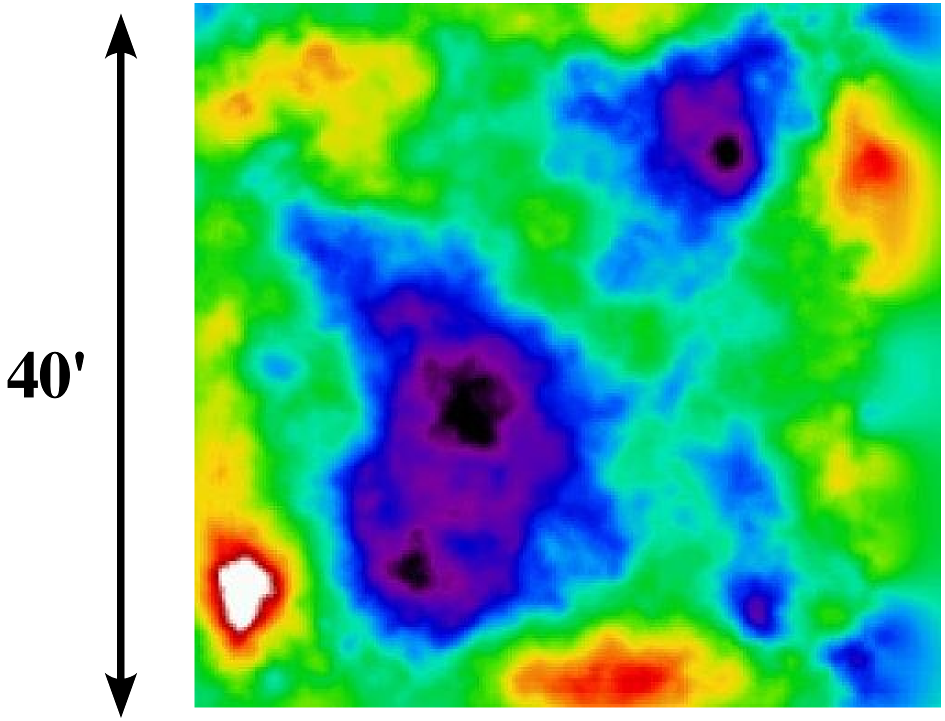
•Lens/source redshift dependence (at right).

•Cluster mass profile has big impact on detectability, (Bartelmann, King & Schneider 2001). =>To constrain cosmology with cluster counts, need mock surveys. (More easily simulated than X-ray, SZE, or optical detection.)

•Lensing measures 2-d density, but clusters are embedded in larger structures and are subject to chance projections (more later).



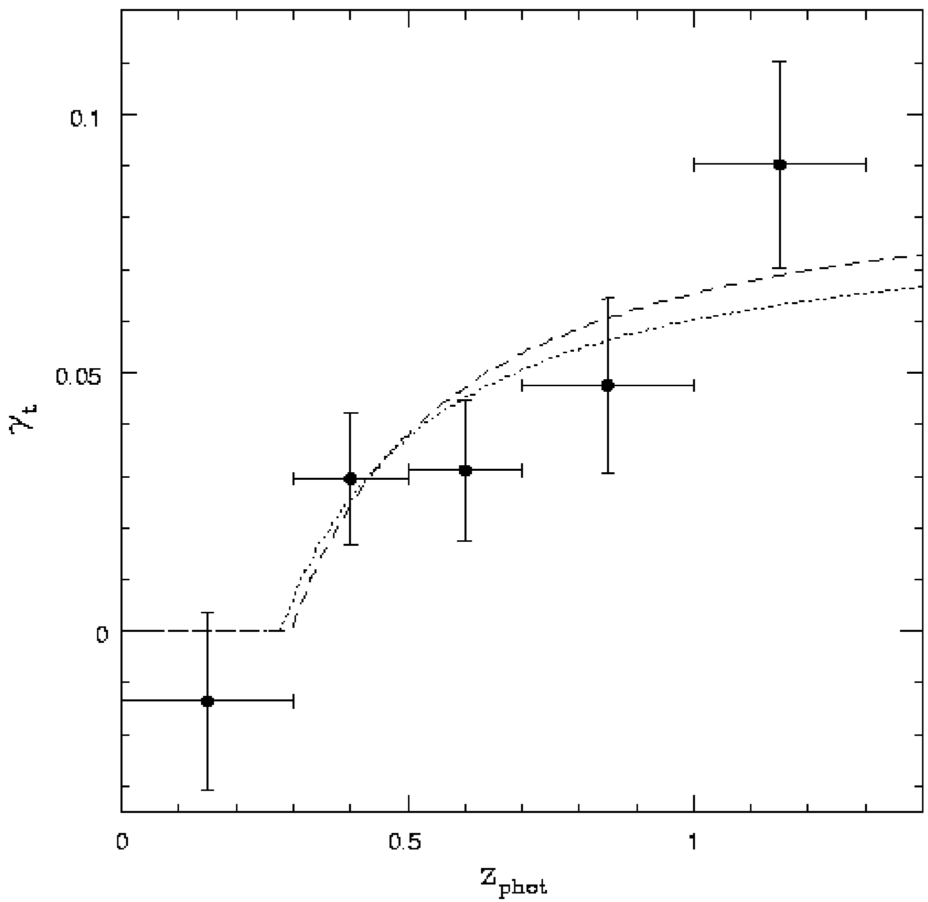
Pre-DLS Pilot Survey:
First confirmed shear-selected cluster, z=0.27

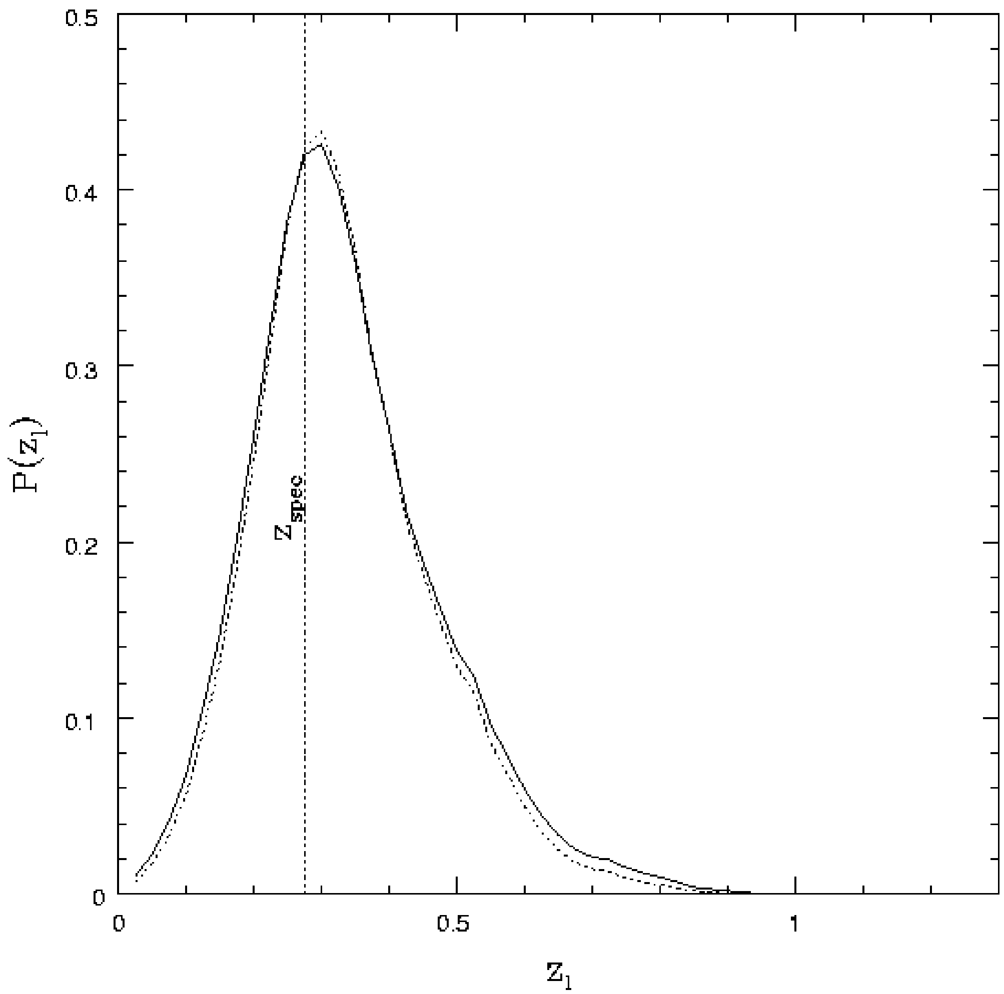


Wittman et al, ApJ **557**, L89 (2001)

Pilot survey:

Locating the lens *along the line of sight*

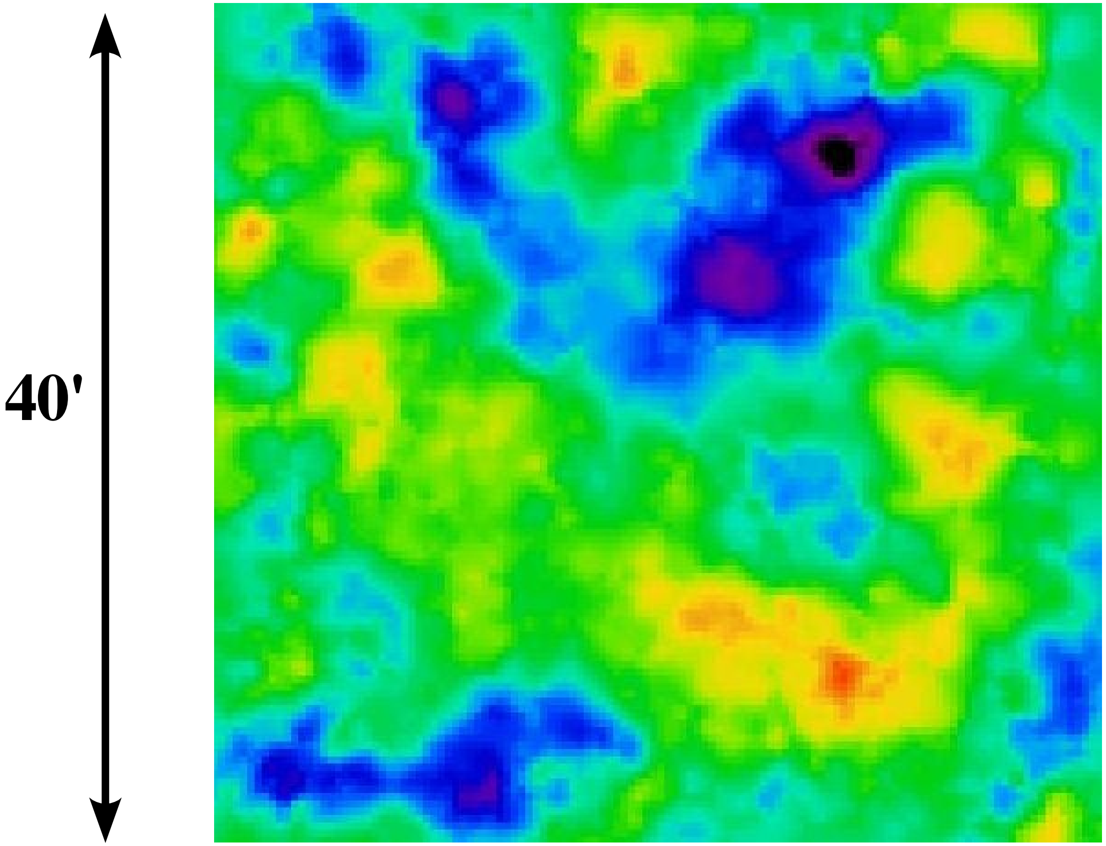




Wittman et al, ApJ **557**, L89 (2001)

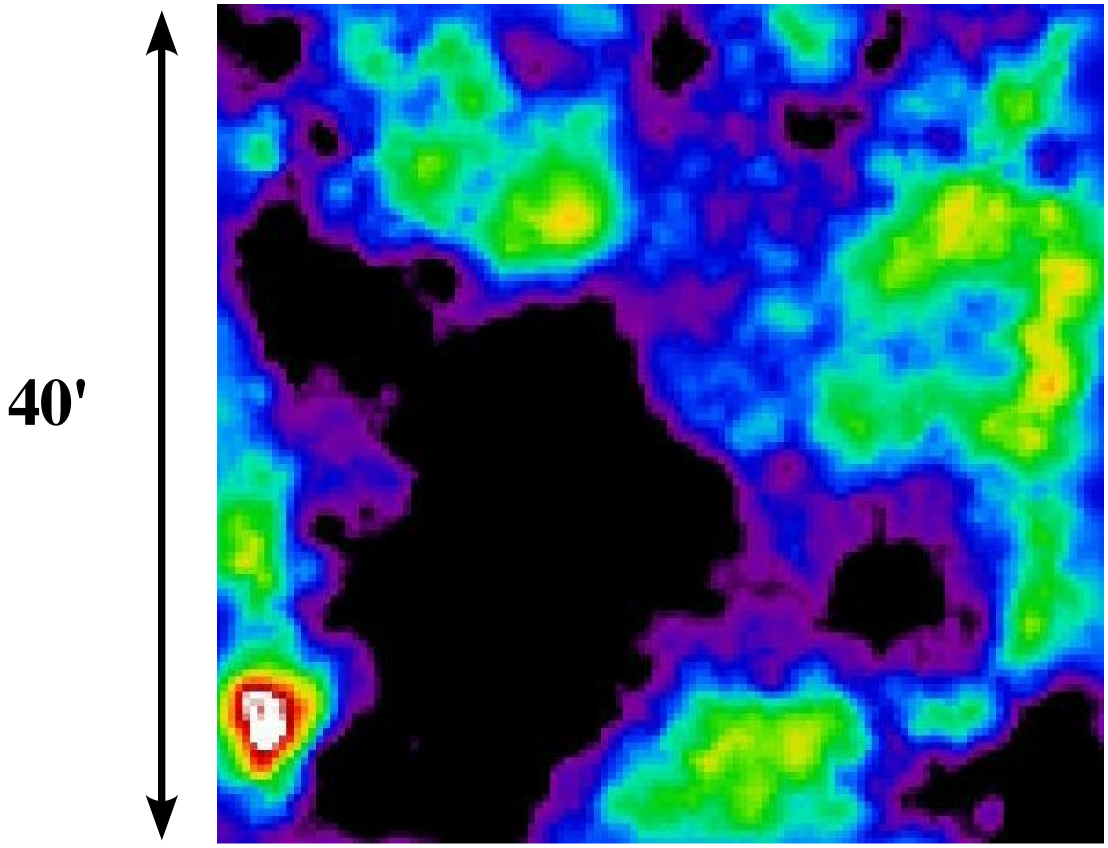
Pilot survey:

Mass map using low-z sources only



Pilot survey:

Mass map using hi-z sources only



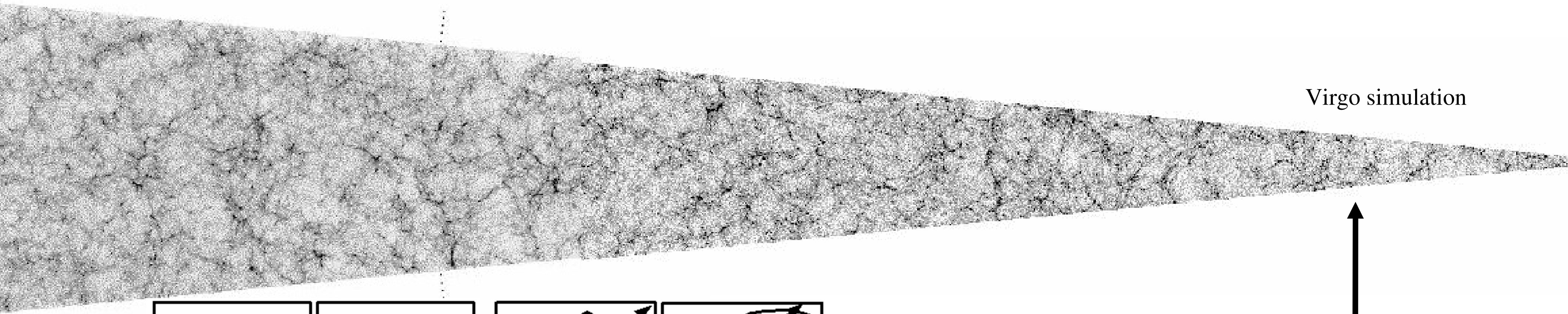
Shear-selected clusters: history

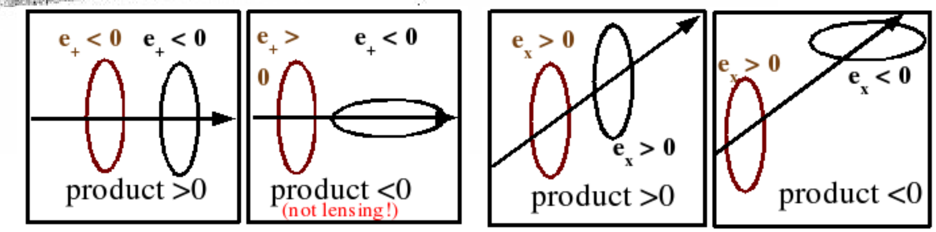
Now several others solidly identified, with redshifts:

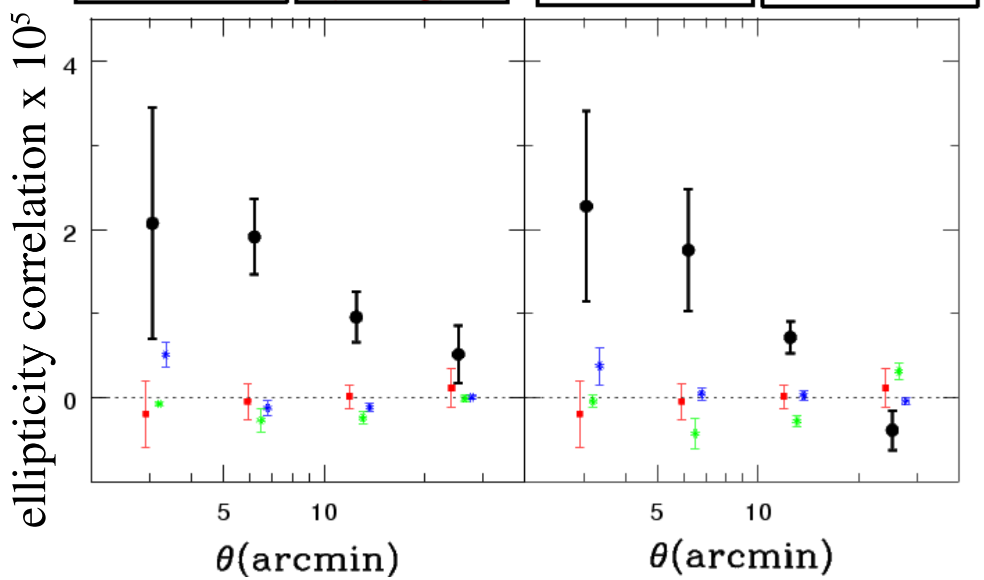
- Dahle et al 2002: 2-3 clusters, z ~ 0.4-0.5 using one color
- Wittman et al 2002, 2003: 1 cluster, z=0.68, spectroscopic, tomographic
- GaBoDS 2005: several cluster candidates

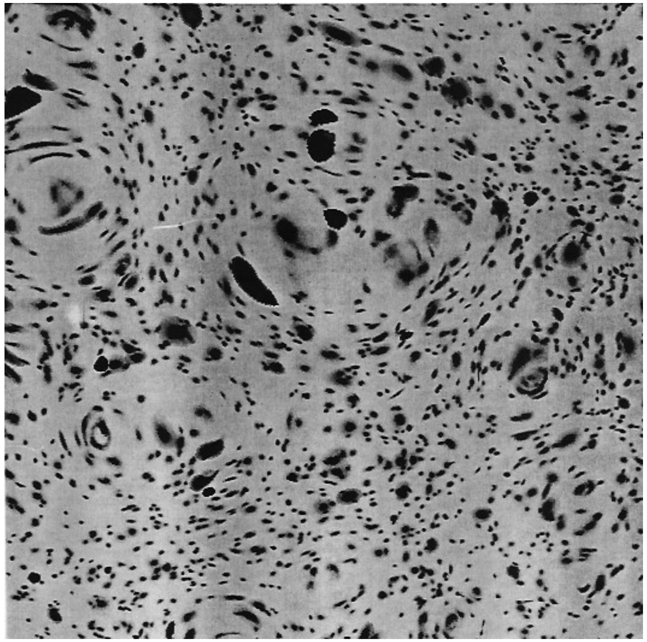
We need bigger samples, with comprehensive followup!

Same Survey Can Measure Cosmic Shear









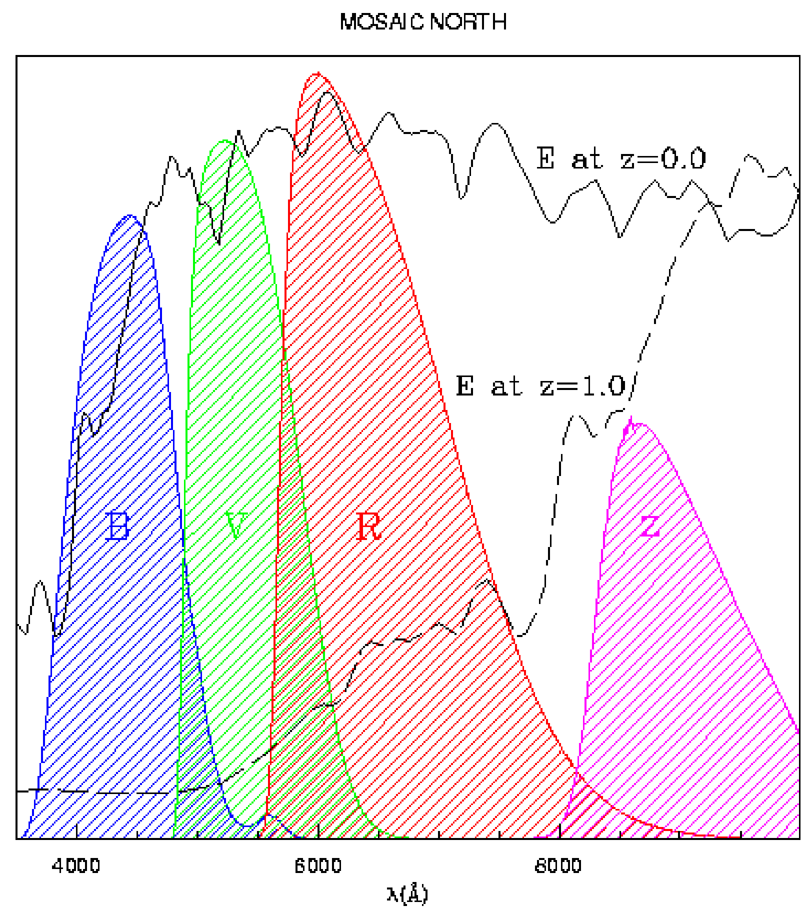
Wittman et al 2000, *Nature* 405, 143

</Motivation>

<Deep Lens Survey>

DLS Basic Parameters

(1) multiband imaging for photometric redshifts accurate to <20% up to at least z =1.5



DLS Basic Parameters

(2) deep enough to derive redshifts and shapes for 50 galaxies/arcmin^2

(3) sub-arcsecond angular resolution for shape measurements

- Total exposure time of *18 ksec in R* and *12 ksec in BVz*
- Split into 20 exposures per filter
- Observe in *R* when seeing in good (*FWHM < 0.9”*)

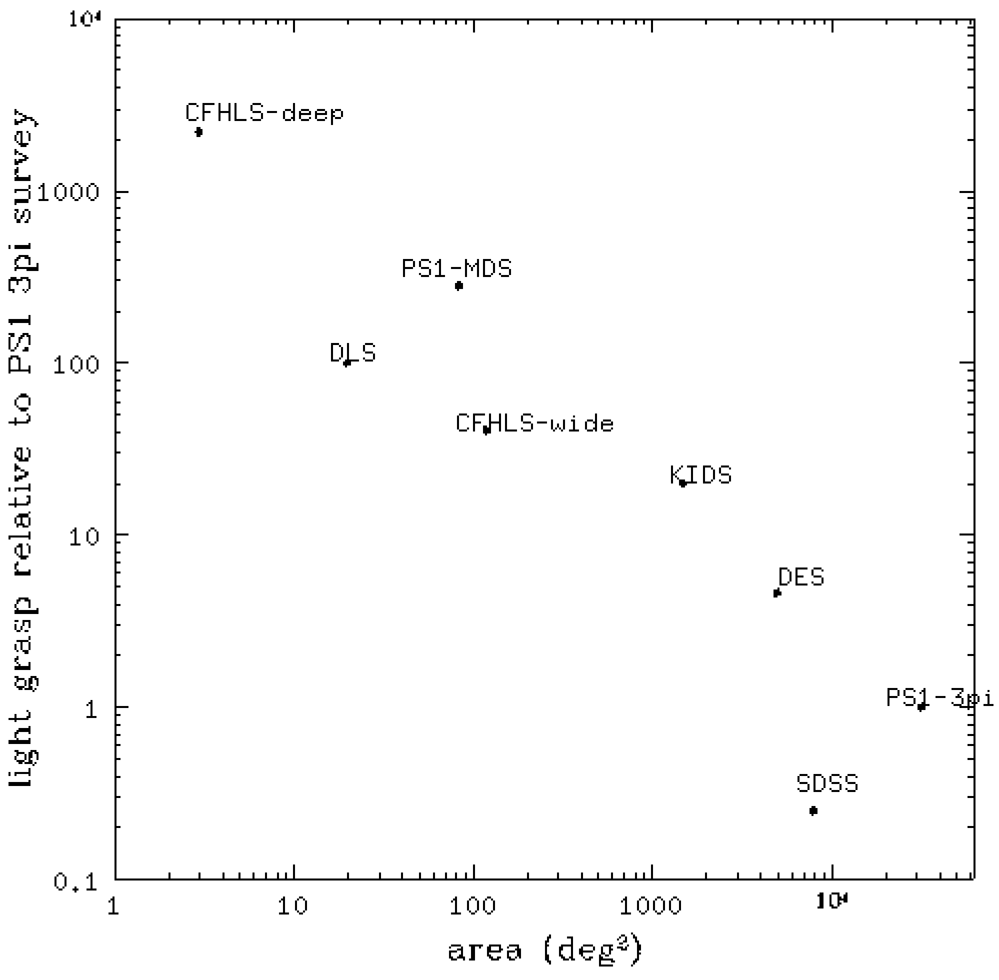
DLS Basic Parameters

(4) independent, well-separated fields, selected without regard to already-known structures, to sample cosmic variance

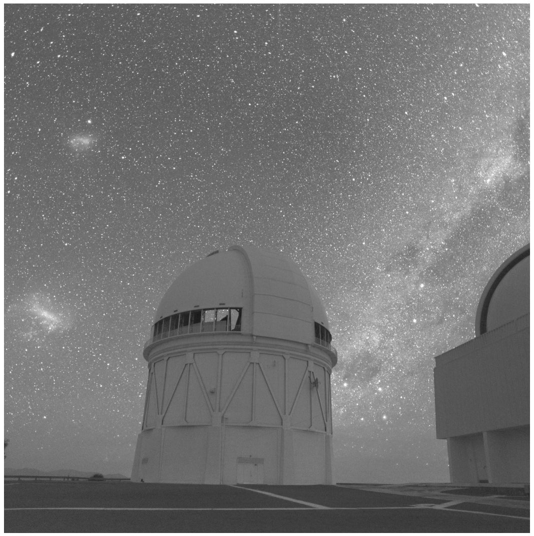
(5) in each field, cover an area larger than largest expected structures

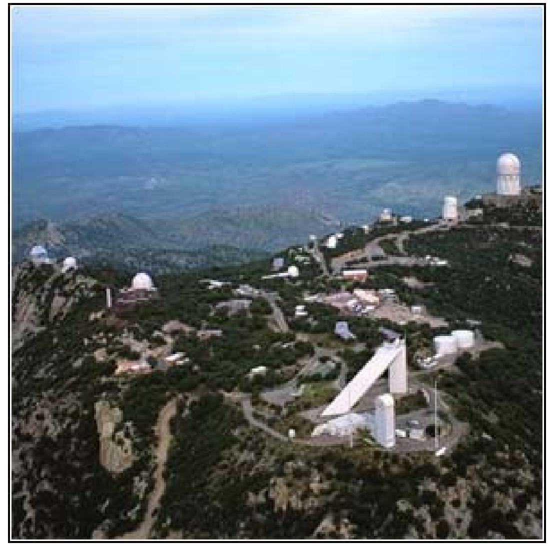
- five 2 x 2 degree fields
- ~100 nights on 4-m telescopes!

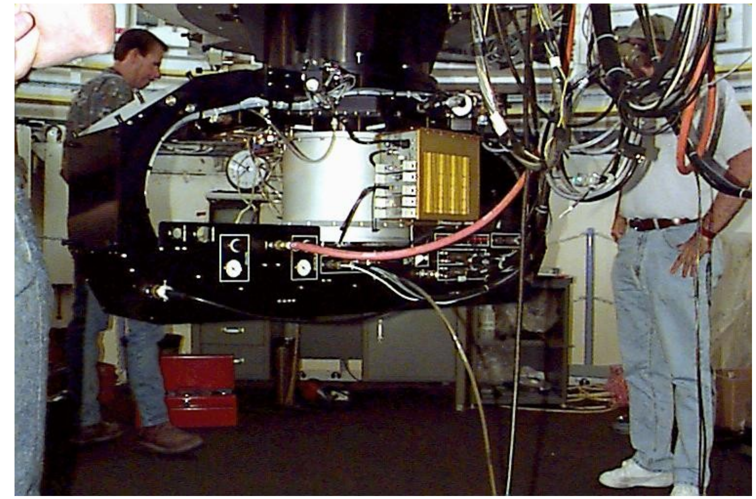
Optical Survey Landscape



CTIO and KPNO 4-m telescopes + Mosaic cameras: 35' FOV







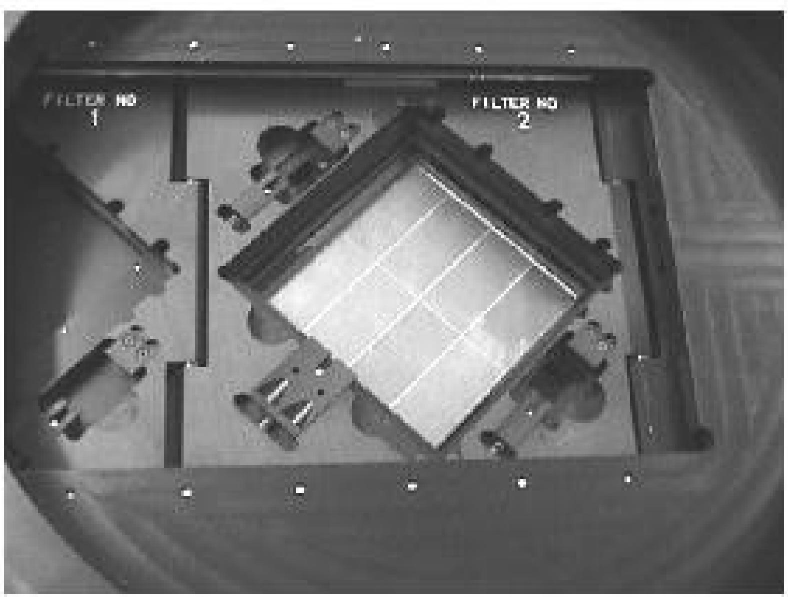
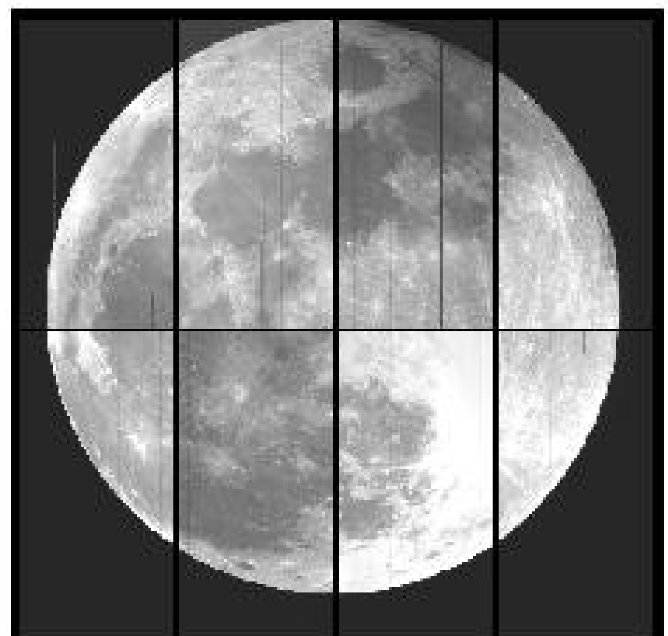


Figure 3. Eight 3-side buttable CCDs mounted in a 2 x 4 array as viewed



120 nights observing
1.5 TB imaging data
5000 science images
5000 calib. images
4 filters
5 fields
2 observatories
6 years

Muller *et al*, Proc. SPIE **3355**, 577 (1998)

Layout of Each Field

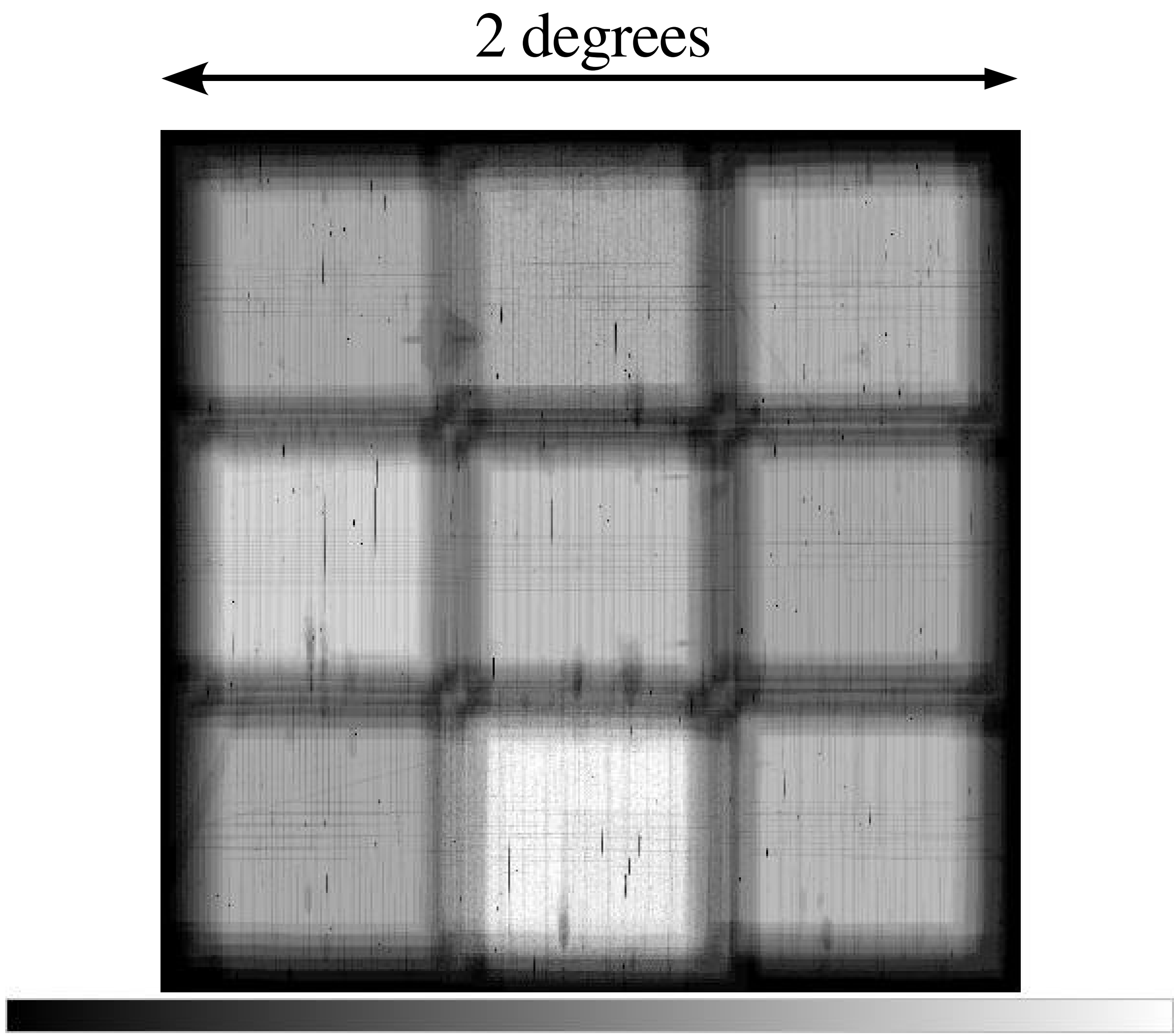
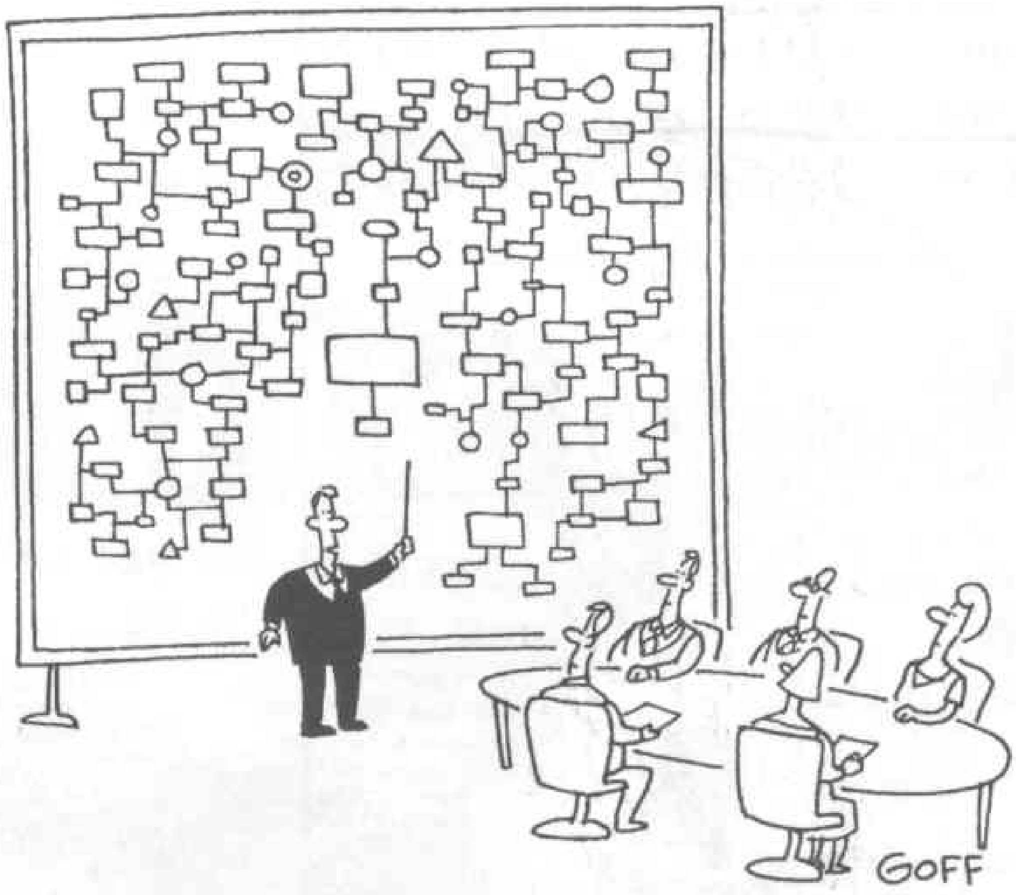
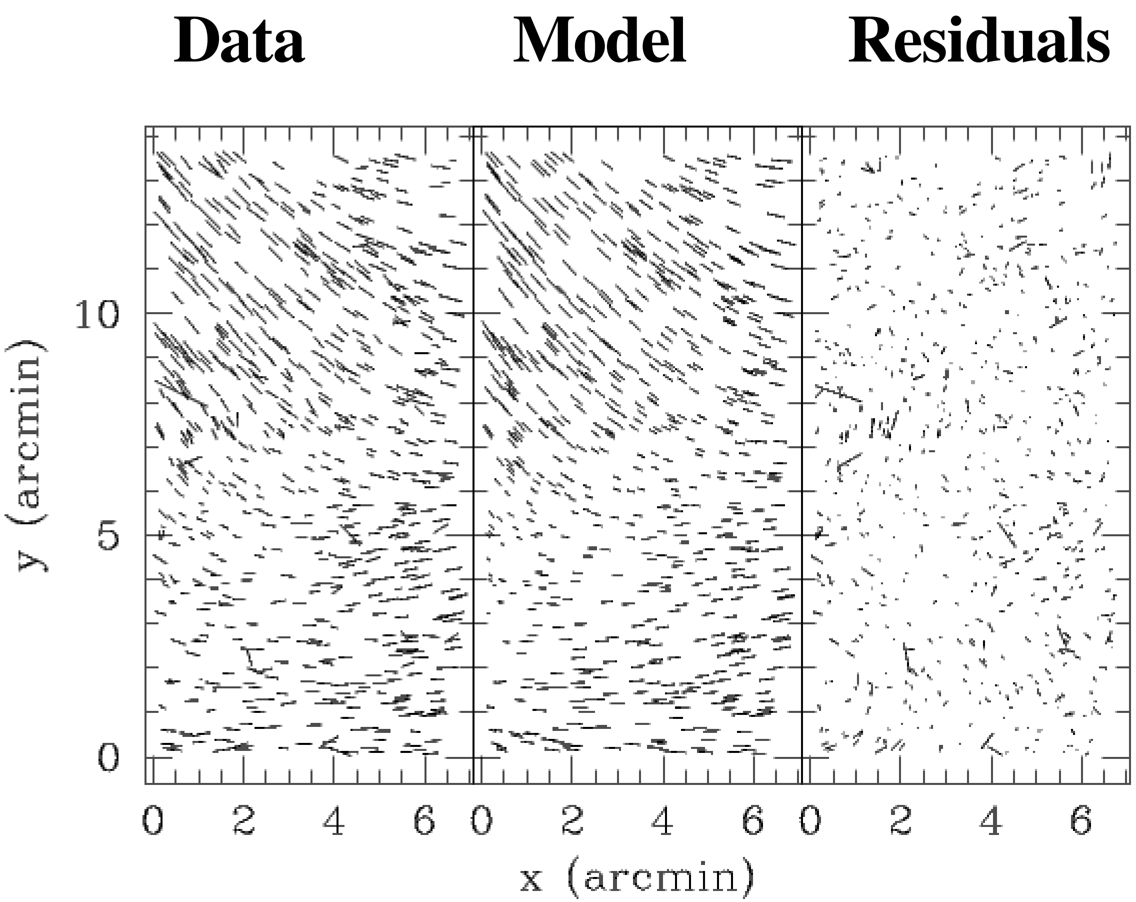


Image processing pipeline



"AND THAT'S WHY I NEED A VACATION."

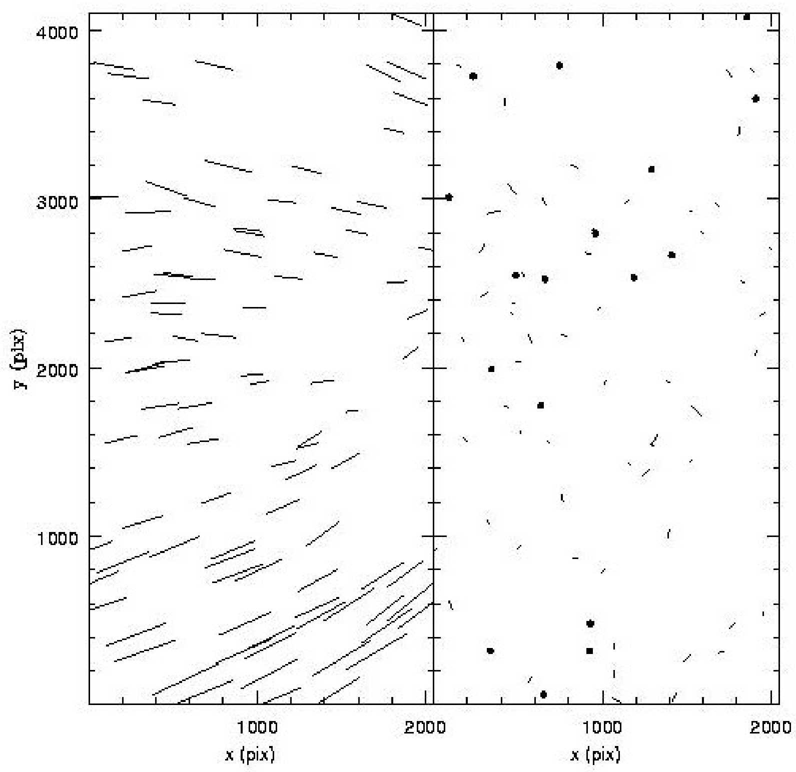
Making the PSF Round: Concept



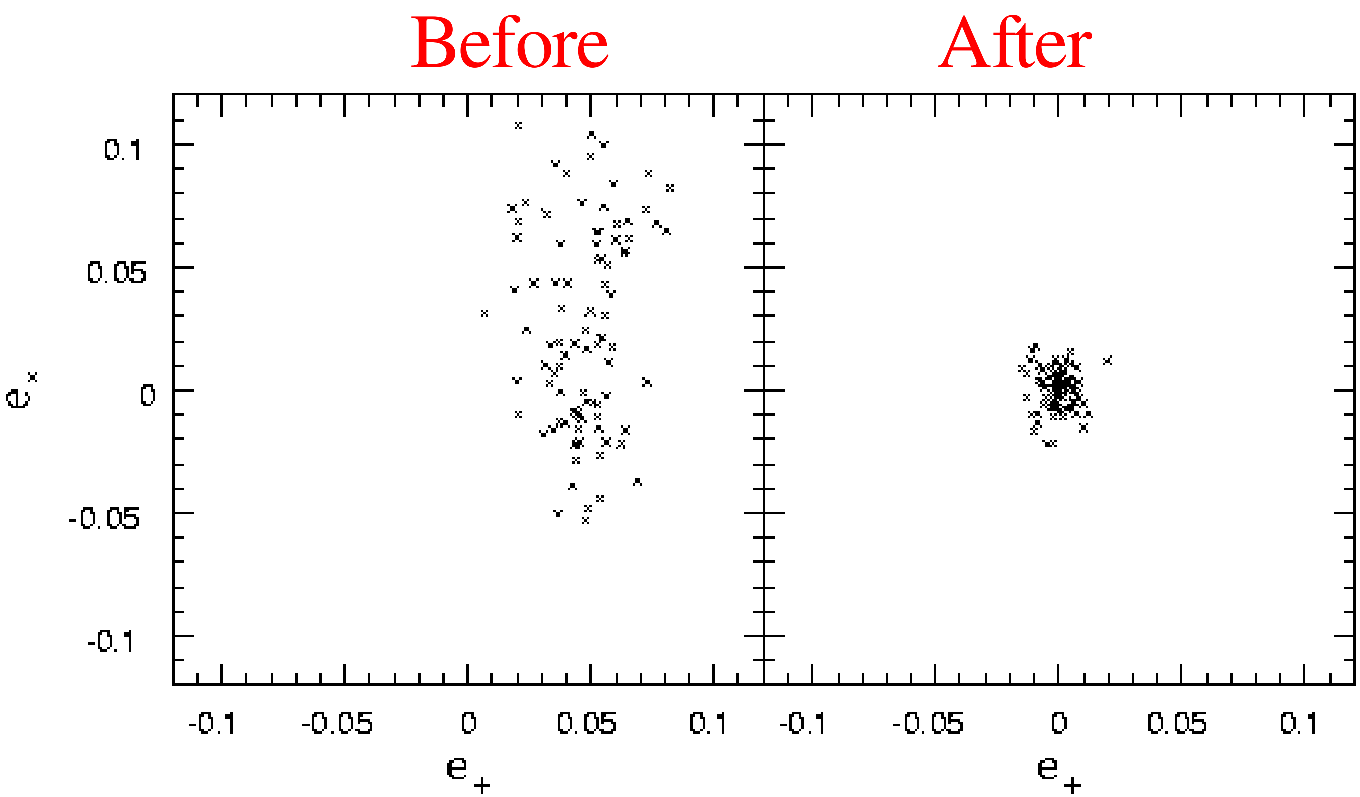
Wittman, ApJL 632, 5 (2005)

Making the PSF Round: Reality

Before **After**

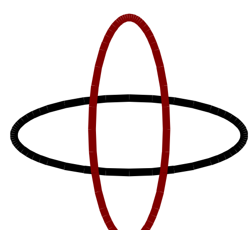


Making the PSF round:



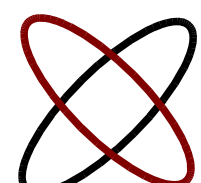
$e_+ = \epsilon \cos{(2\theta)}$ $\quad$ $e_\times = \epsilon \sin{(2\theta)}$

$e_+ > 0$



$e_+ < 0$

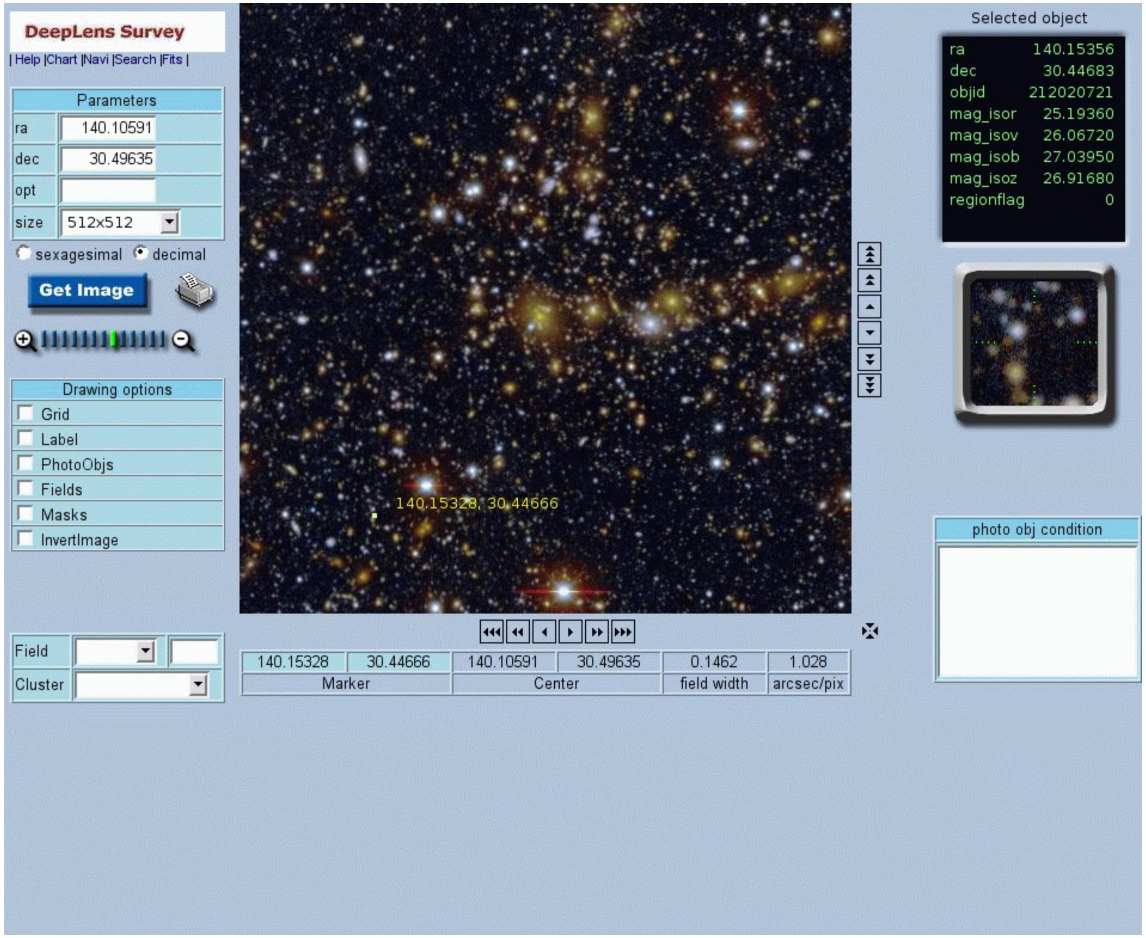
$e_\times > 0$



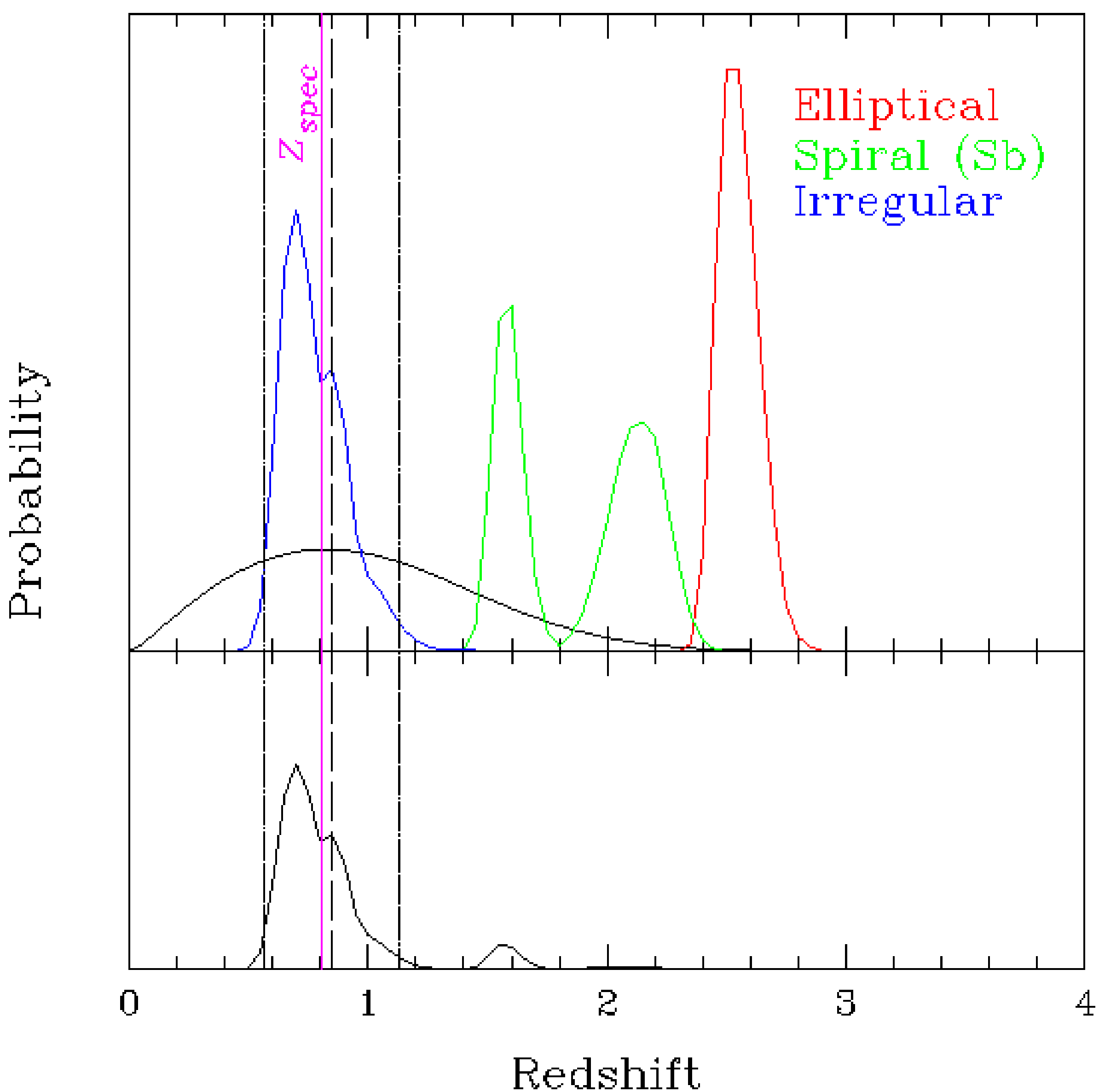
$e_\times < 0$

Status

•data taking complete in 4 of 5 fields
•stacks with good photometry completed April 2006
•photometric redshift algorithm tweaks summer 2006
•now it's fun!
•public release soon

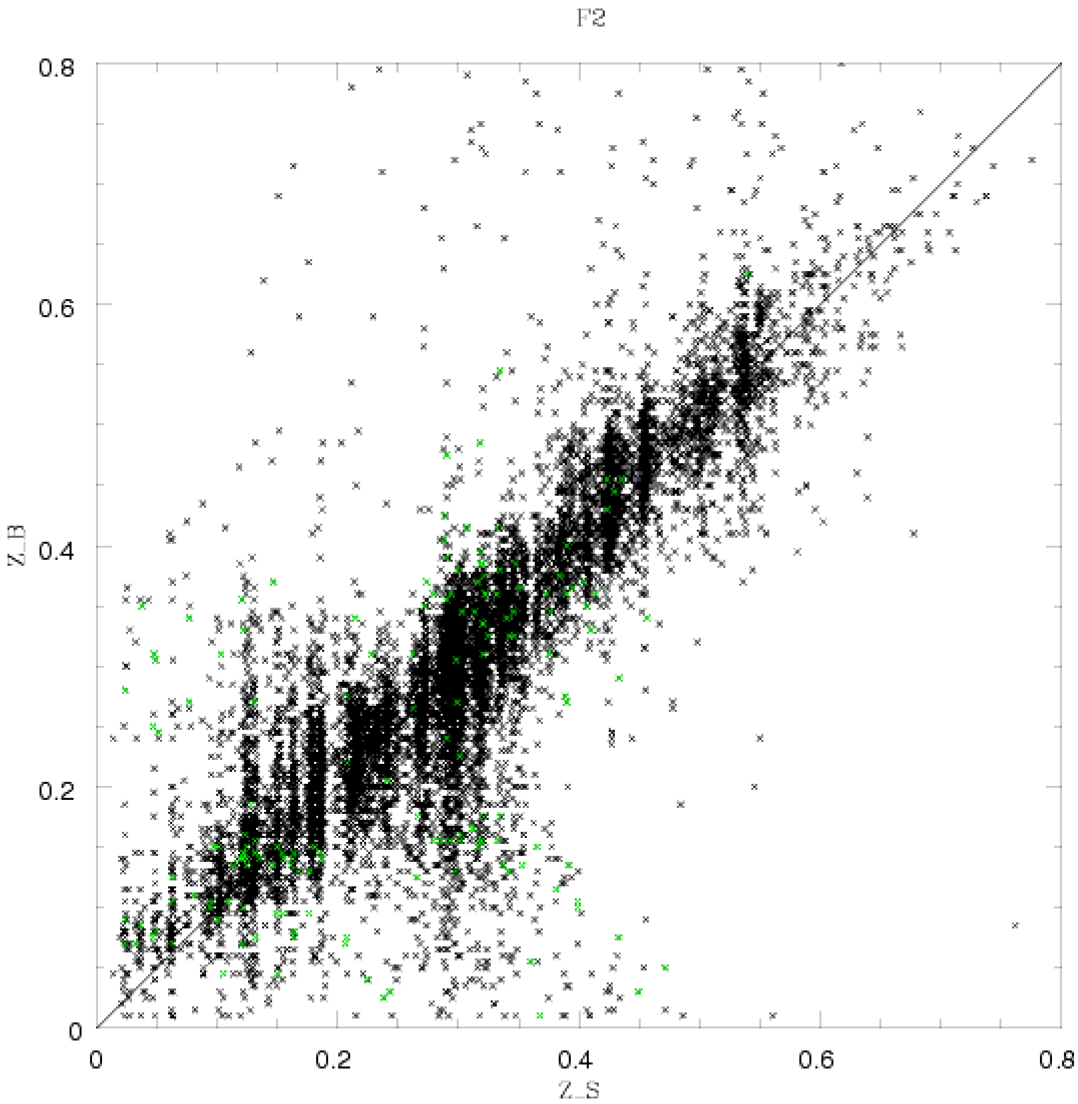


Photometric redshifts: Example

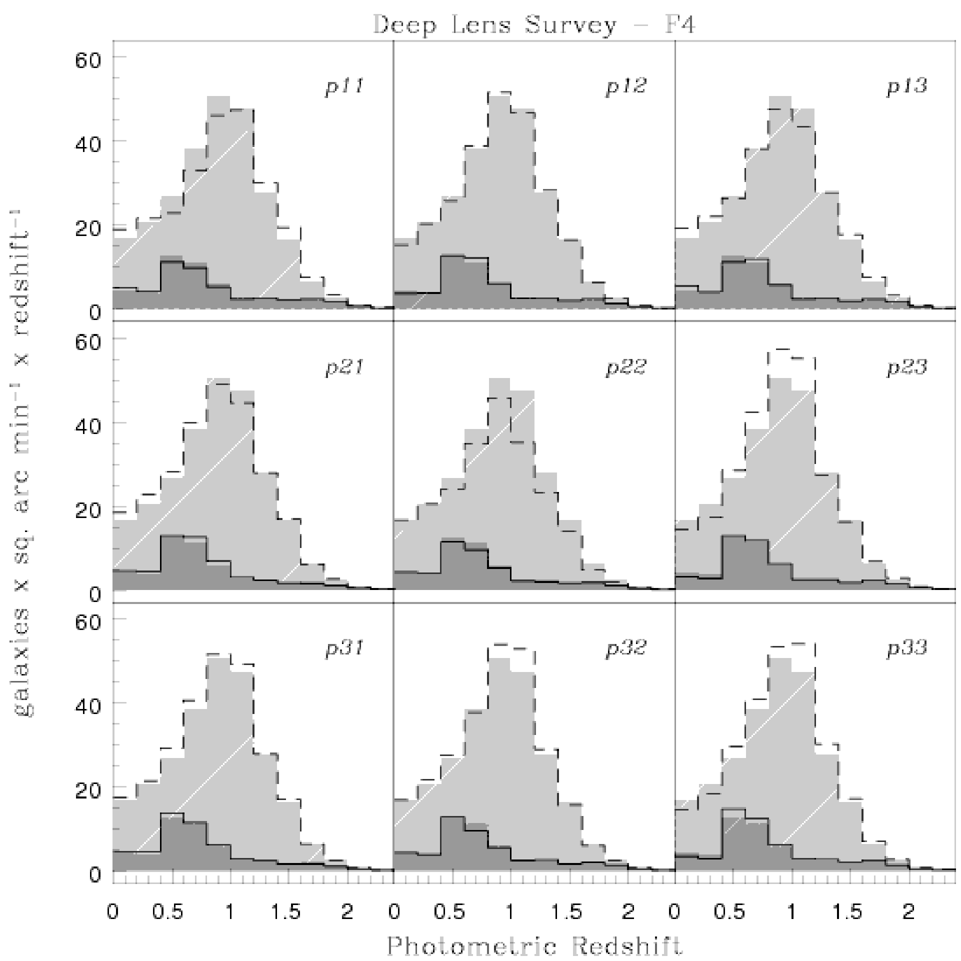


Photometric Redshifts: Verification

(Vera Margoniner)



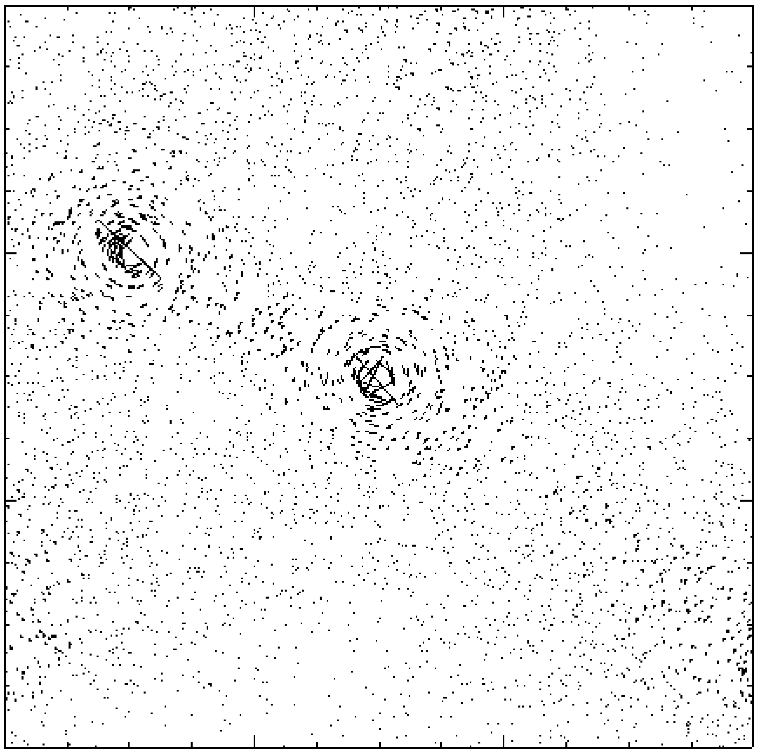
DLS Source Redshift Distribution
(from photometric redshifts)



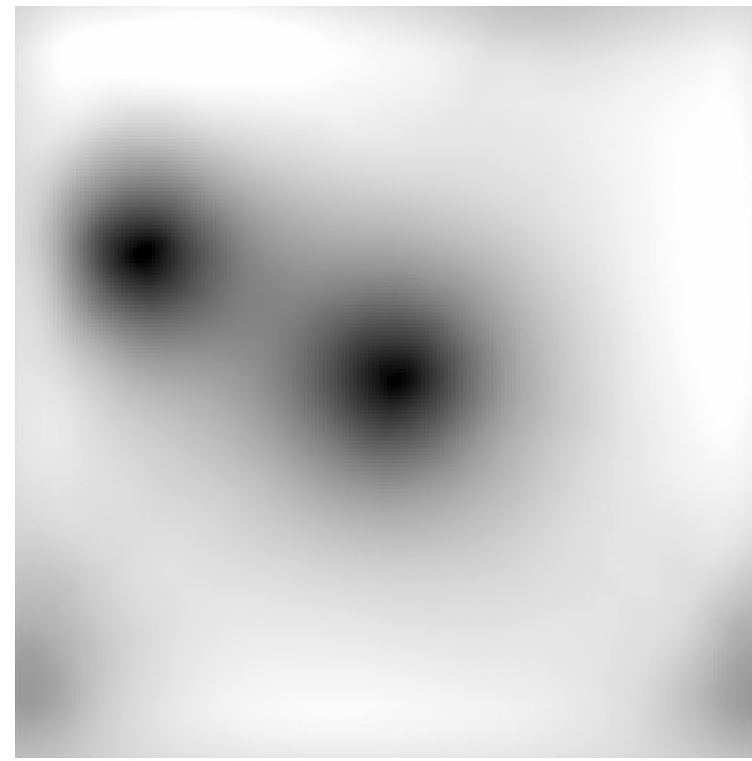
</Deep Lens Survey>

<Shear-selected Sample>

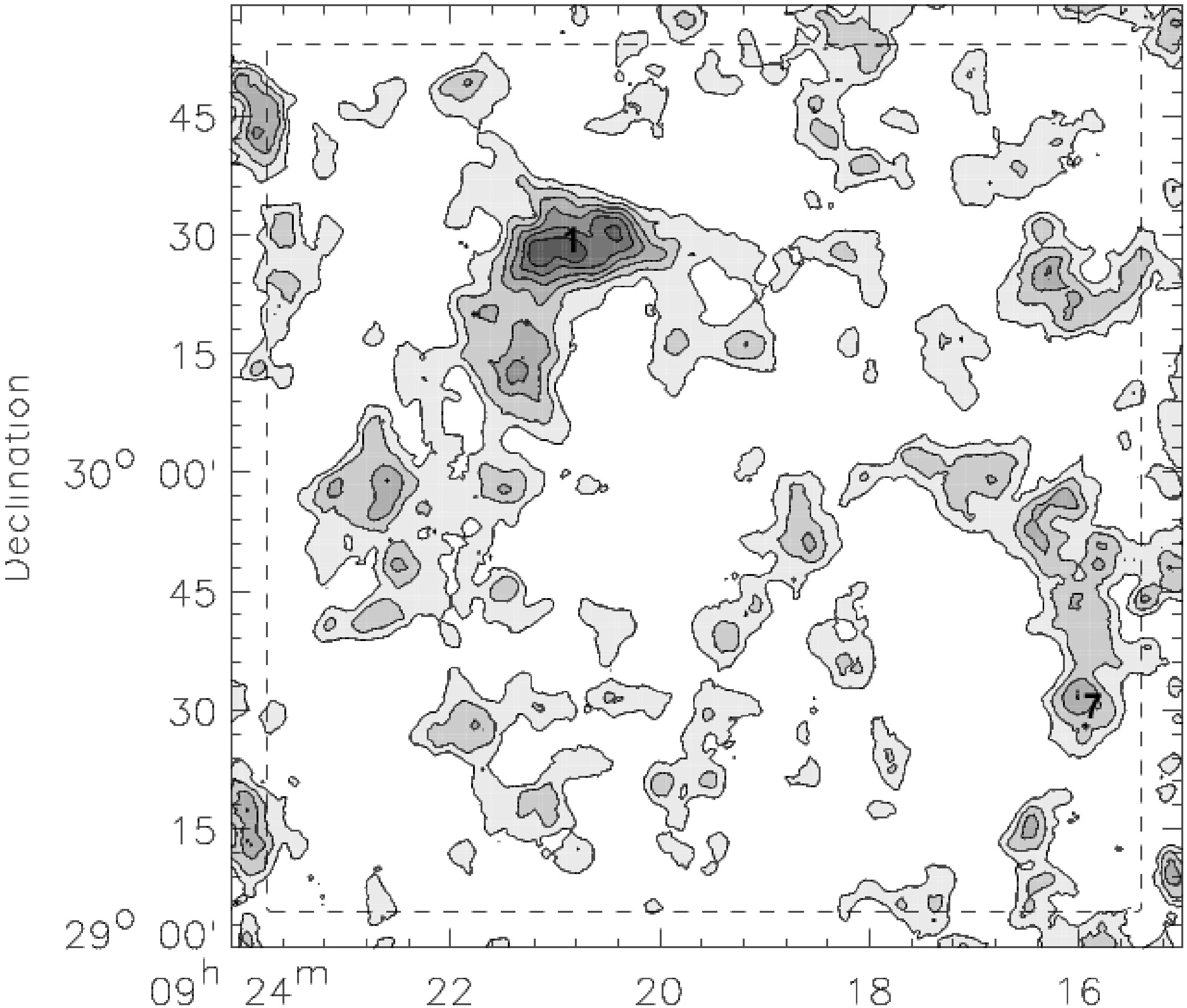
Cluster Detection



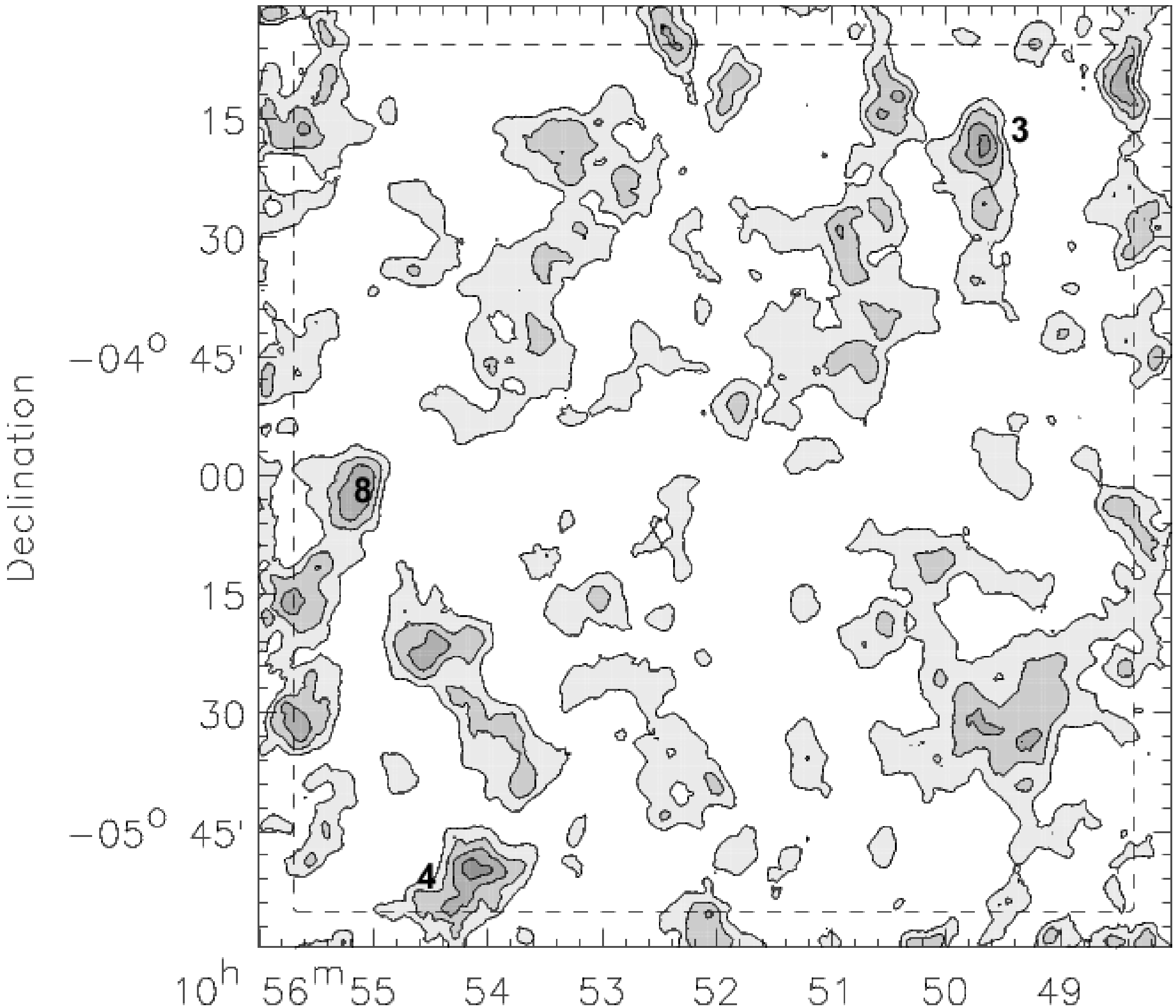
$\otimes \gamma_{\mathrm{model}} =$



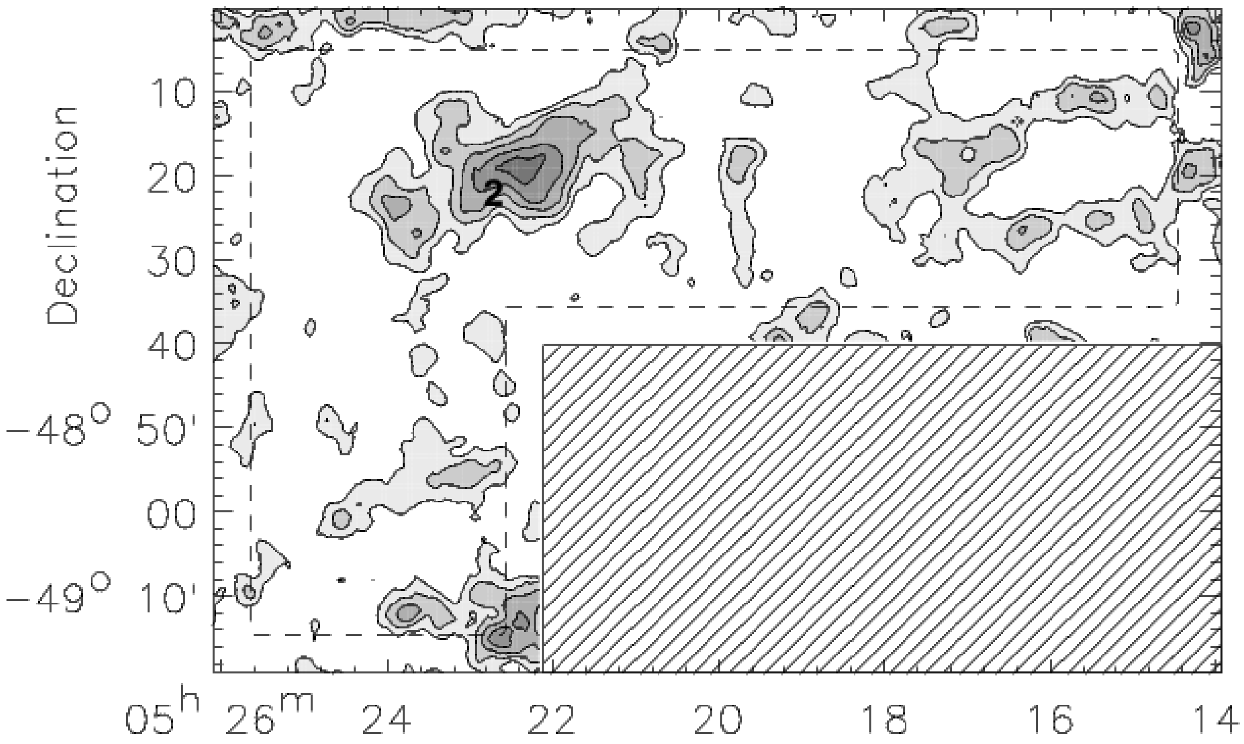
Candidates: Field 2



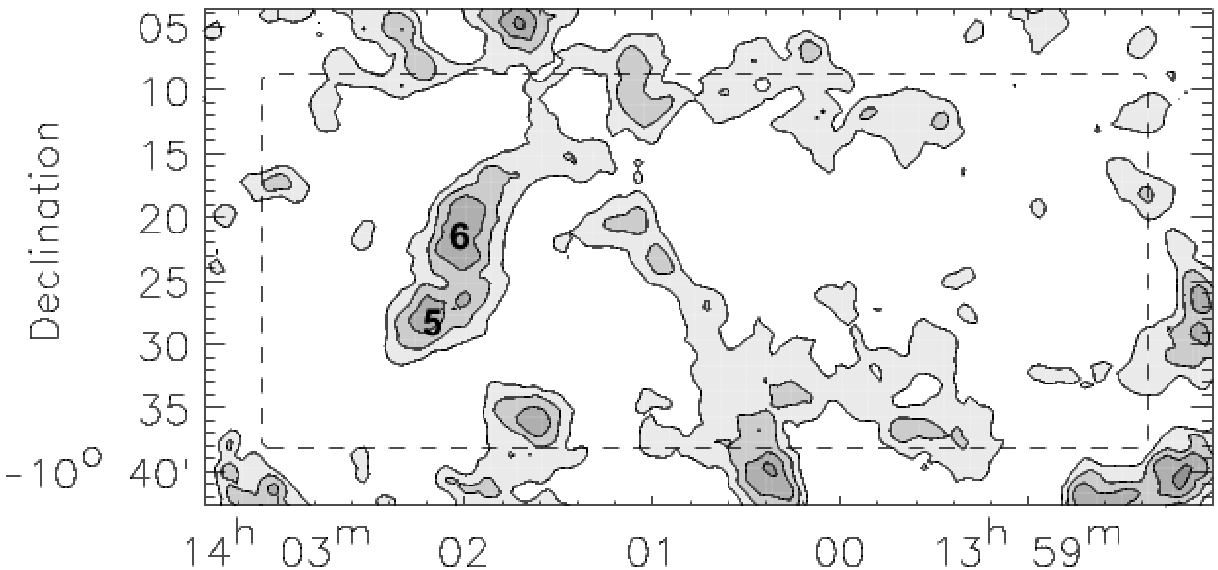
Candidates: Field 4



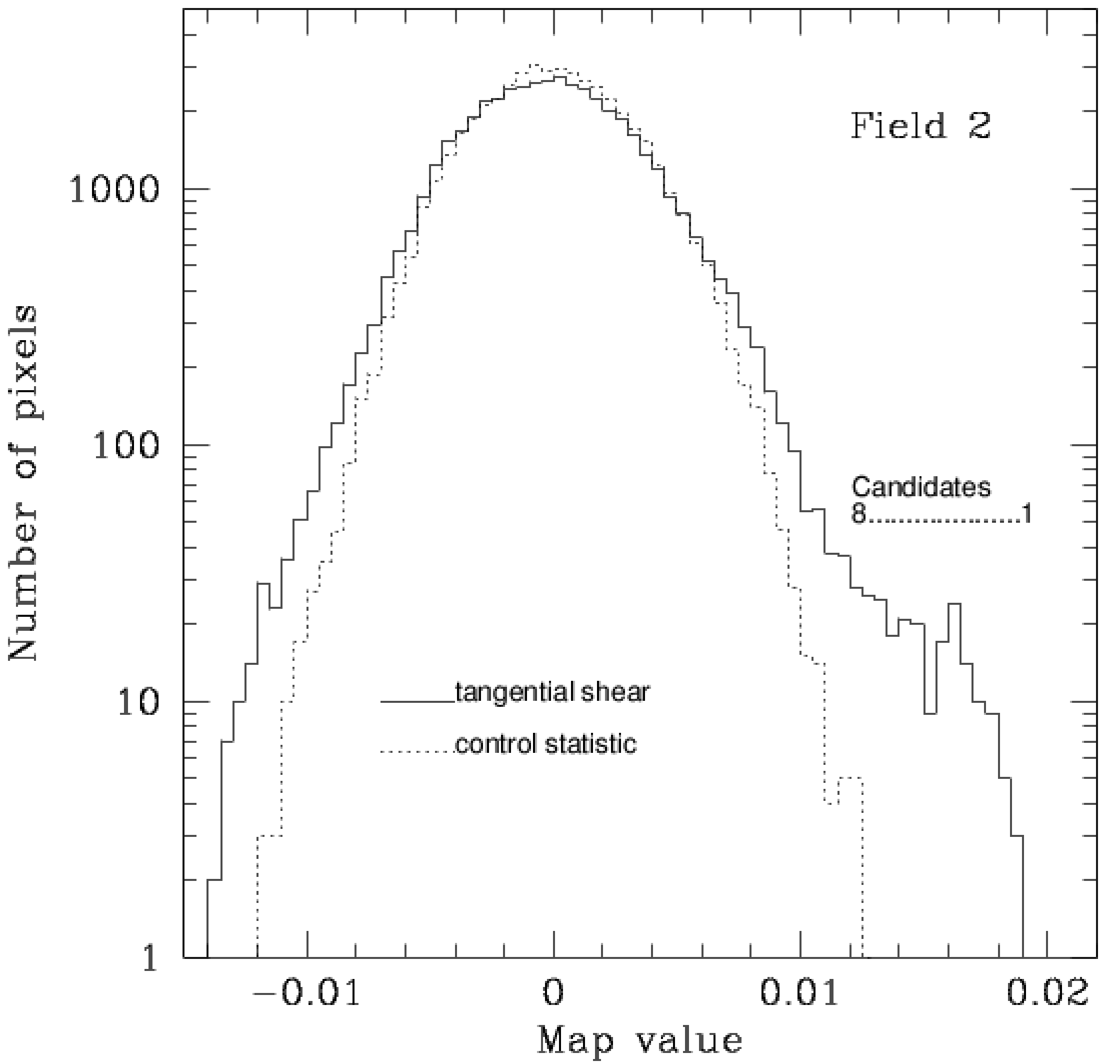
Candidates: Field 3



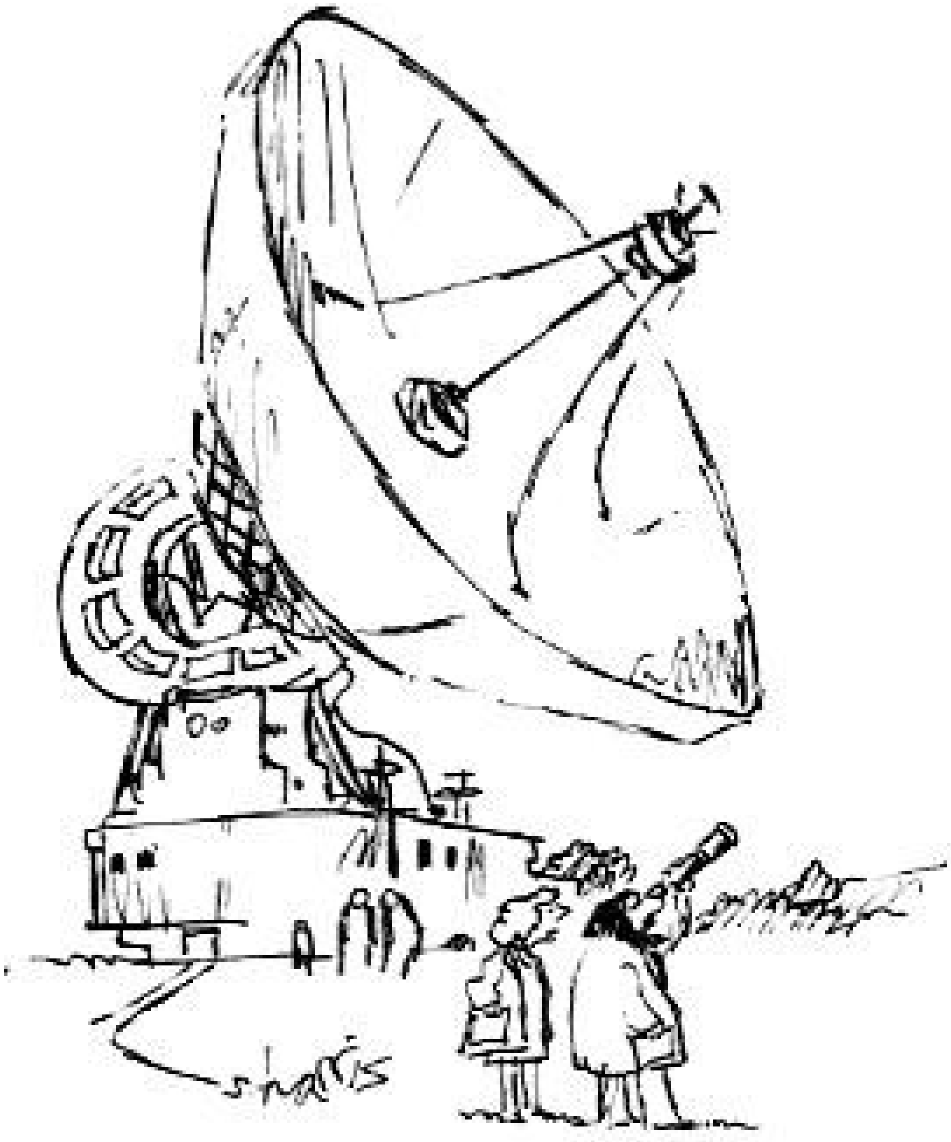
Candidates: Field 5



Candidates Are Real



Followup Campaign

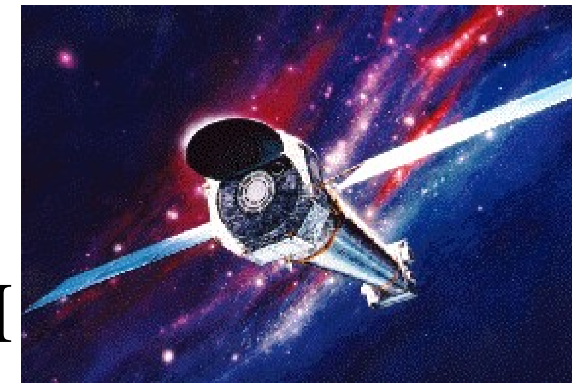


"Just checking."

Followup Campaign

- literature search
- DLS multiband imaging

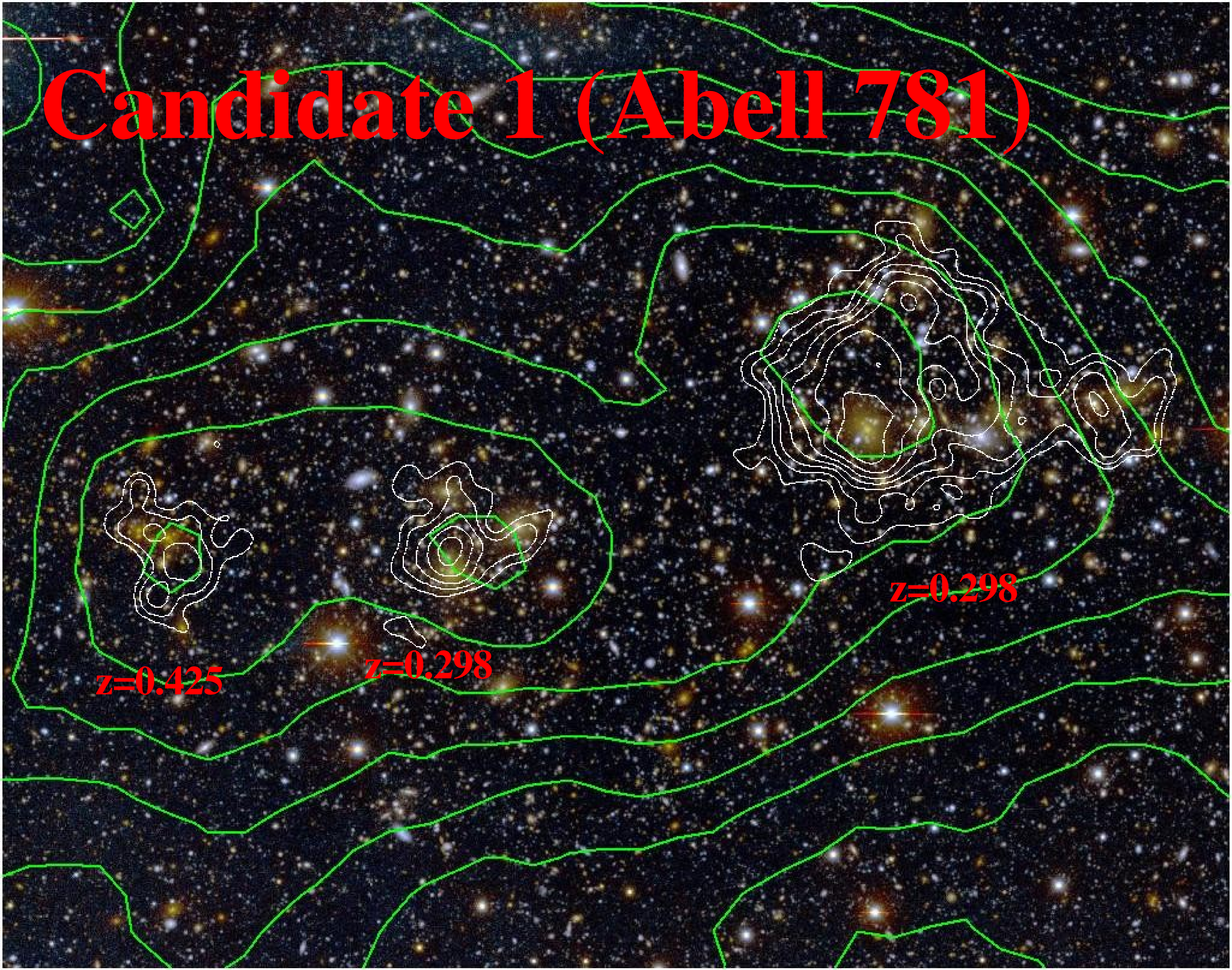
- X-ray spectro-imaging: Chandra, XMM



- spectroscopic redshifts: literature search
- spectroscopic redshifts: Keck/LRIS and CTIO/Hydra

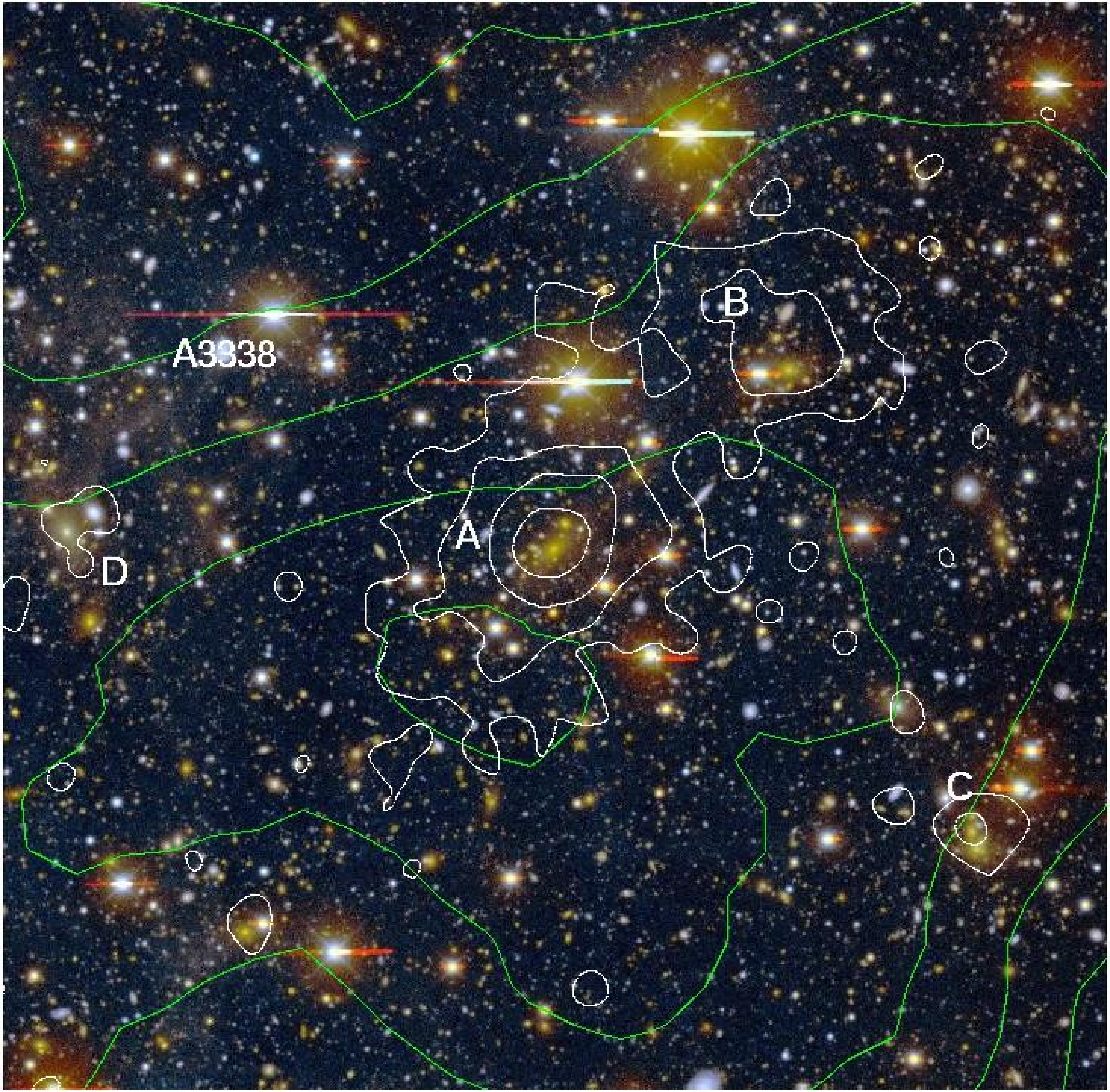
- redshift survey in Field 2 (MMT/Hectospec)

+ Spitzer data coming in fall 2006

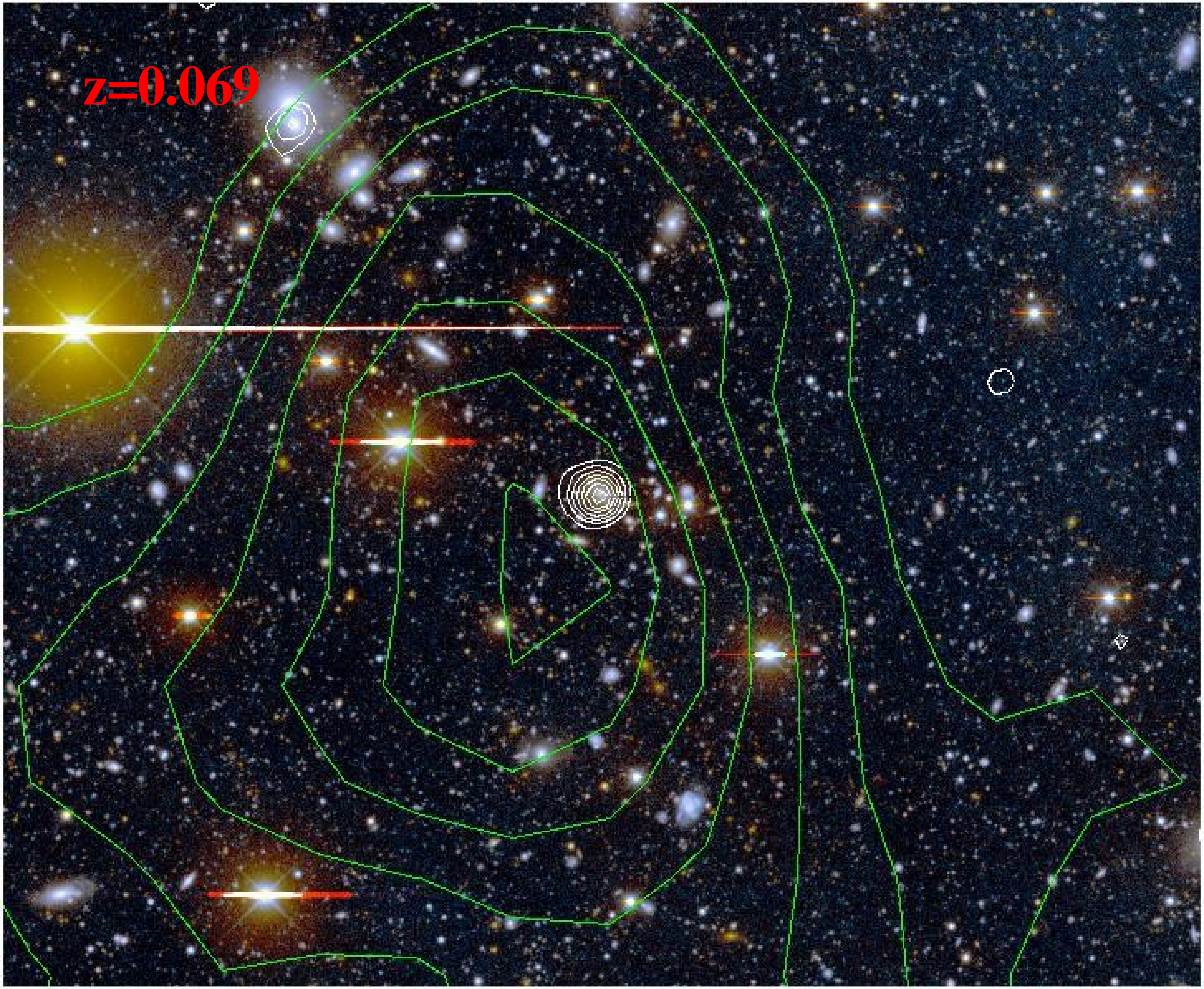

Candidate 1 (Abell 781)
z=0.425
z=0.298
z=0.298

Candidate 2: z=0.296

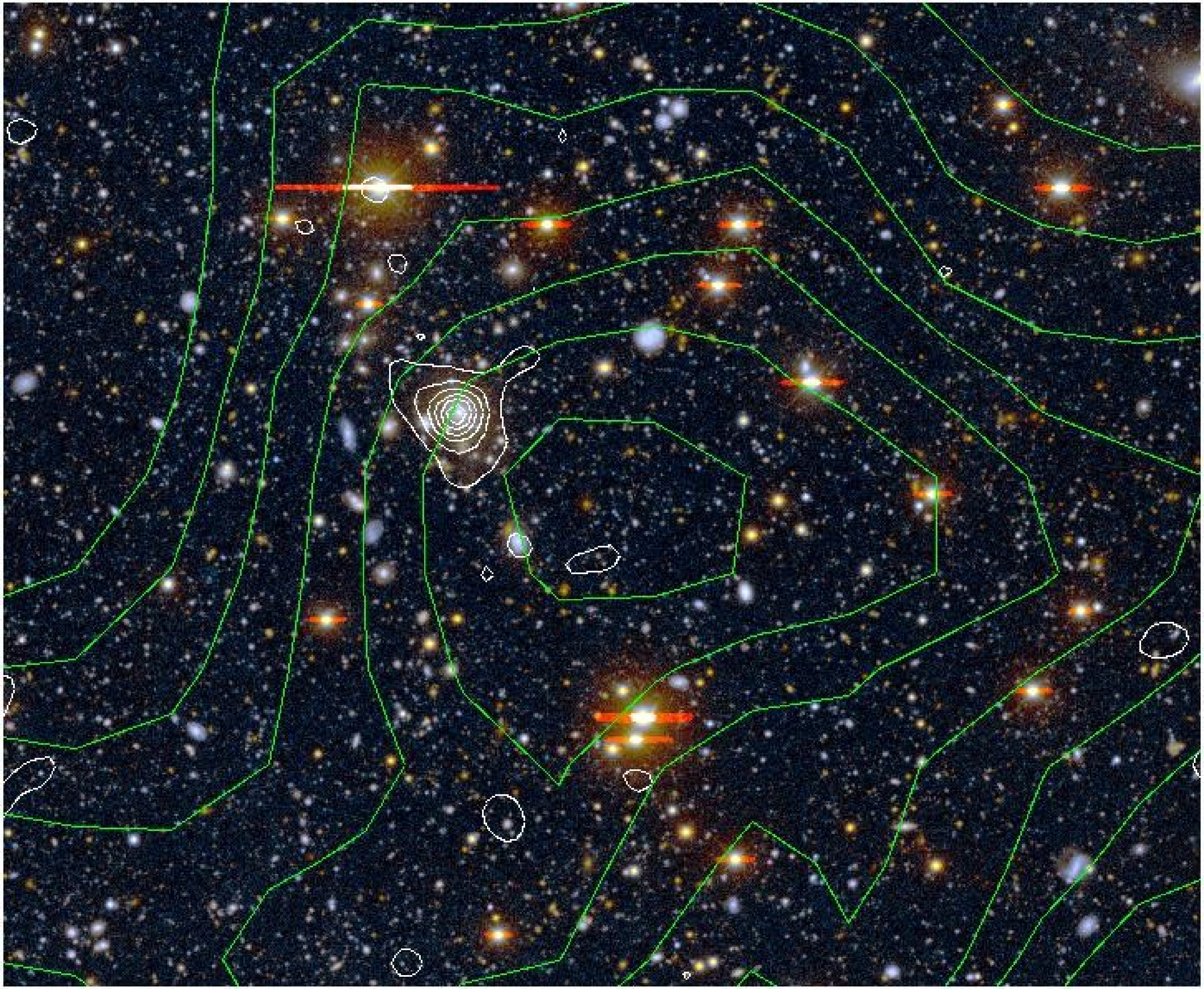
z=0.21



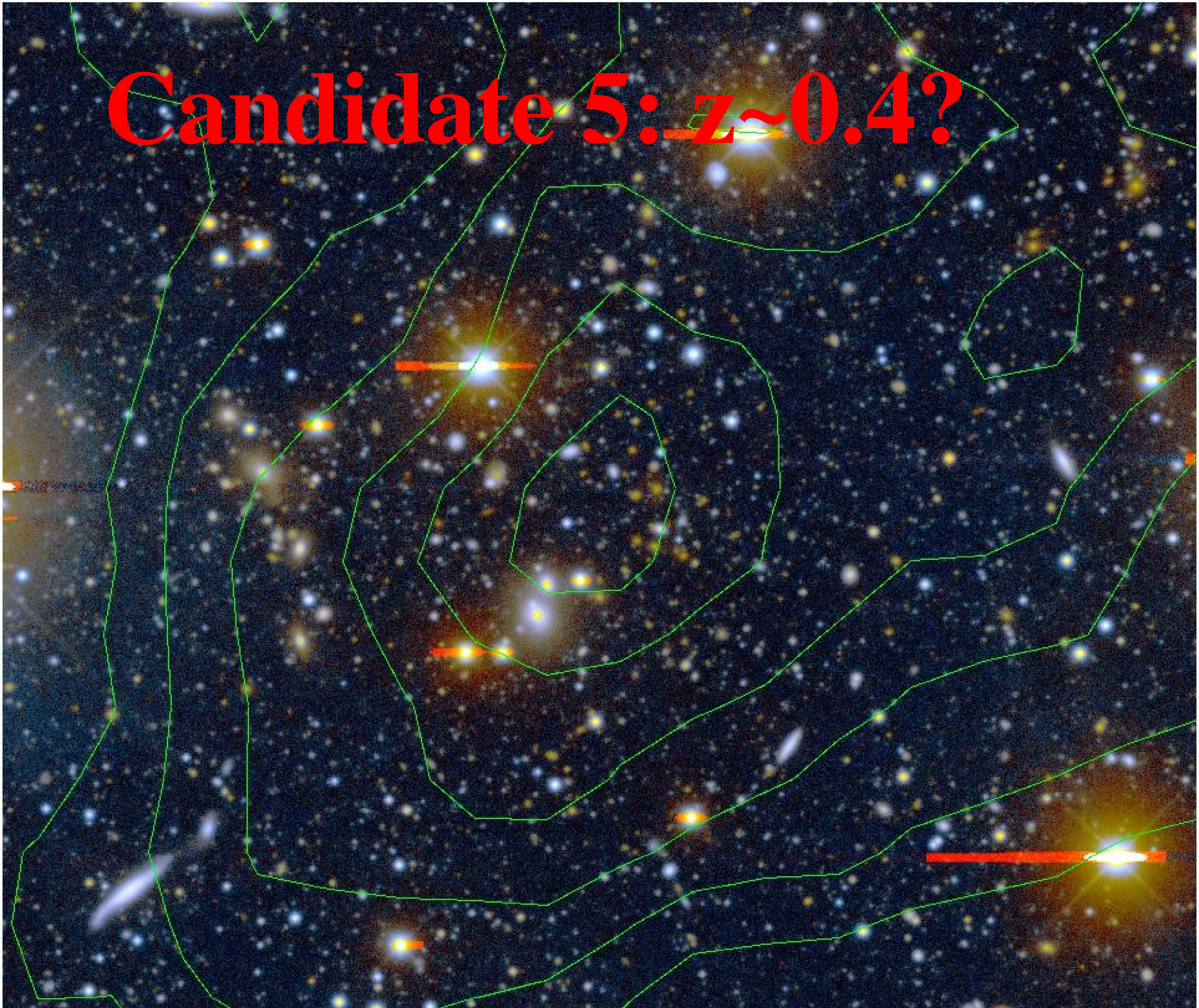
Candidate 3: z=0.267



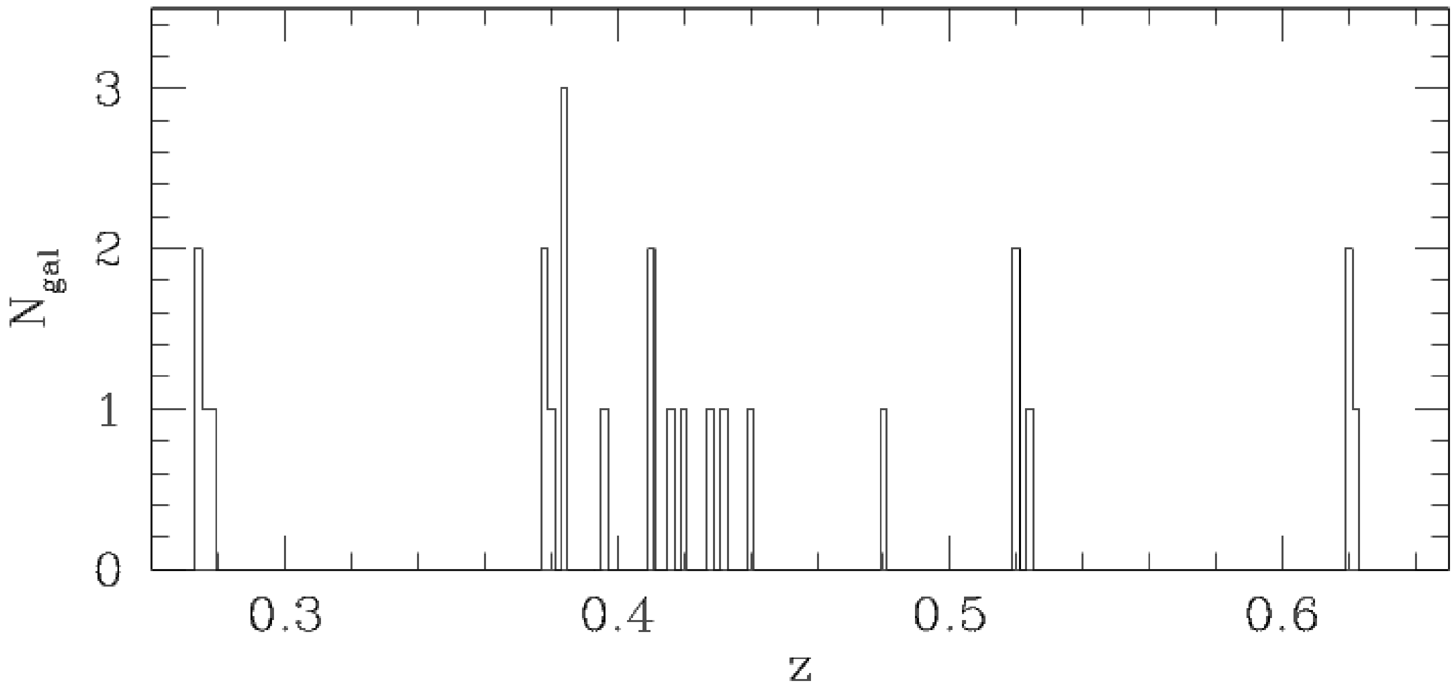
Candidate 4: z=0.190



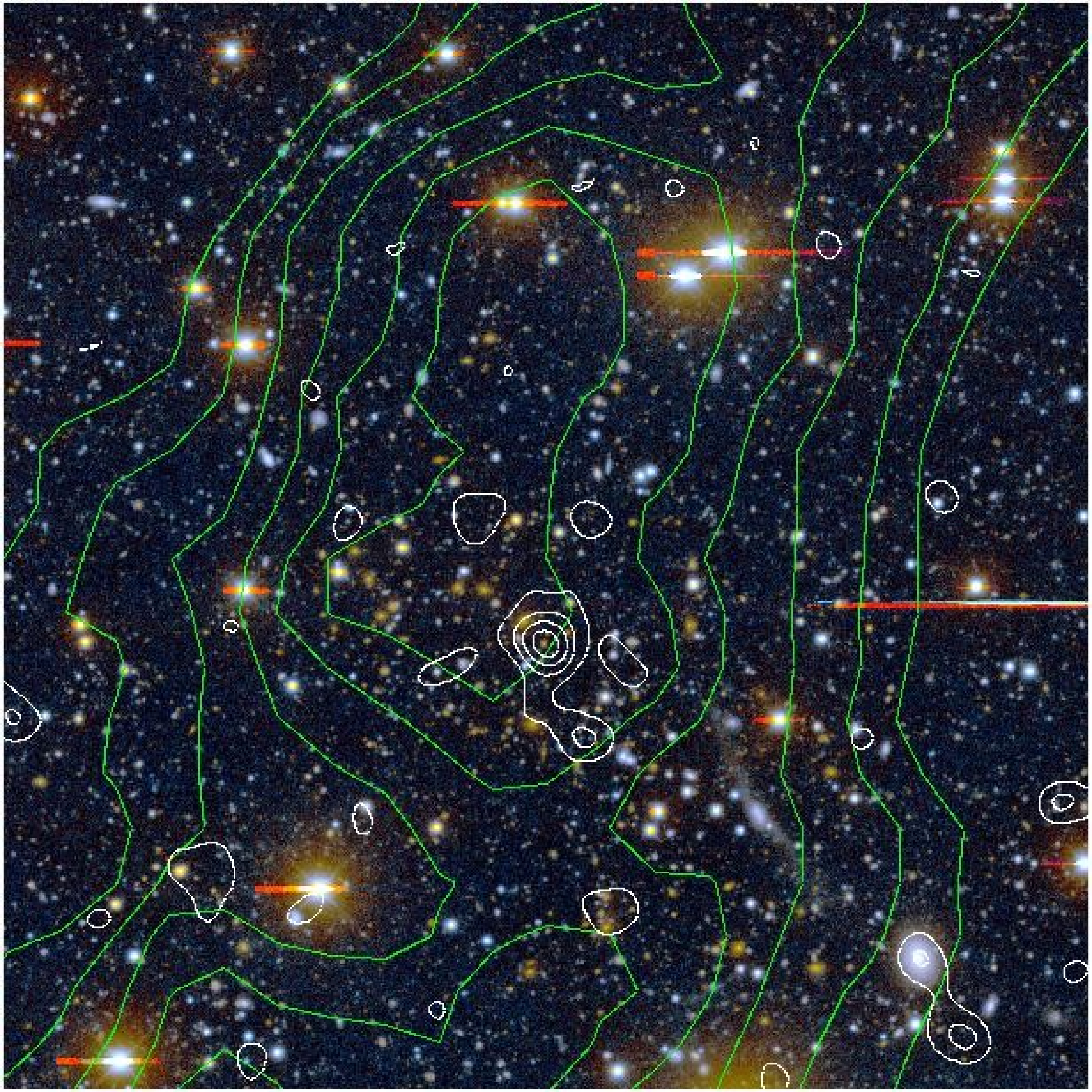
Candidate 5: z~0.4?

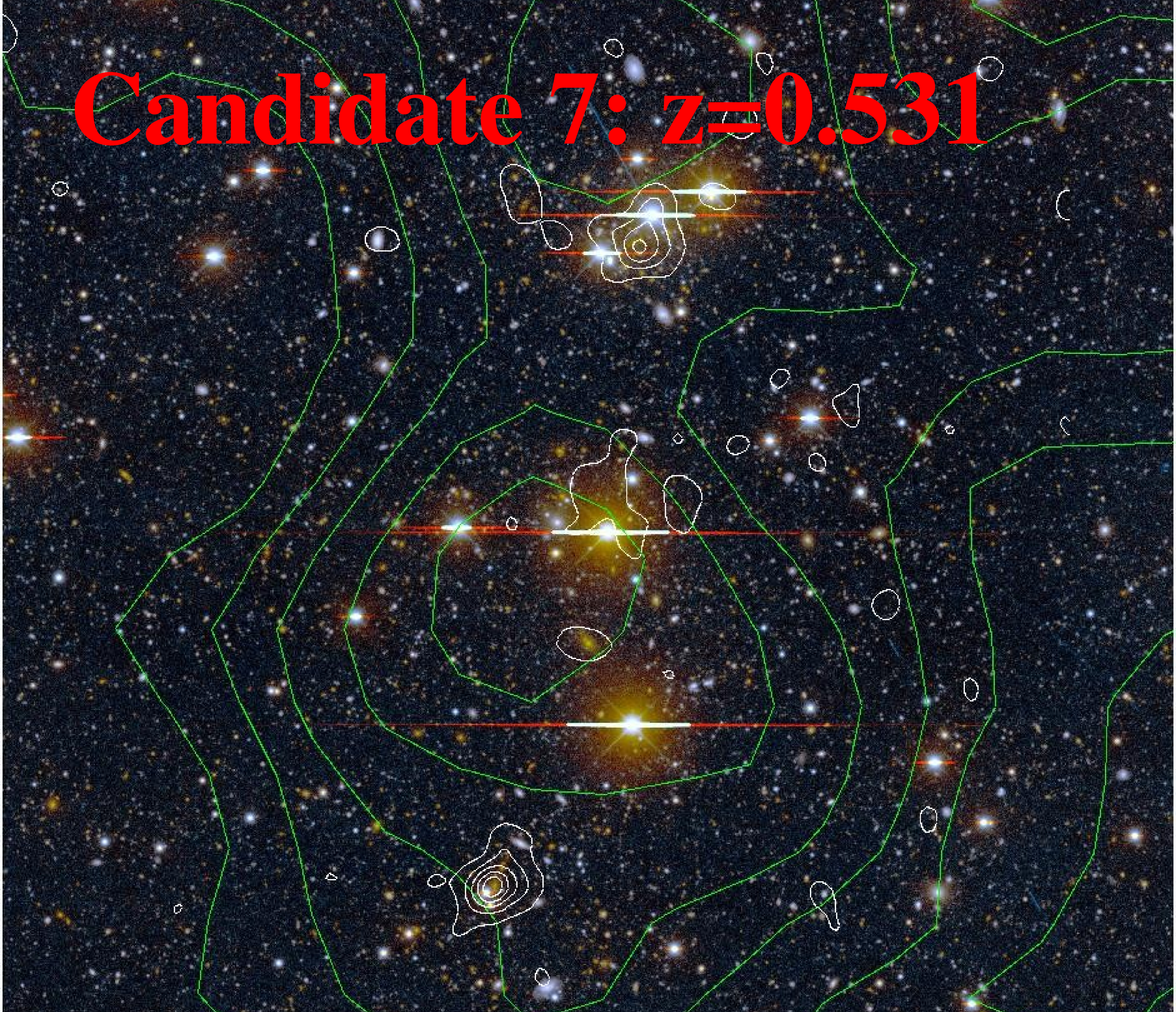


Candidate 5: Spectroscopy

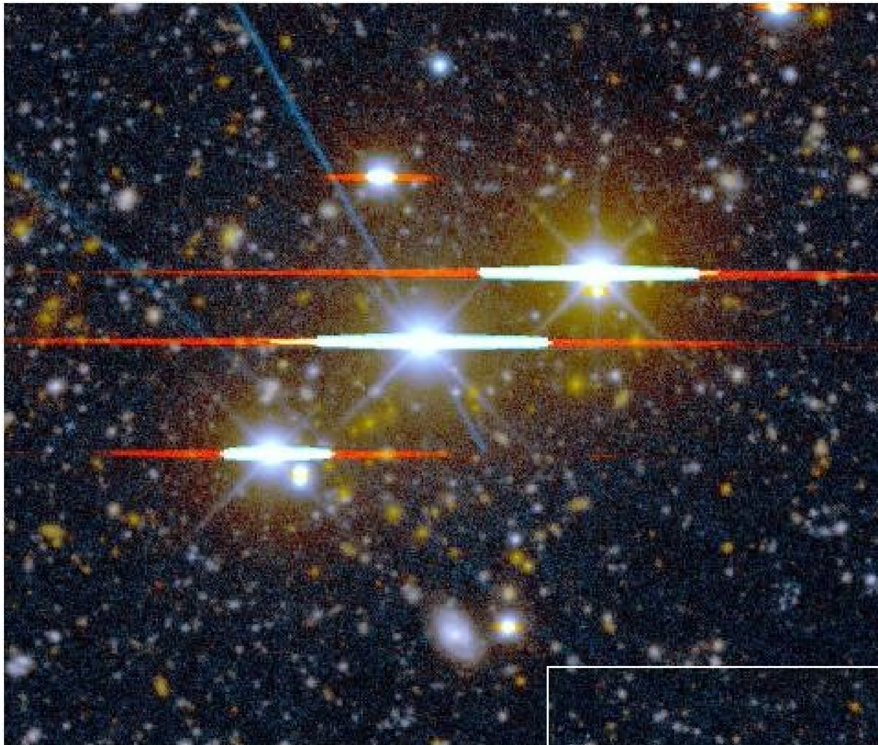


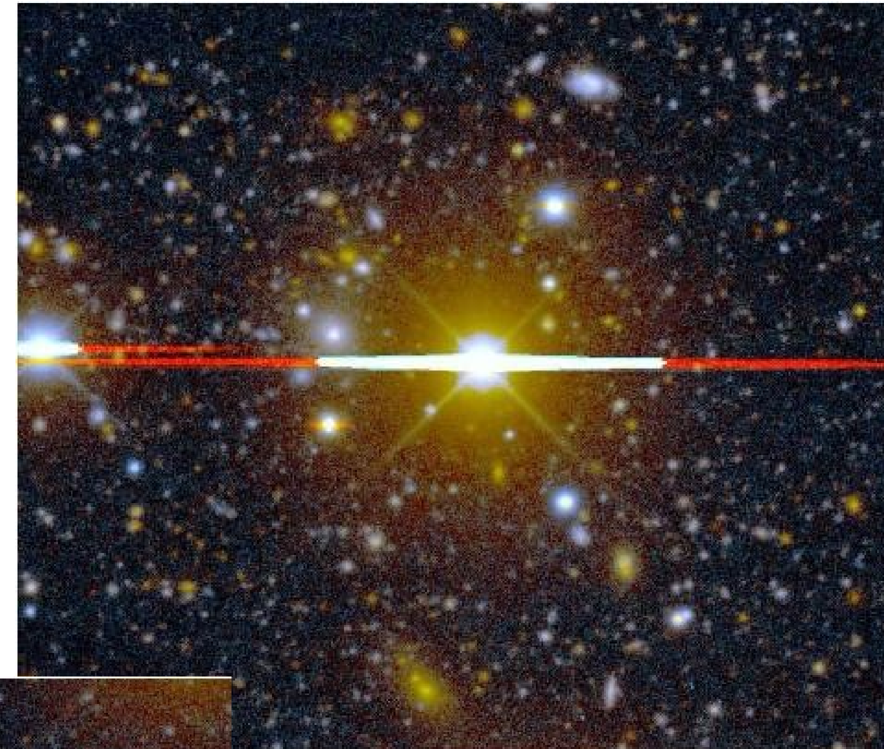
Candidate 6: z=0.427

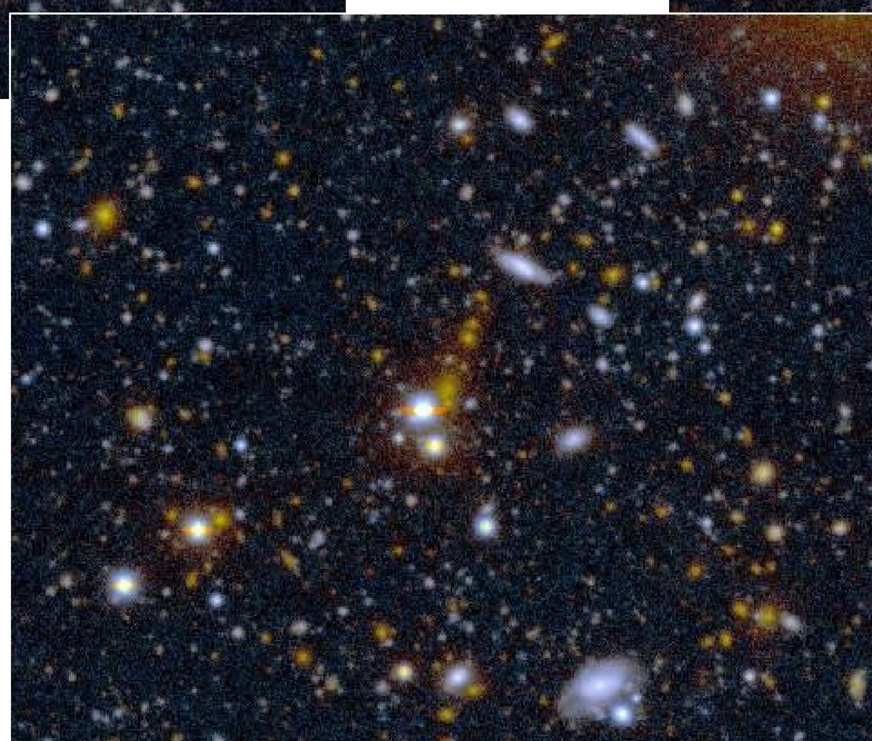


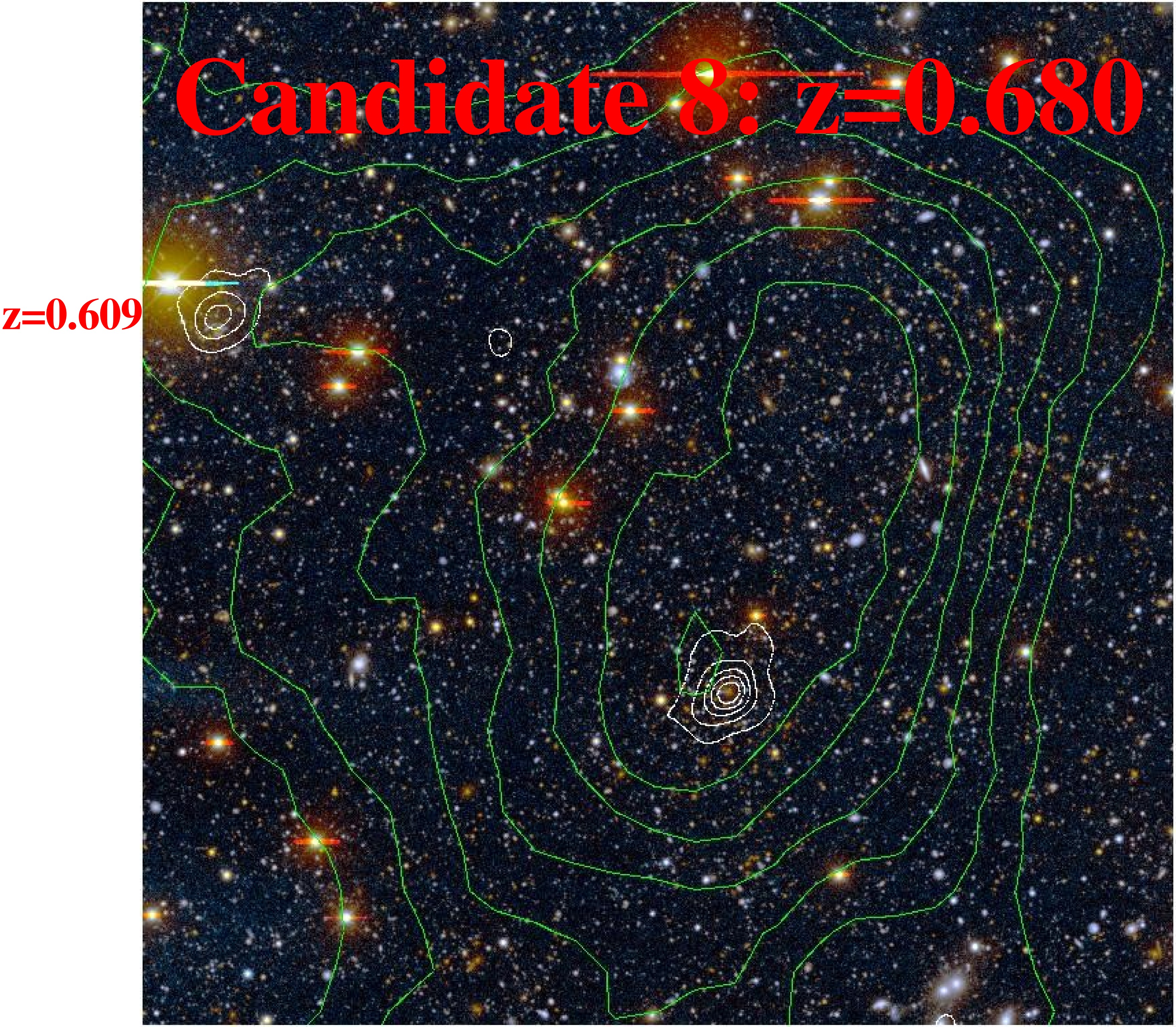

Candidate 7: z=0.531

Candidate 7 details





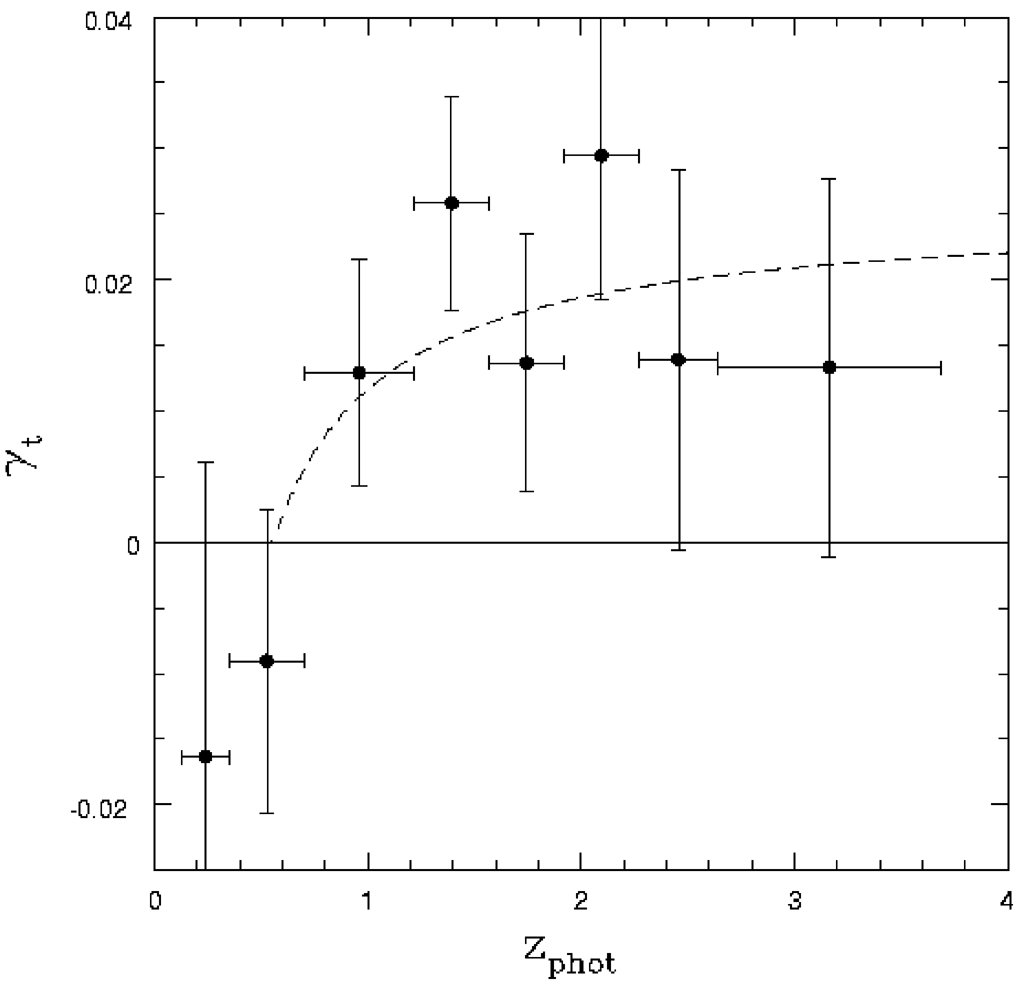


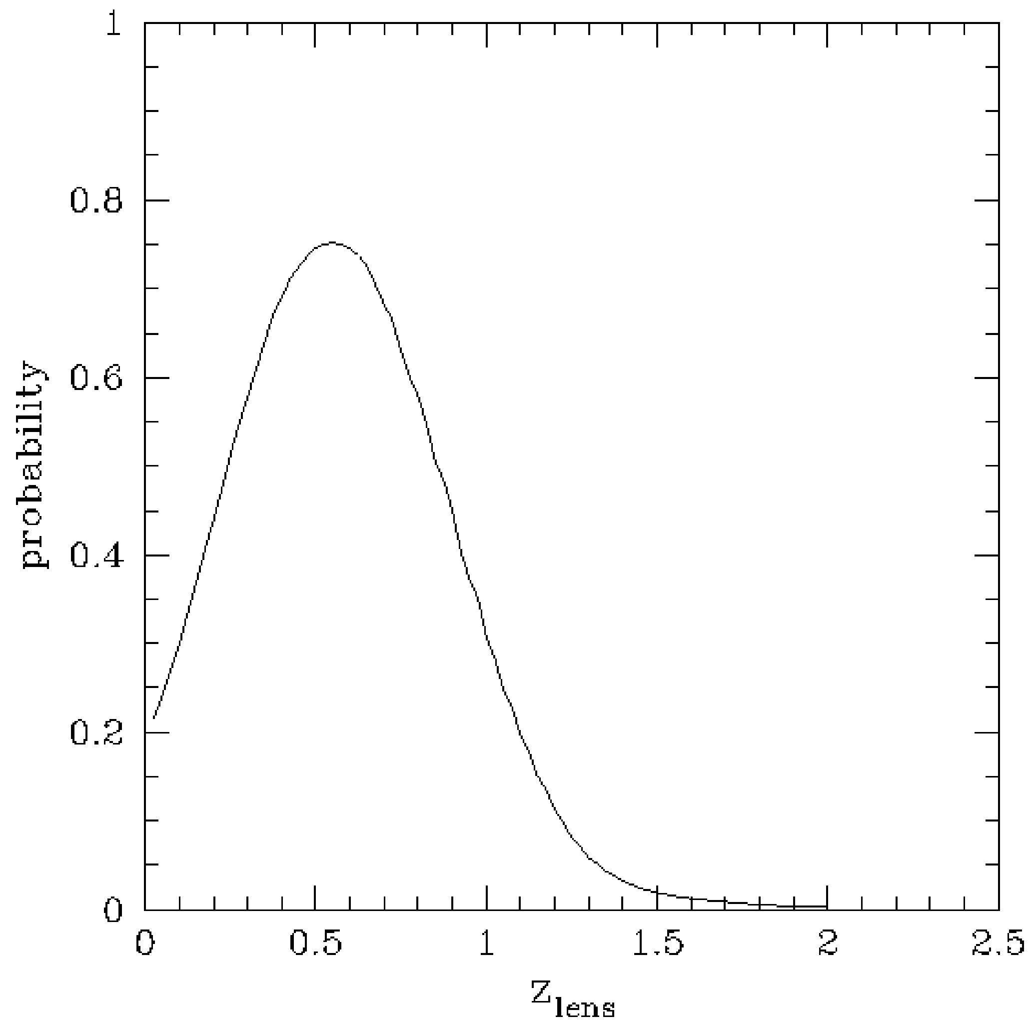

Candidate 8: z=0.680
z=0.609


Candidate 8: Giant Arc

Tomography of z=0.68 cluster

not just a peak on a massmap!





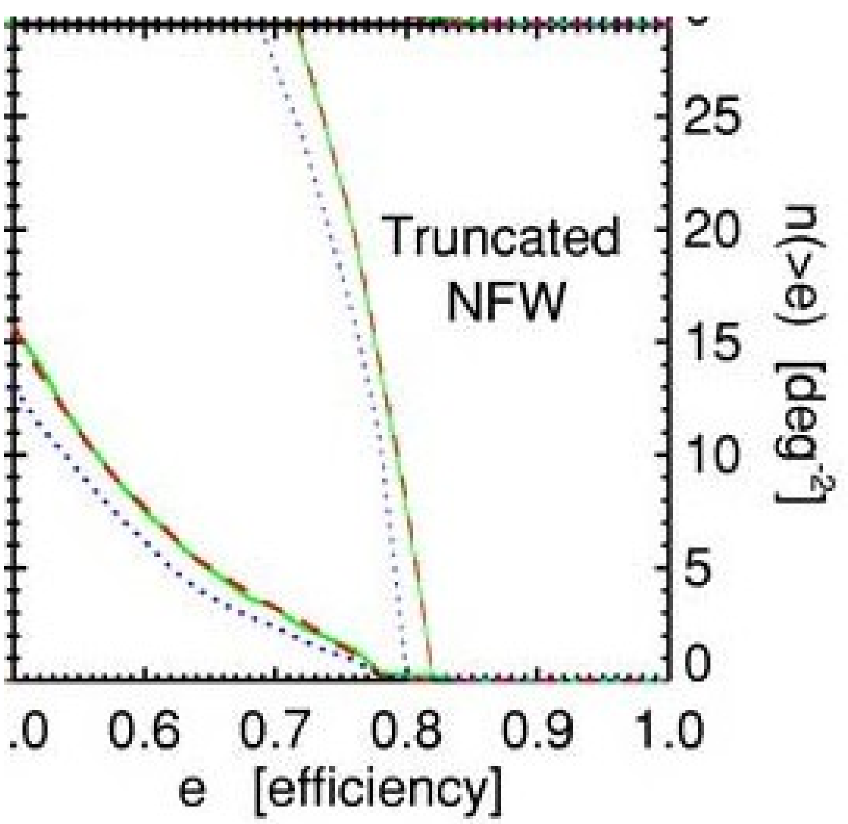
Wittman et al 2003, ApJ

</Shear-selected Sample>

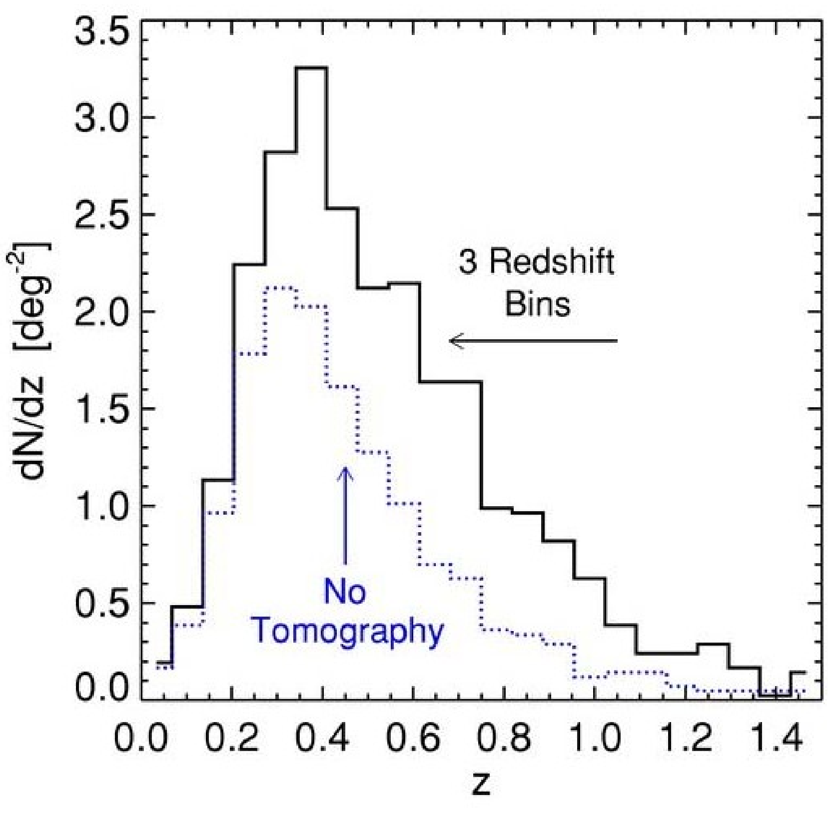
<Analysis>

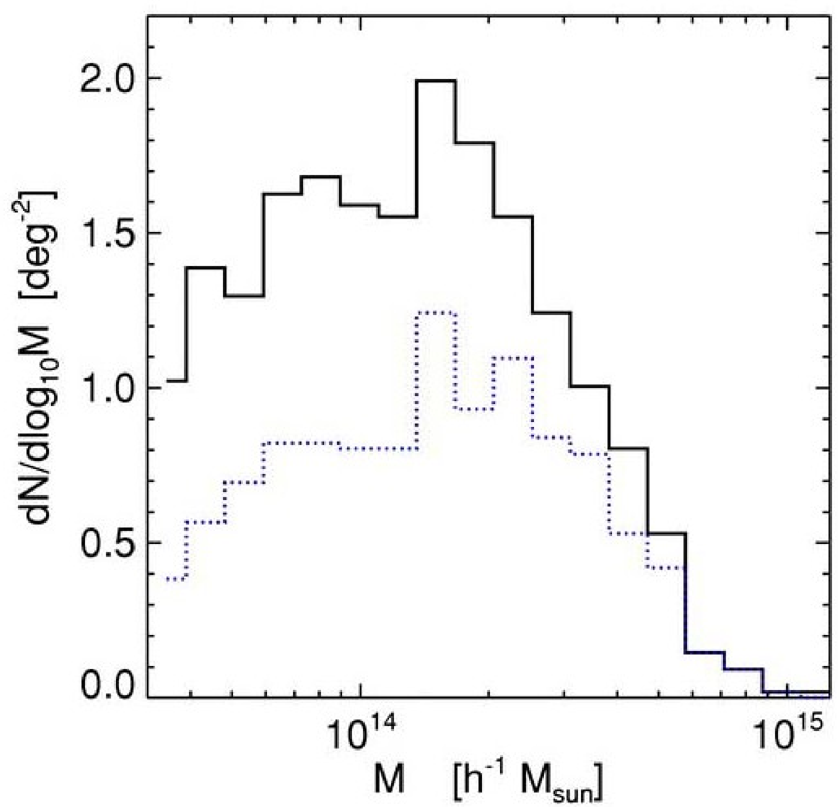
Projections

•Simulations by White et al (2002), Hennawi & Spergel (2005) show that projections will always be present:



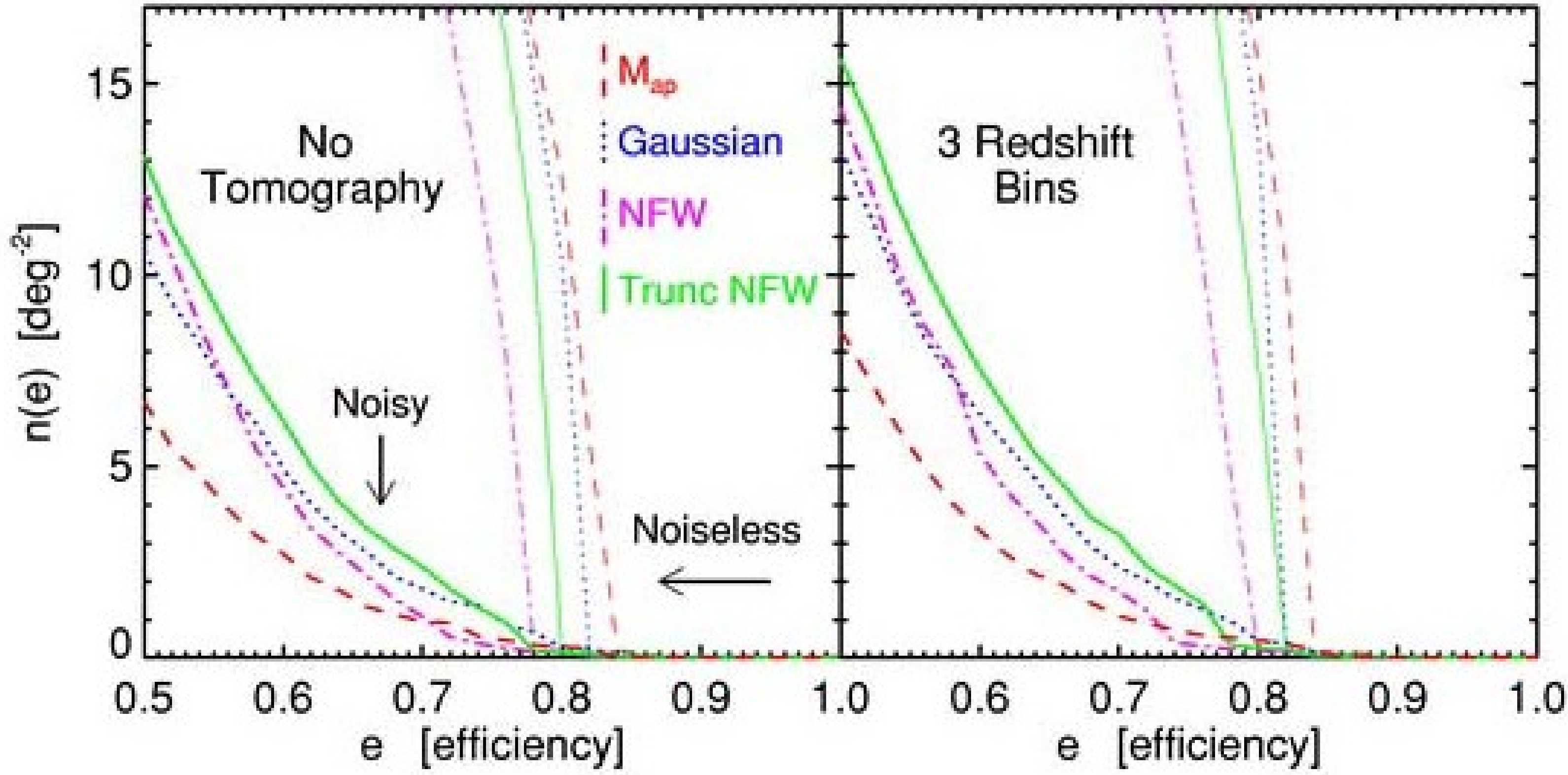
Does tomography help?





Hennawi & Spergel (2005)

Yes, but...

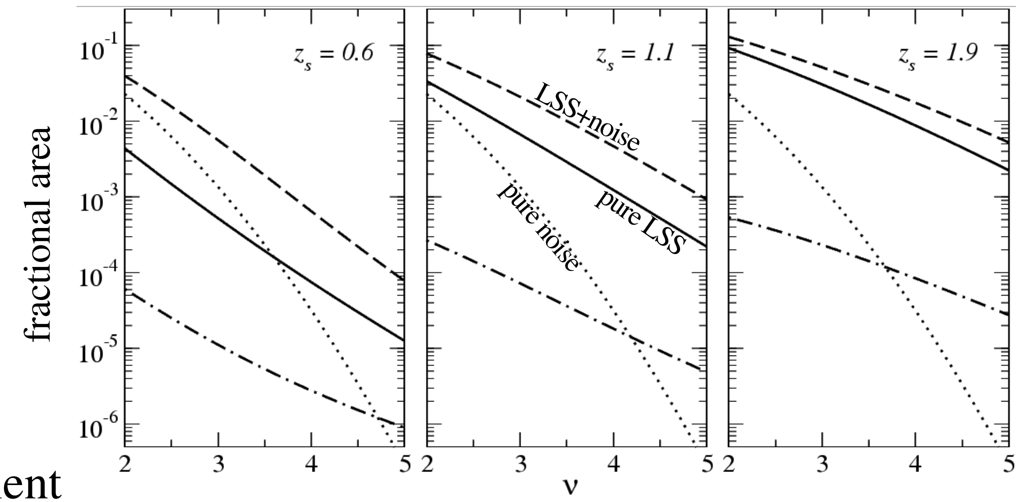


Hennawi & Spergel (2005)

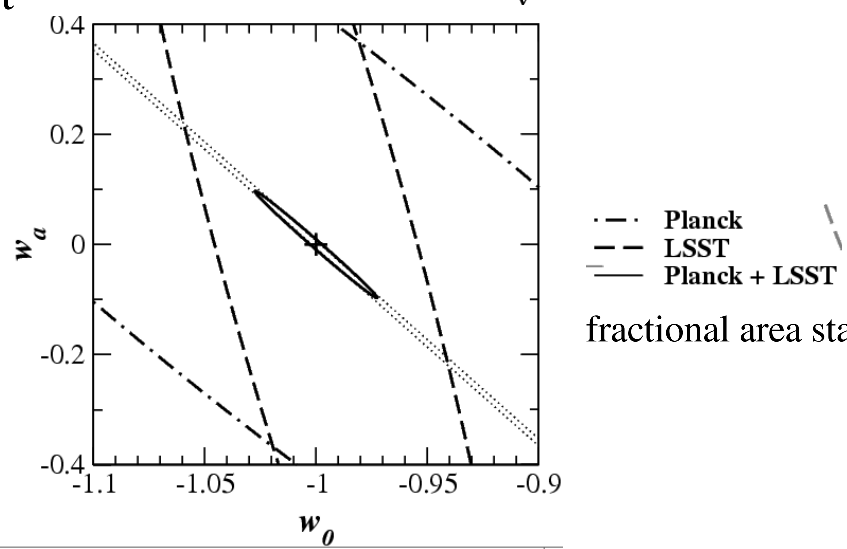
Dealing with projections: Two options

Fight them: *follow up with X-ray and/or spectroscopy to confirm.*

- expensive, but assigning a redshift to each shear peak is valuable
- introduces taint of baryon/star formation bias
- probably necessary for studying clusters as astrophysical laboratories (galaxy evolution, etc.).



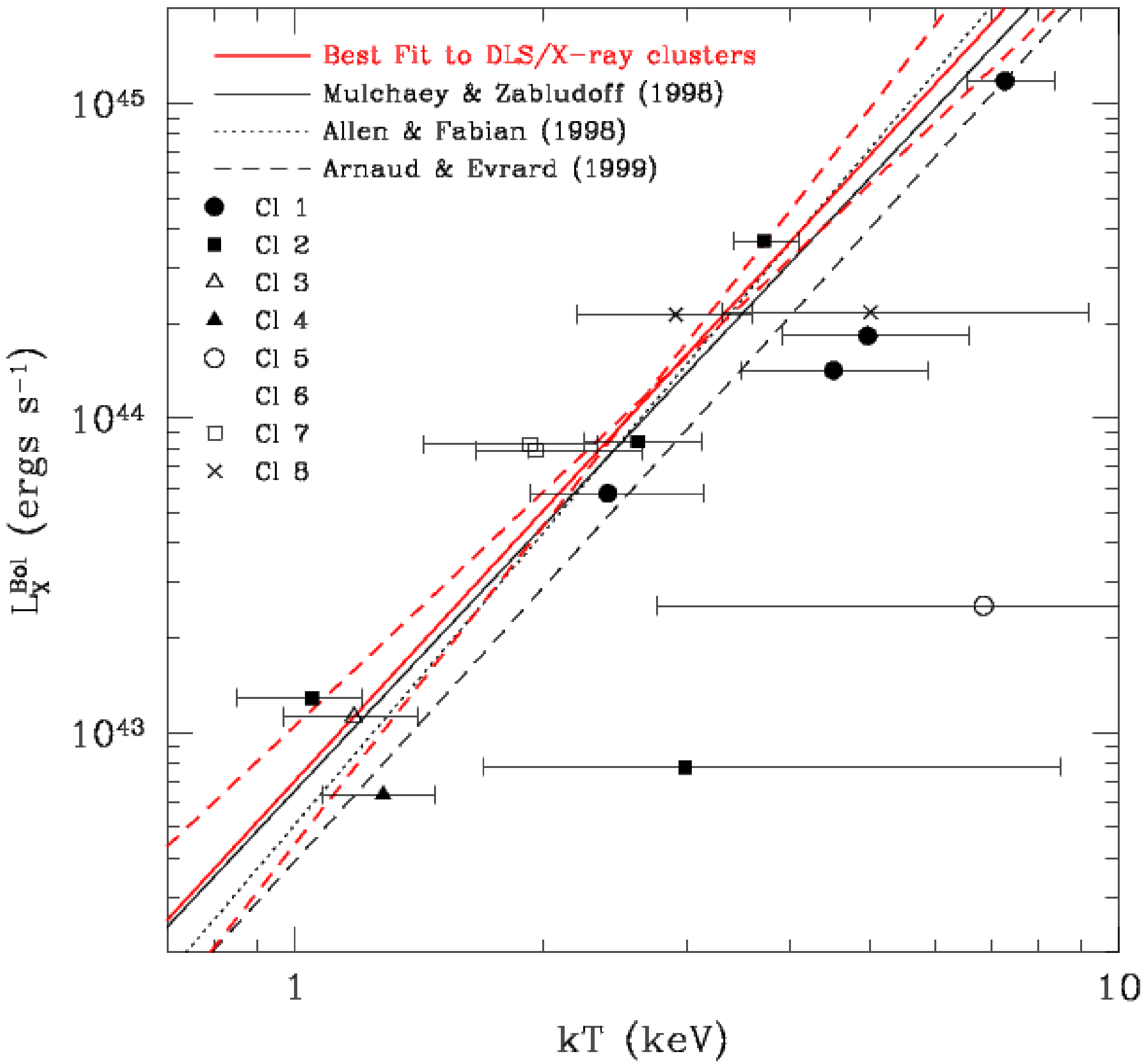
Embrace them: Just count shear peaks as a function of *source* redshift. Gives excellent constraints on cosmology:



fractional area statistic only!

Wang et al, astro-ph/0512513

Comparison with X-ray Selected Samples



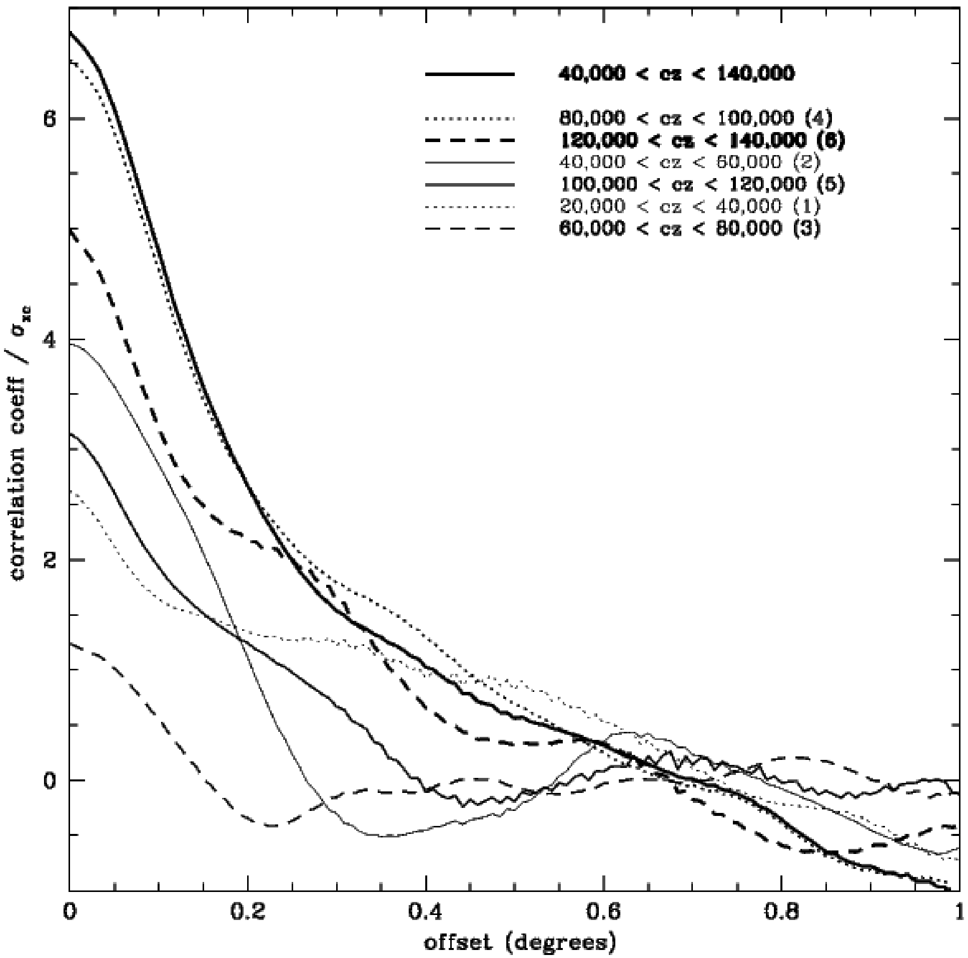
Hughes et al, in prep

Other Comparisons

- Optical cluster search underway on DLS data.

- Cross-correlation with velocity field in F2 (figure at right).

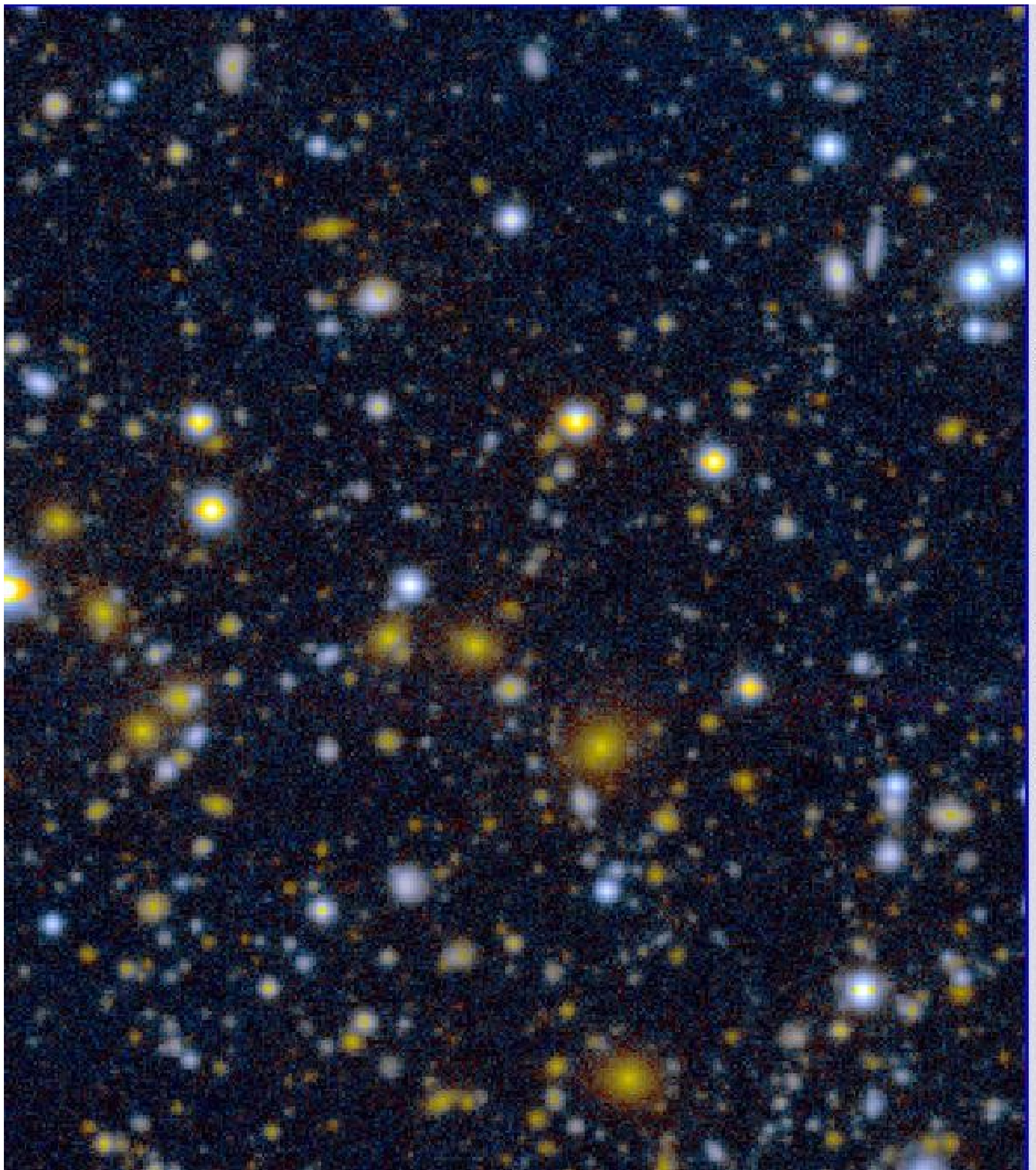
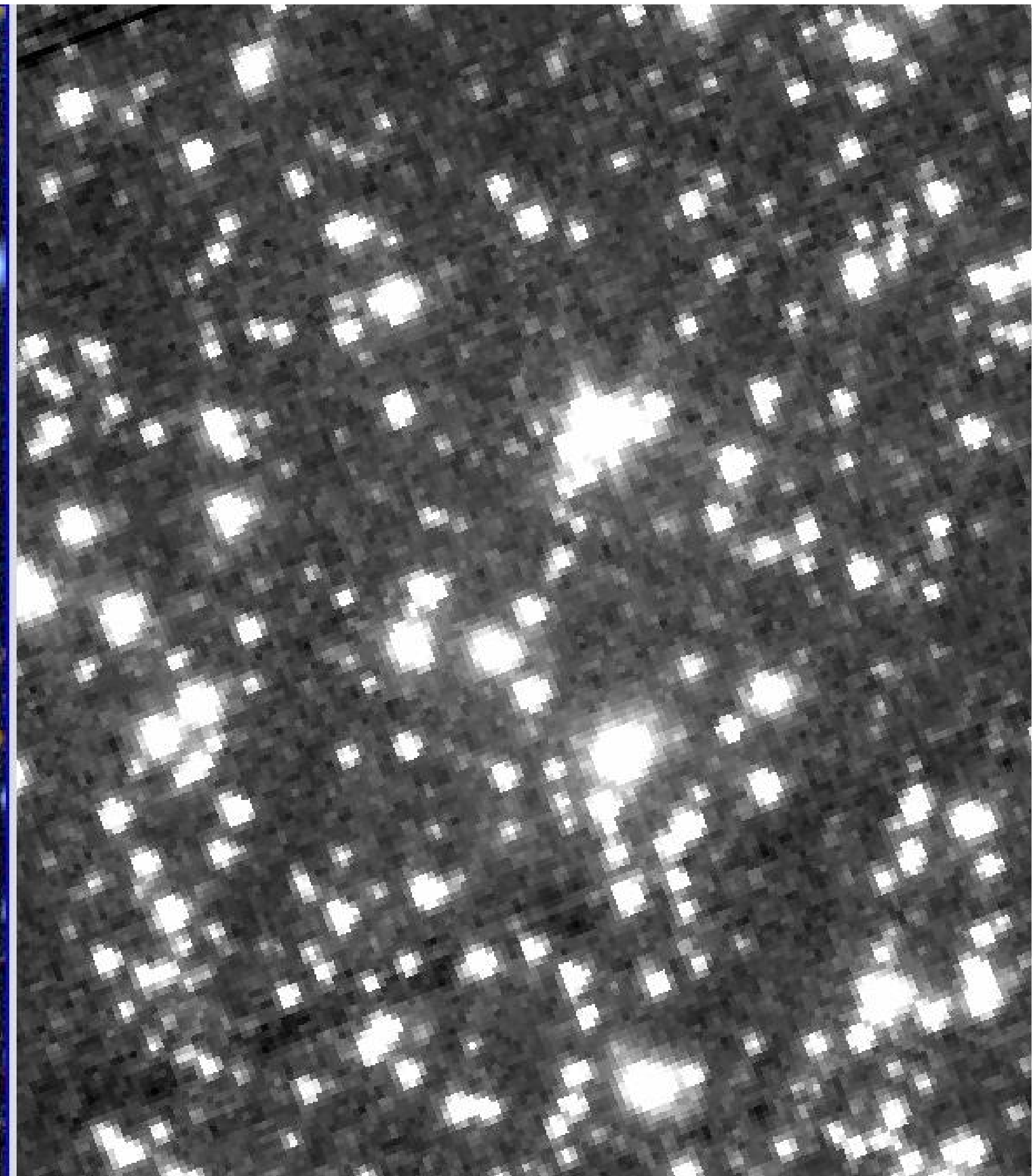
- Two DLS fields to be surveyed by SZE instruments.



Geller et al, ApJL 635, 125 (2005)

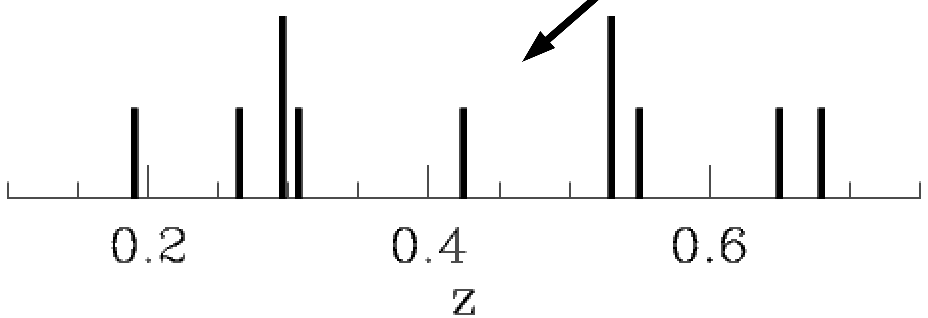
Stellar Masses from Spitzer

BVR First data just arrived! 3.6 um

Summary of Selection Methods

Selection method	Projection effects?	Emitted light?	Redshift independent?	Dynamical state?	Star formation history?	Sample availability
Optical	yes	yes	no	no	yes	high
X-ray	no	yes	no	yes	no	medium
Shear	yes	no	no	no	no	infancy
SZE	no?	no	almost	yes	no	infancy



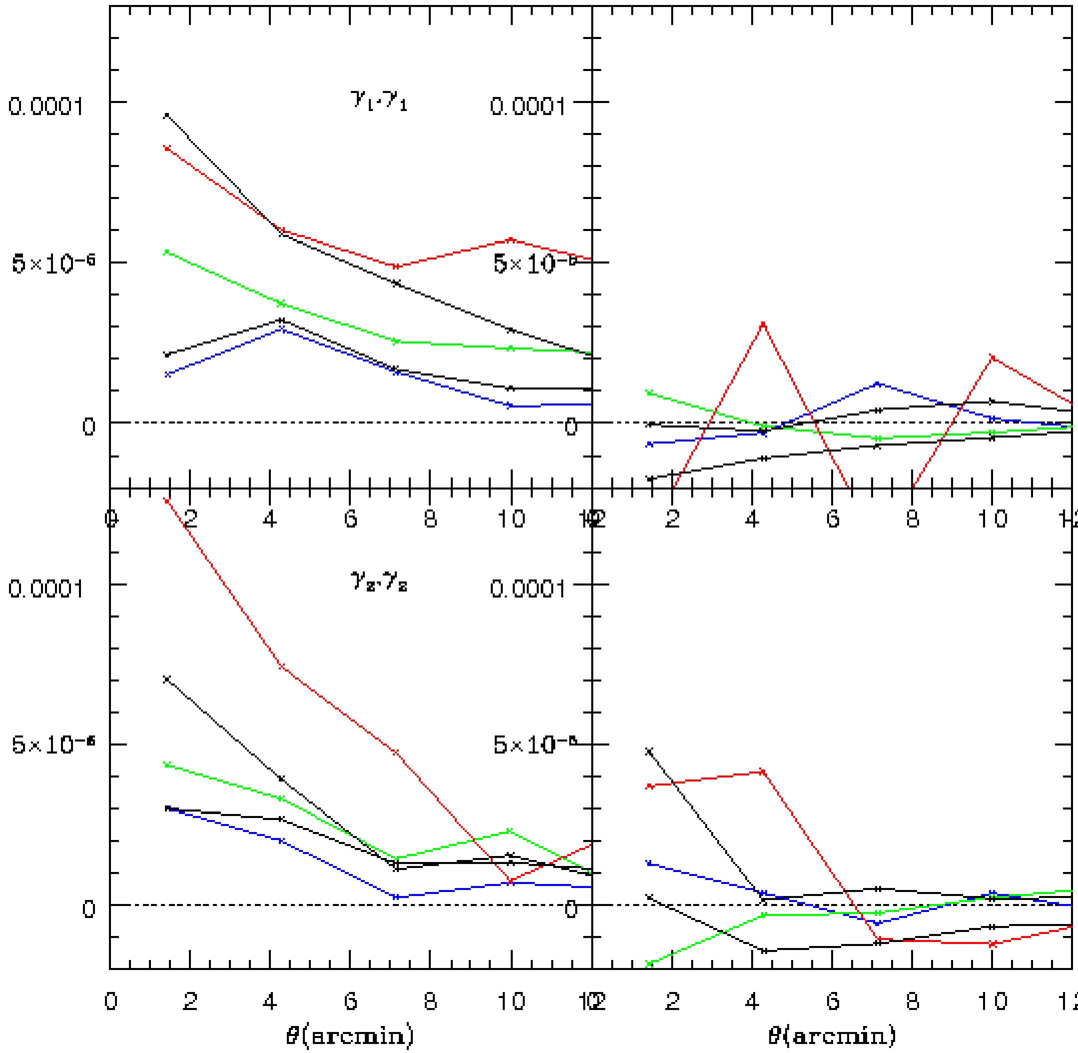
Observed shear-selected sample n(z)

Bottom line: ALL methods must be used to get an accurate picture of clusters!

</Analysis>

<Cosmic Shear>

Cosmic Shear: Work in Progress!



Caution: This plot contains known large systematics. Main purpose here is to illustrate redshift dependence:

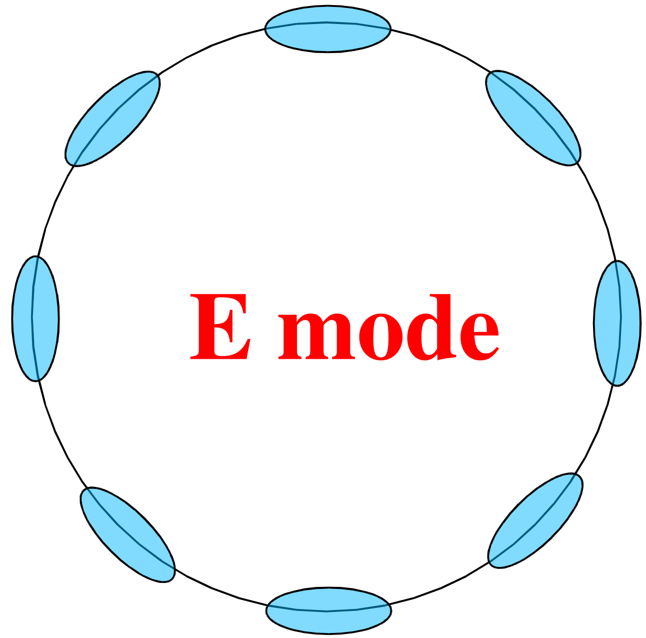
red: $1 < z < 1.5$

green: $0.5 < z < 1.0$

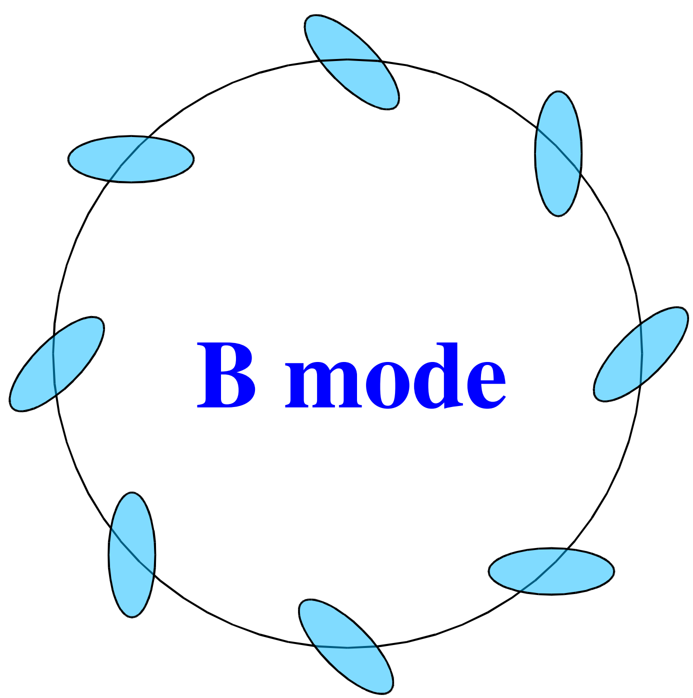
blue: $0 < z < 0.5$

black: cross-correlations of adjacent redshift slices

Monitoring systematic errors

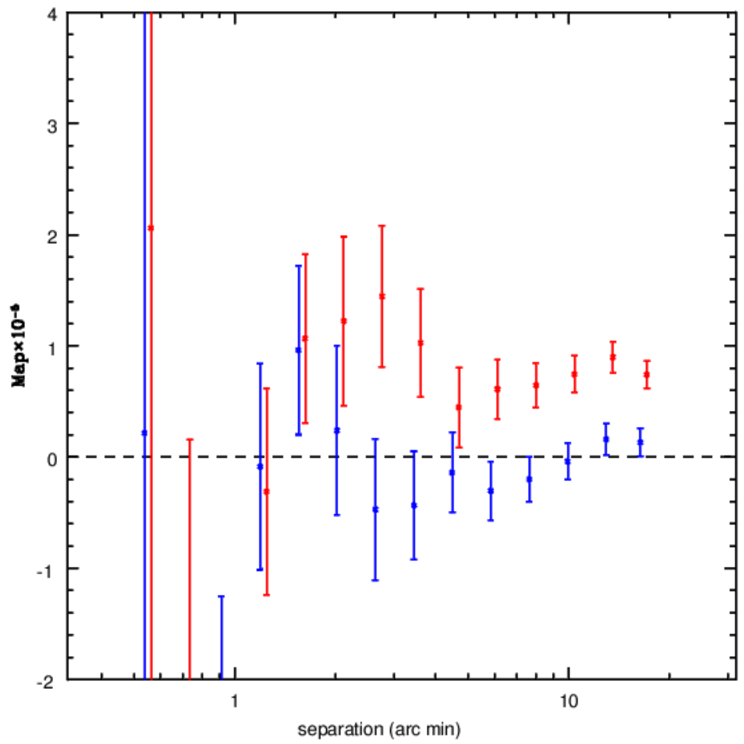


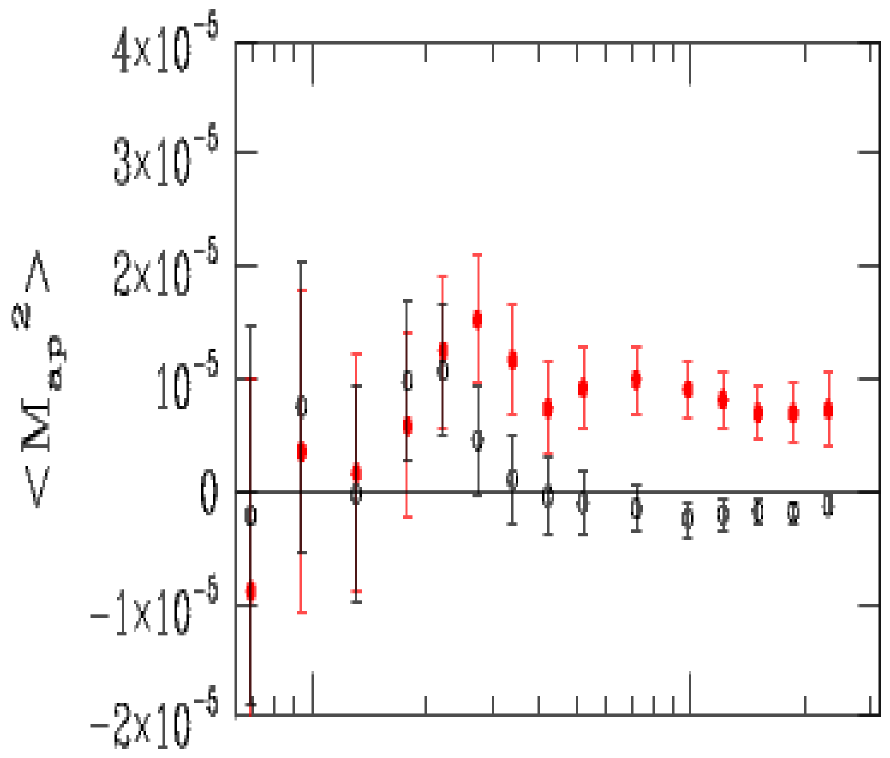
induced by:
- -lensing
- -intrinsic alignments?
- -systematic errors?



induced by:
- -intrinsic alignments?
- -systematic errors?

Cosmic Shear: B modes

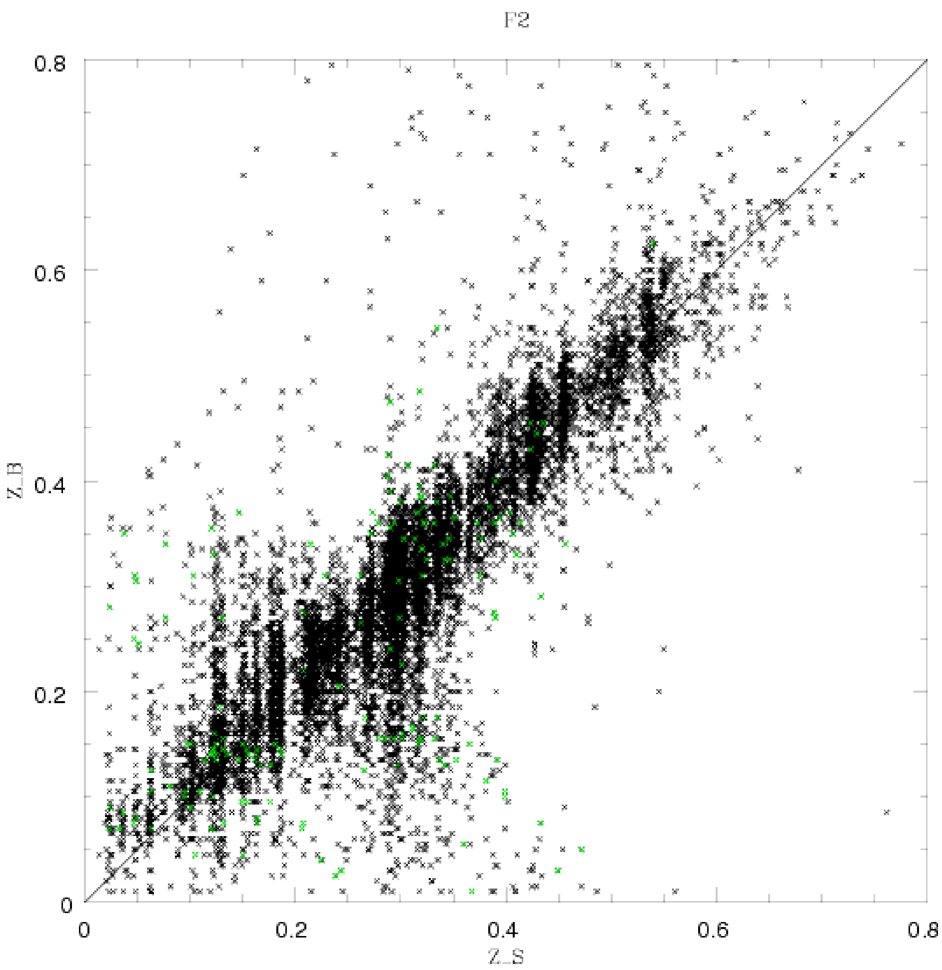




2% of DLS data! (0.25 deg^2)

Semboloni et al astro-ph/0511090
CFHLS Deep

Another Potential Systematic: Photometric Redshifts



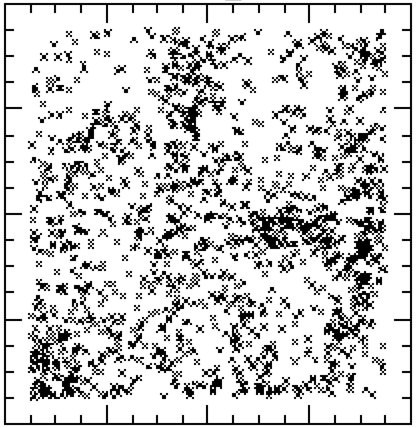
This plot is nice, but what does it look like for sources too faint for (or otherwise unrepresentative of) spectroscopy?

This issue looms larger as surveys get more statistically precise!

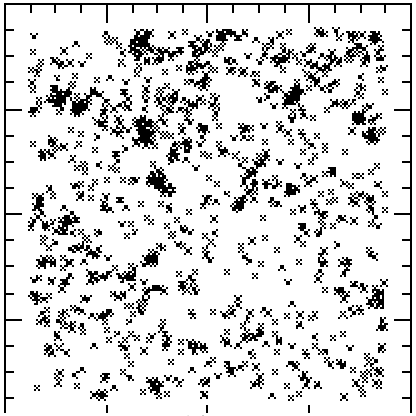
New Test of Photometric Redshifts
(thanks to Jeff Newman)

Angular cross-correlations of a series of redshift slices from a spectroscopic survey with a photo-z slice reveals its true redshift distribution.

Spectroscopic survey

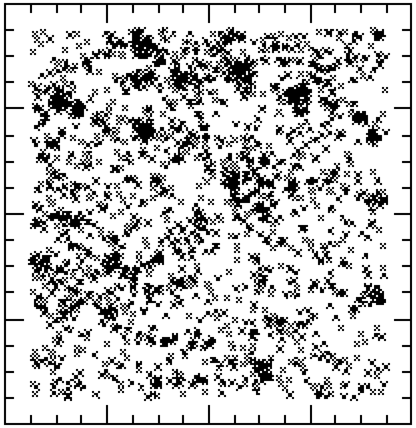


Slice 1

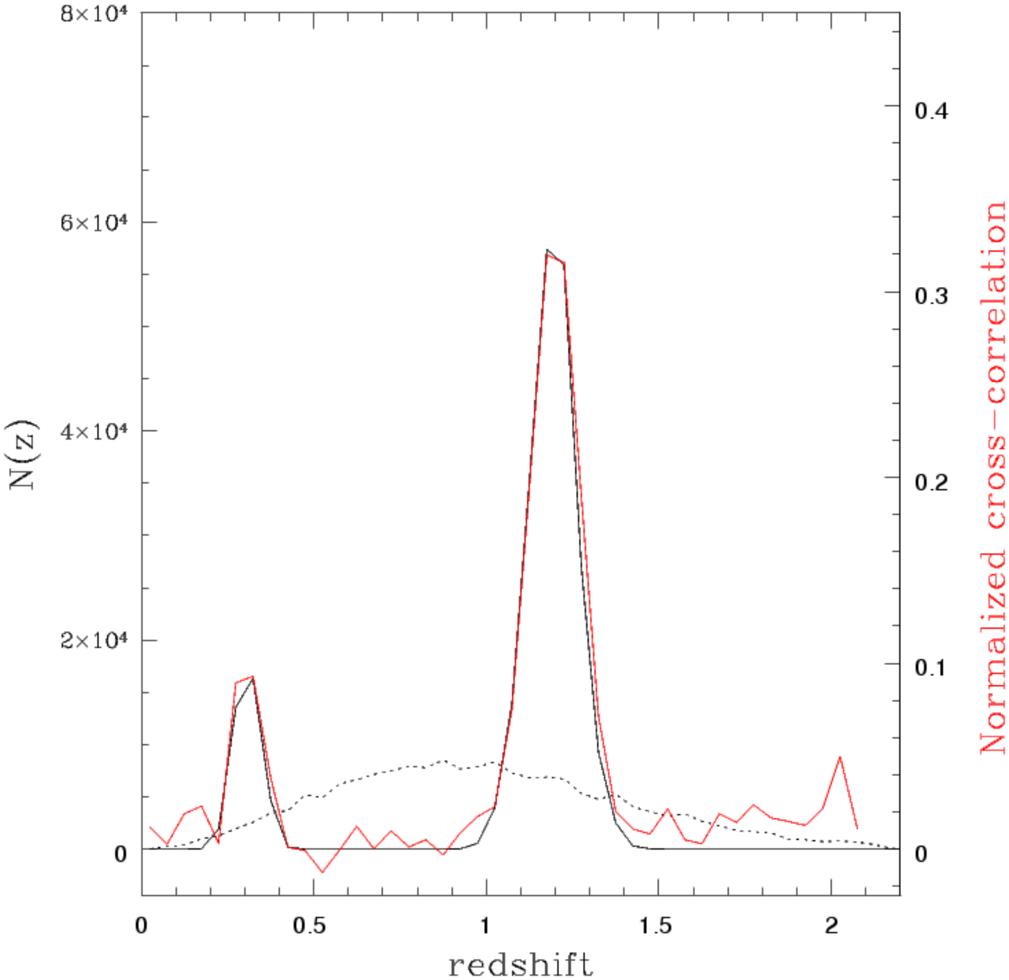


Slice 2

Photo-z slice



Unrealistic Example

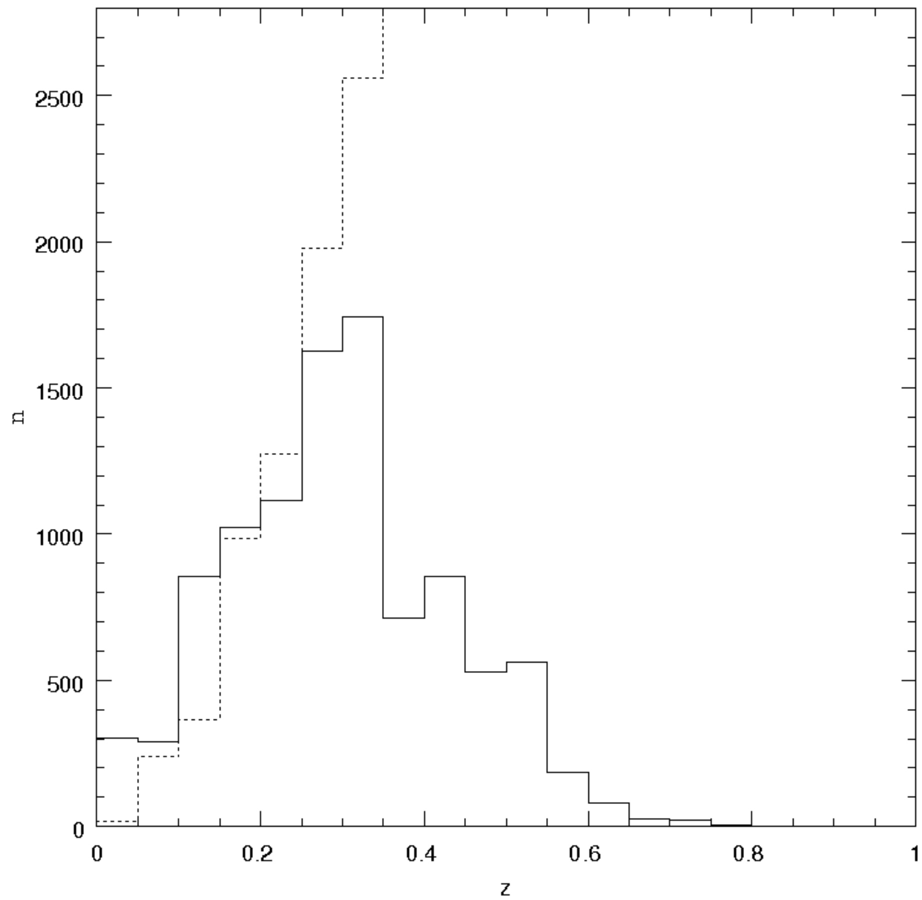


Start with M. White simulation of 4x4 deg patch with 1.7M galaxies. Take random 1/10 of these as "spec-troscopic sample" (dotted line).

Black: true n(z) of hypothetical z-phot slice with many catastrophic errors due to degeneracy in color-color space.

Red: angular cross-correlation with spectroscopic sample.

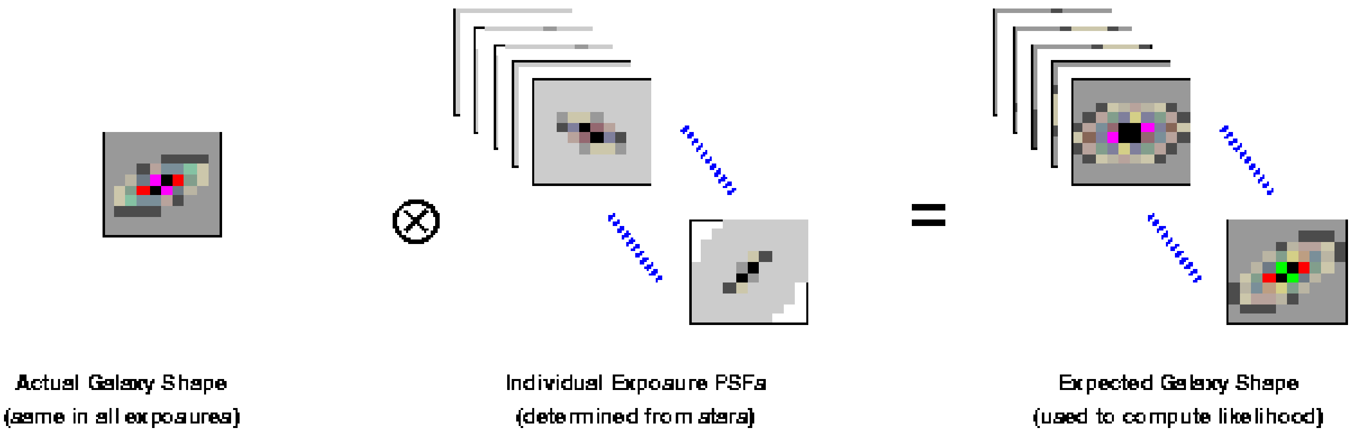
Next Step: Use Actual DLS Redshift Survey



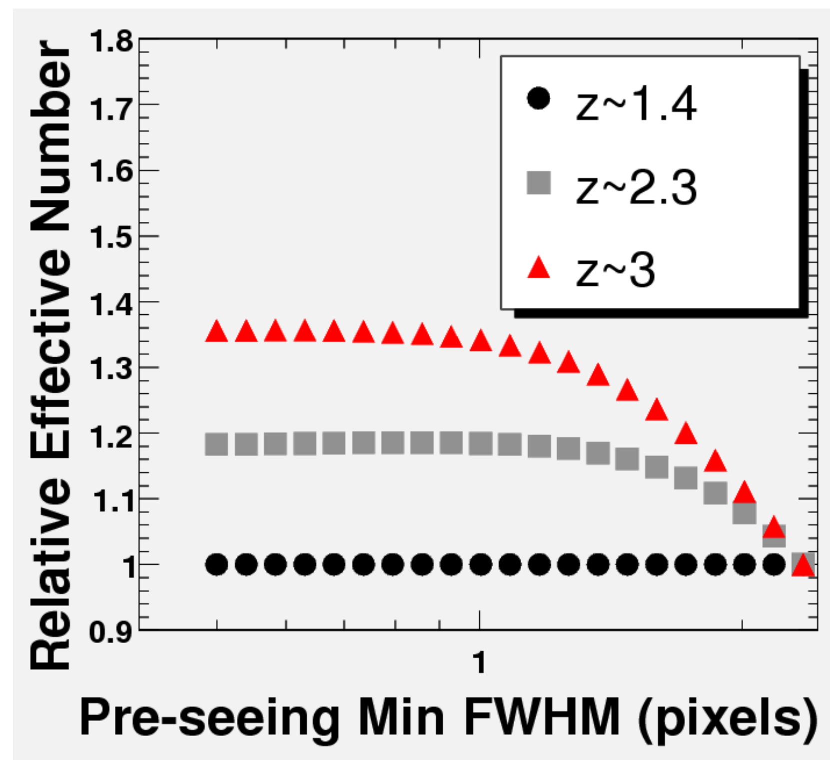
Solid: redshift survey in DLS Field 2

Dotted: redshift survey from previous example.

MultiFit Analysis of Full Dataset
(Chris Roat)



- PSF estimation errors random, not systematic
- Weights better-seeing images properly
- Also testing shapelet version from Bernstein, Rusin & Nakajima (U. Penn)
- Appears computationally feasible for LSST



To-do list

Shear-selected clusters:

•mass calibration of all clusters
•mass vs. X-ray luminosity and temperature: different from X-ray selected samples?
•mass vs. optical luminosity: different from optically-selected samples?
•improve shear selection: tomographic filter
•extend sample to 20 deg^2 (in progress)
•investigate offsets

Cosmic shear:

•Finish PSF anisotropy correction. Upgrade to Jarvis & Jain PCA method (in progress).
•Better shape measurements: MultiFit
•Cosmological parameters

Summary

•The first-ever shear-selected sample of clusters! astro-ph/0507606. Small (8+) but growing. Currently improving sample via tomographic filter.

•Full comparison with optically-selected DLS sample and X-ray followup data in progress. Spitzer observations underway to determine stellar mass.

•Cosmic shear redshift evolution is detected. Currently working on established and new tests of systematics.

•Watch for upcoming data release.