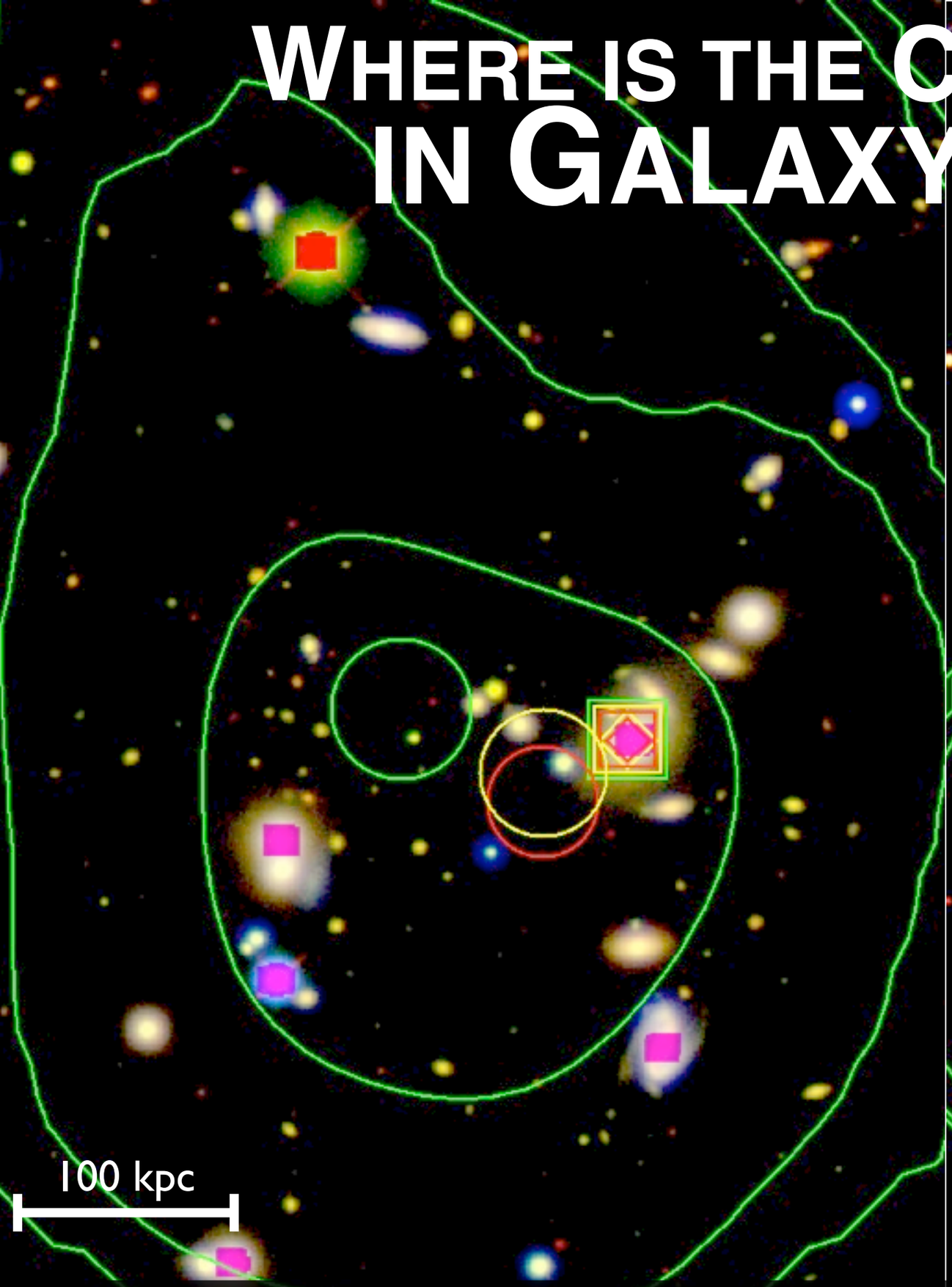
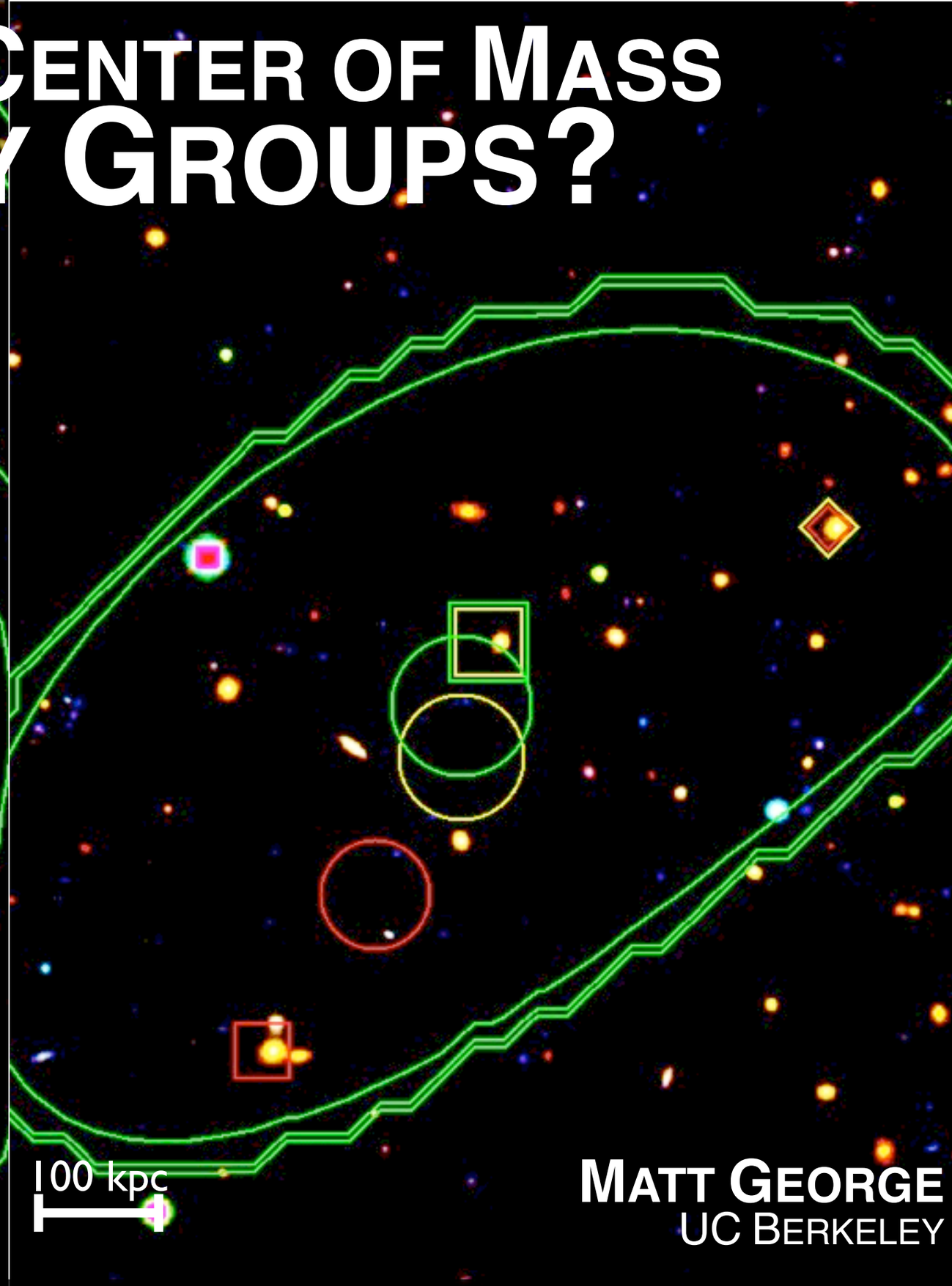
Where is the Center of Mass in Galaxy Groups?



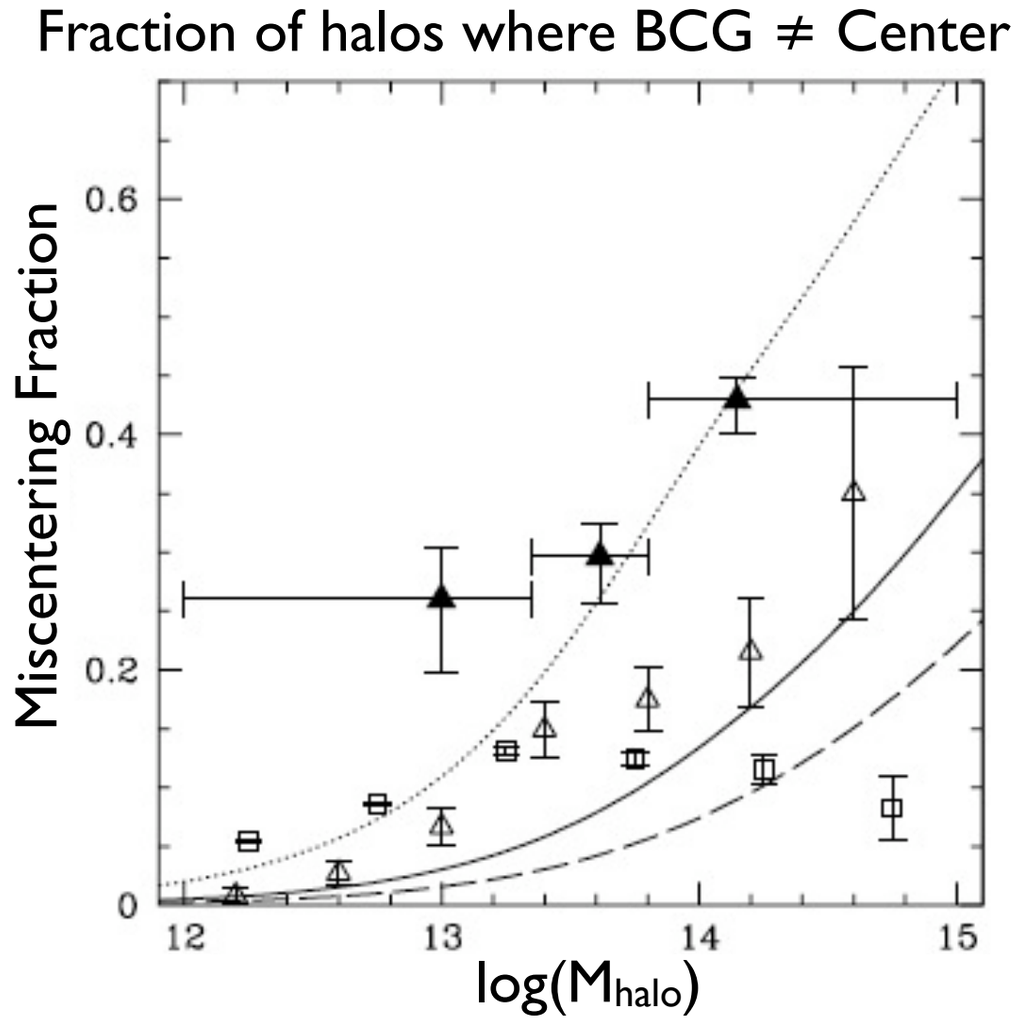


Matt George
UC Berkeley

with Alexie Leauthaud, Kevin Bundy, Jeremy Tinker, Peter Capak, Alexis Finoguenov, Olivier Ilbert, Simona Mei and the COSMOS Collaboration

Motivation for Finding Centers

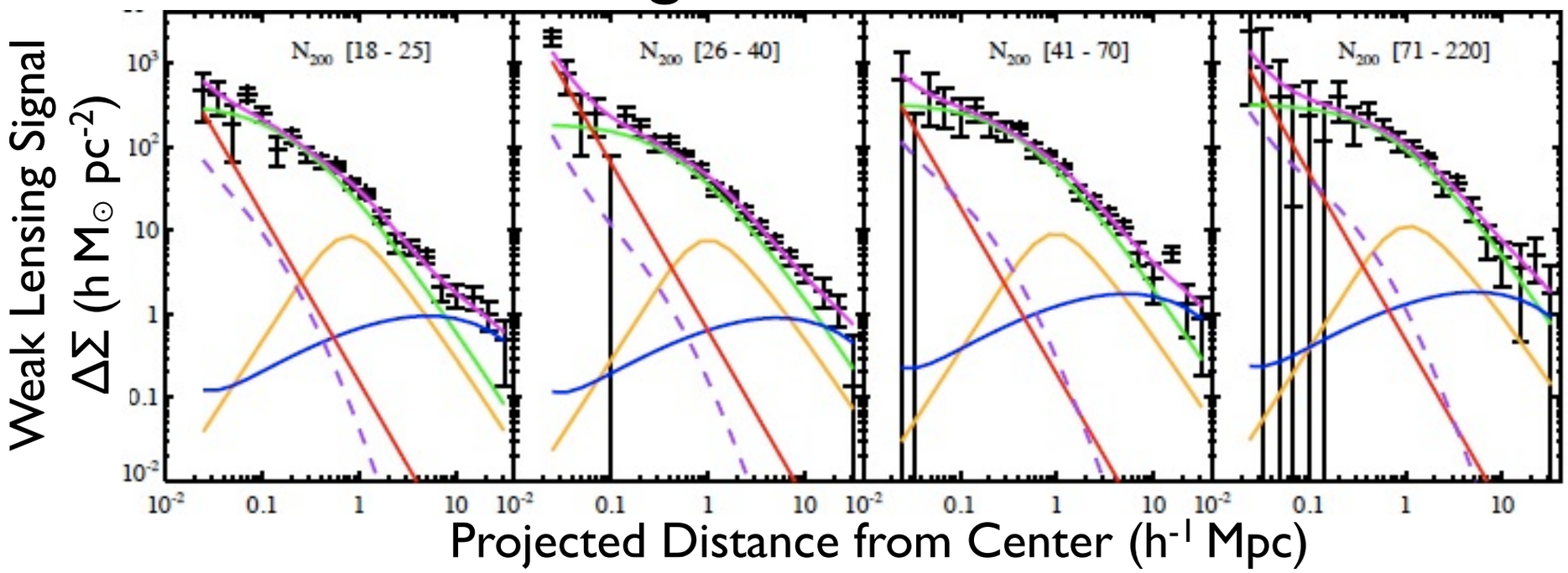
- BCG properties and galaxy evolution
- Cluster finding
- Mass determination
  - satellite kinematics
  - gravitational lensing
- Halo occupation models
- Sloshing and ICM heating
- Measuring mass-concentration and intrinsic alignments



Skibba et al. 2010

MaxBCG

Increasing richness ⟶

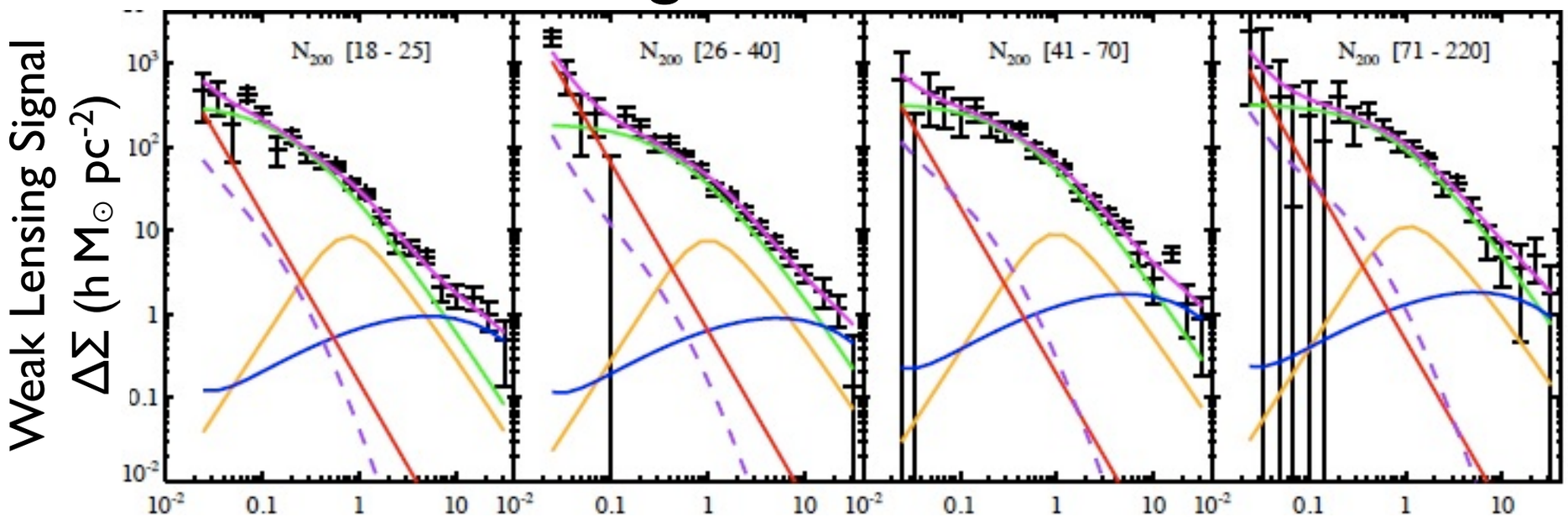


Model components:
NFW
Offset NFW
BCG
Neighboring halos
Non-weak shear
Total

Johnston et al. 2010

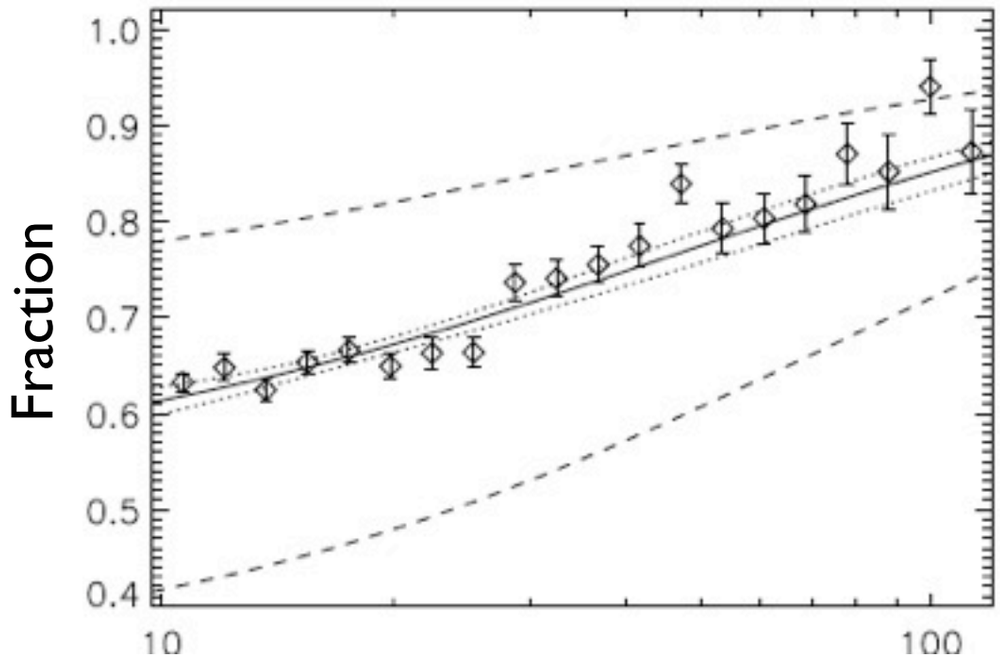
MaxBCG

Increasing richness ⟶

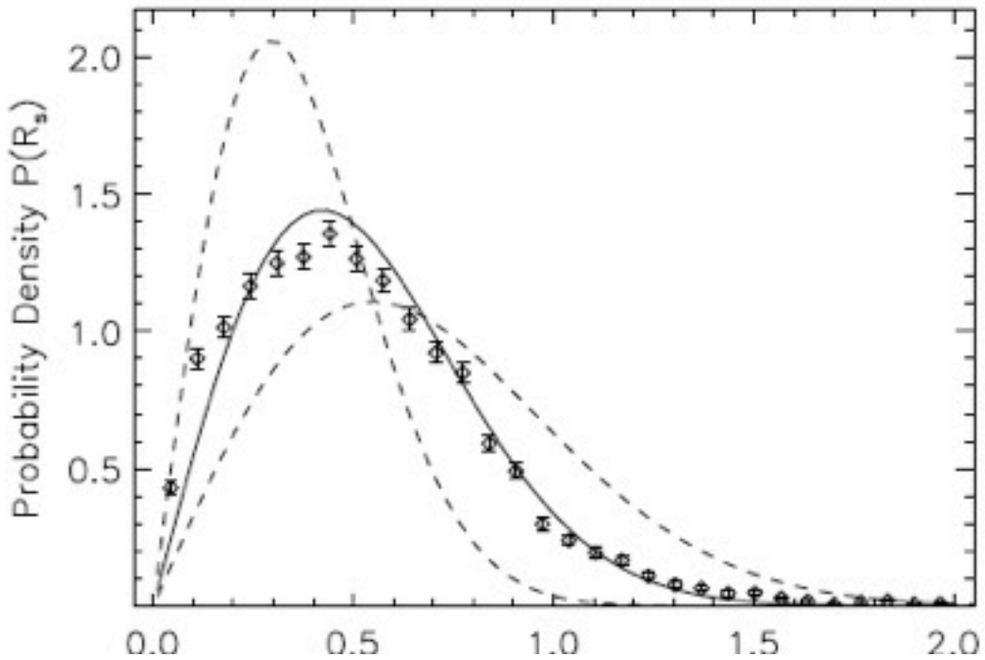


Model components:
NFW
Offset NFW
BCG
Neighboring halos
Non-weak shear
Total

Fraction of Groups with Correct Center



Distribution of Offsets from True Center



Johnston et al. 2010

COSMOS: A panchromatic survey

HST-ACS
I814W

Spitzer MIPS
160, 70, 24 μm

VLA
20 cm

XMM
0.5 -10 keV

Magellan - IMAX

VLT-VIRMOS

Spitzer IRAC
8, 6, 5, 4, 3 μm

IRAM -30m
1.2 mm

CFHT Megacam
u, i**

CFHT Wircam
K

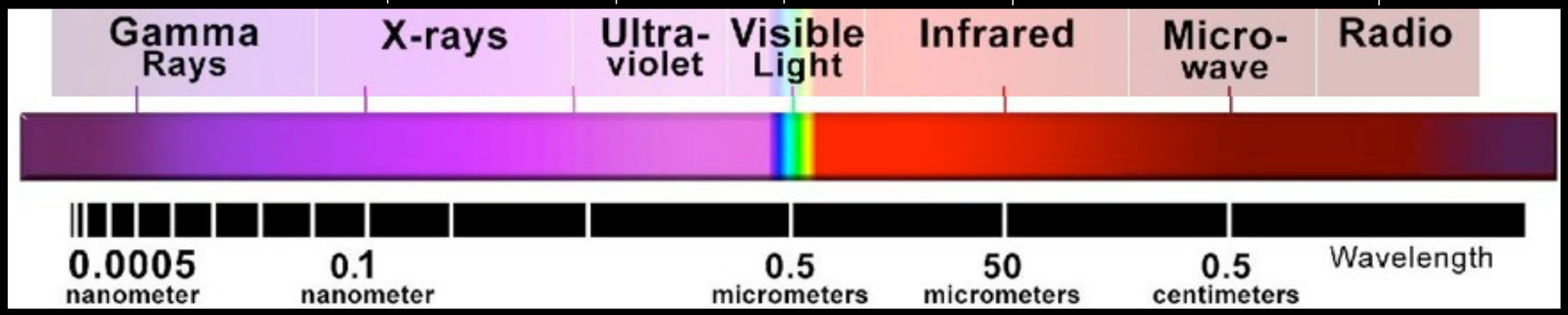
CHANDRA

GALEX
FUV, NUV

Subaru SCam
B,V,r',i,z', NB816

NOAO
Ks

CSO Bolocam
1.1 mm



COSMOS: A panchromatic survey

X-ray group selection

XMM
0.5 -10 keV

CHANDRA

GALEX
FUV, NUV

HST-ACS
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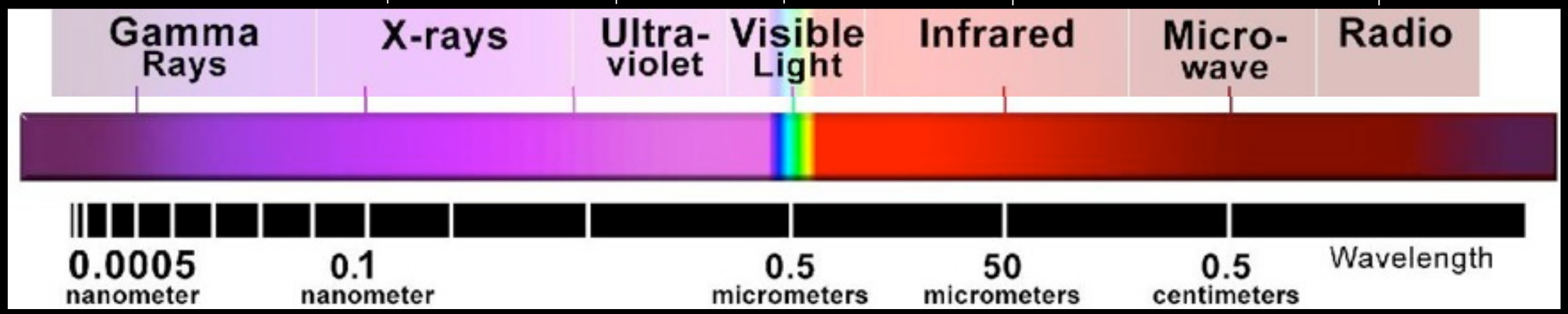

COSMOS: A panchromatic survey

ACS imaging for lensing

X-ray group selection

XMM
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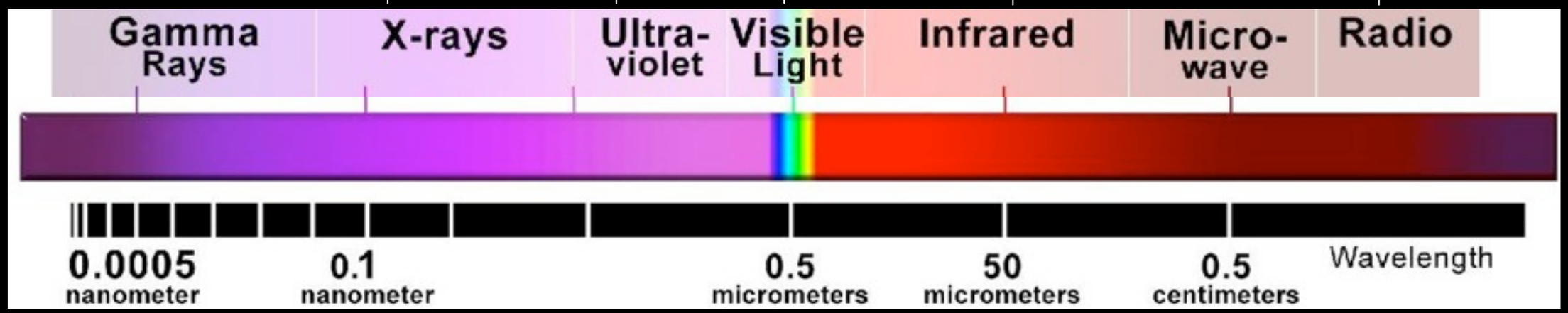

COSMOS: A panchromatic survey

UV/Opt/IR SEDs for photometric redshifts and stellar masses

ACS imaging for lensing

X-ray group selection

XMM
0.5 -10 keV

CHANDRA

HST-ACS
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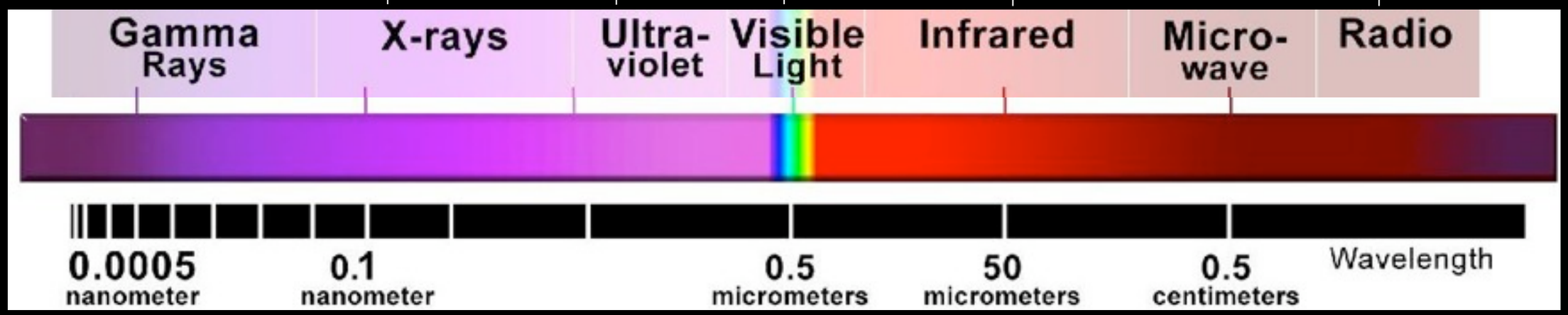
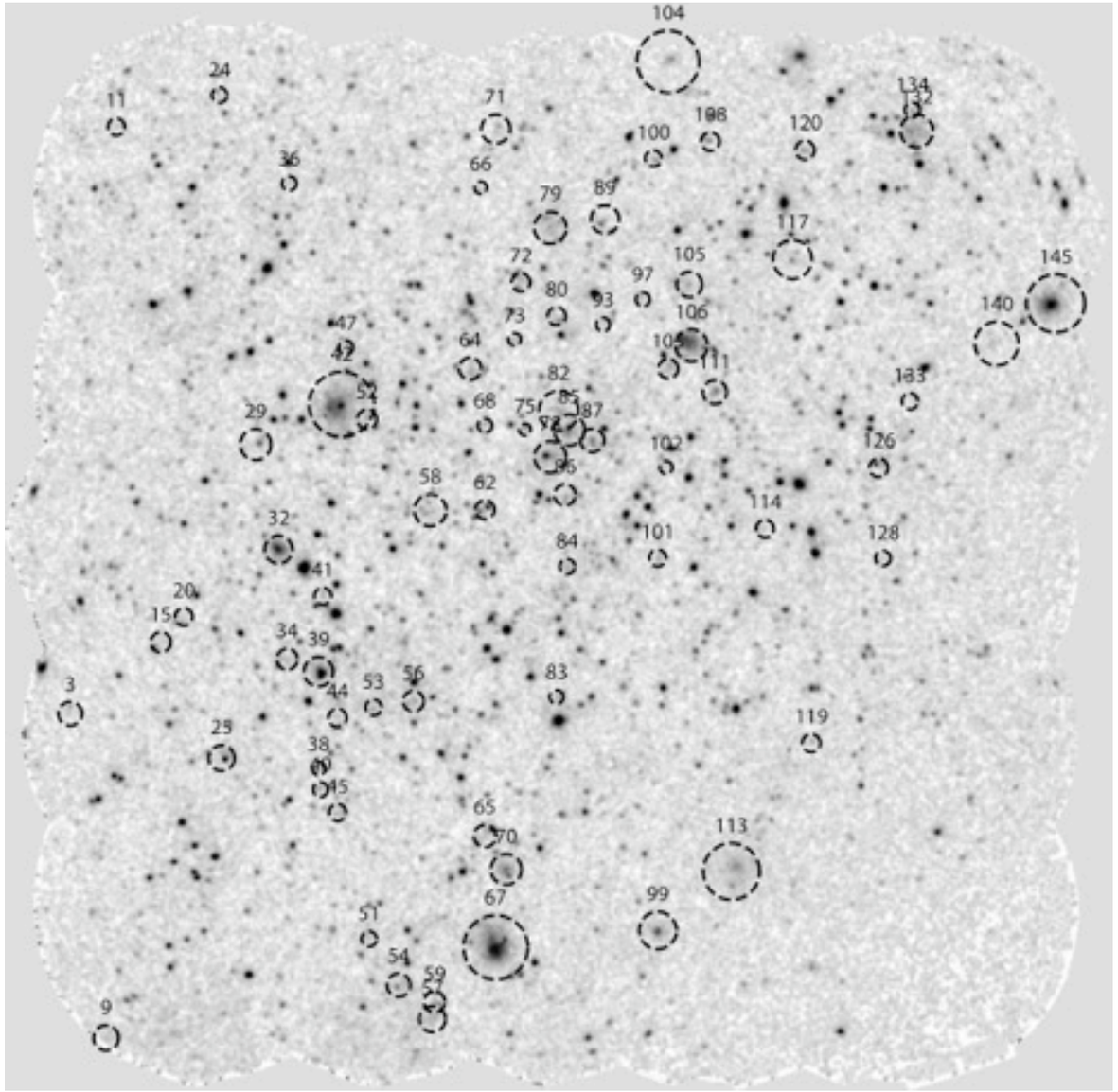
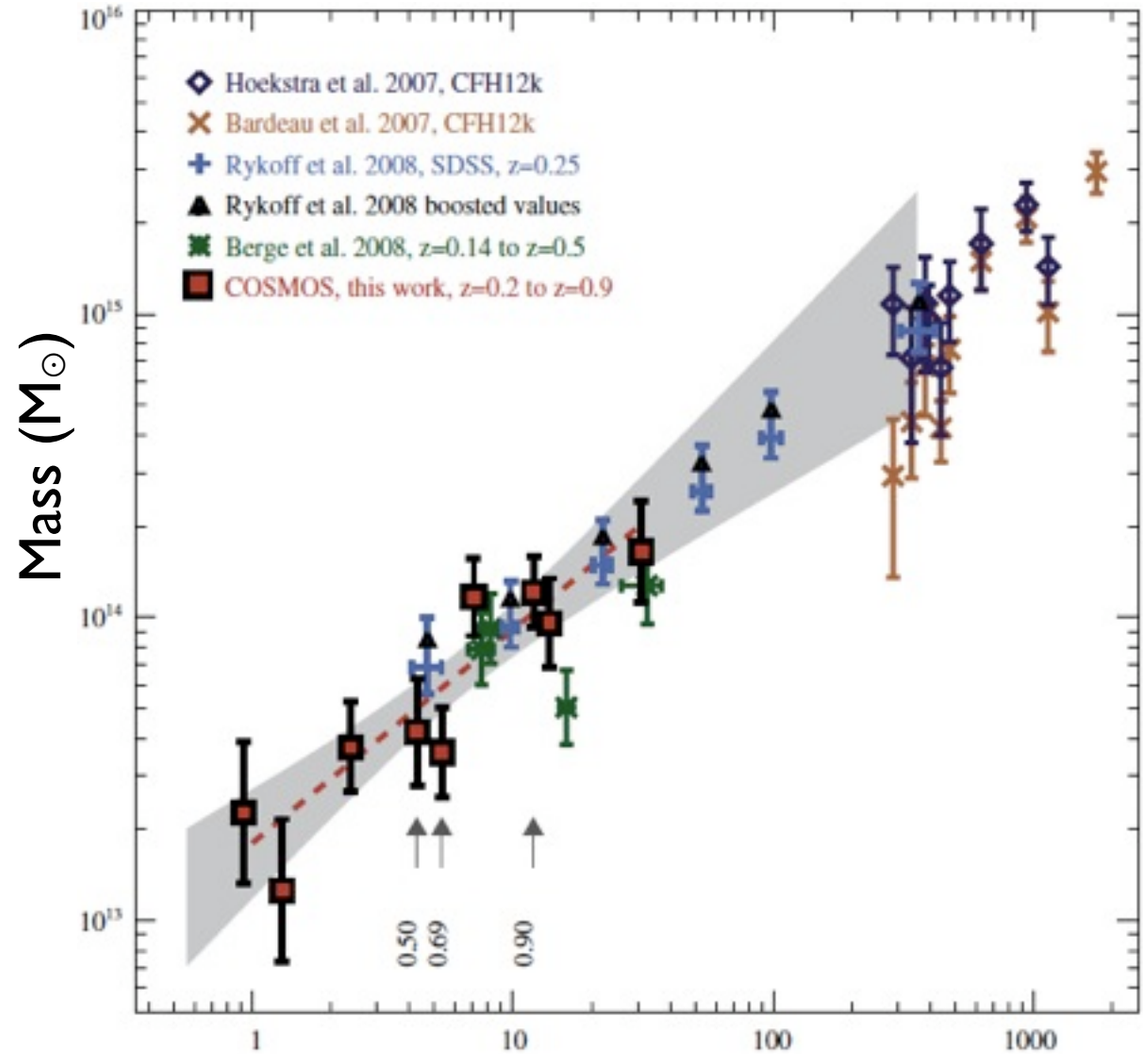


X-ray Selected Groups



Finoguenov et al. 2007 (+2010 in prep)

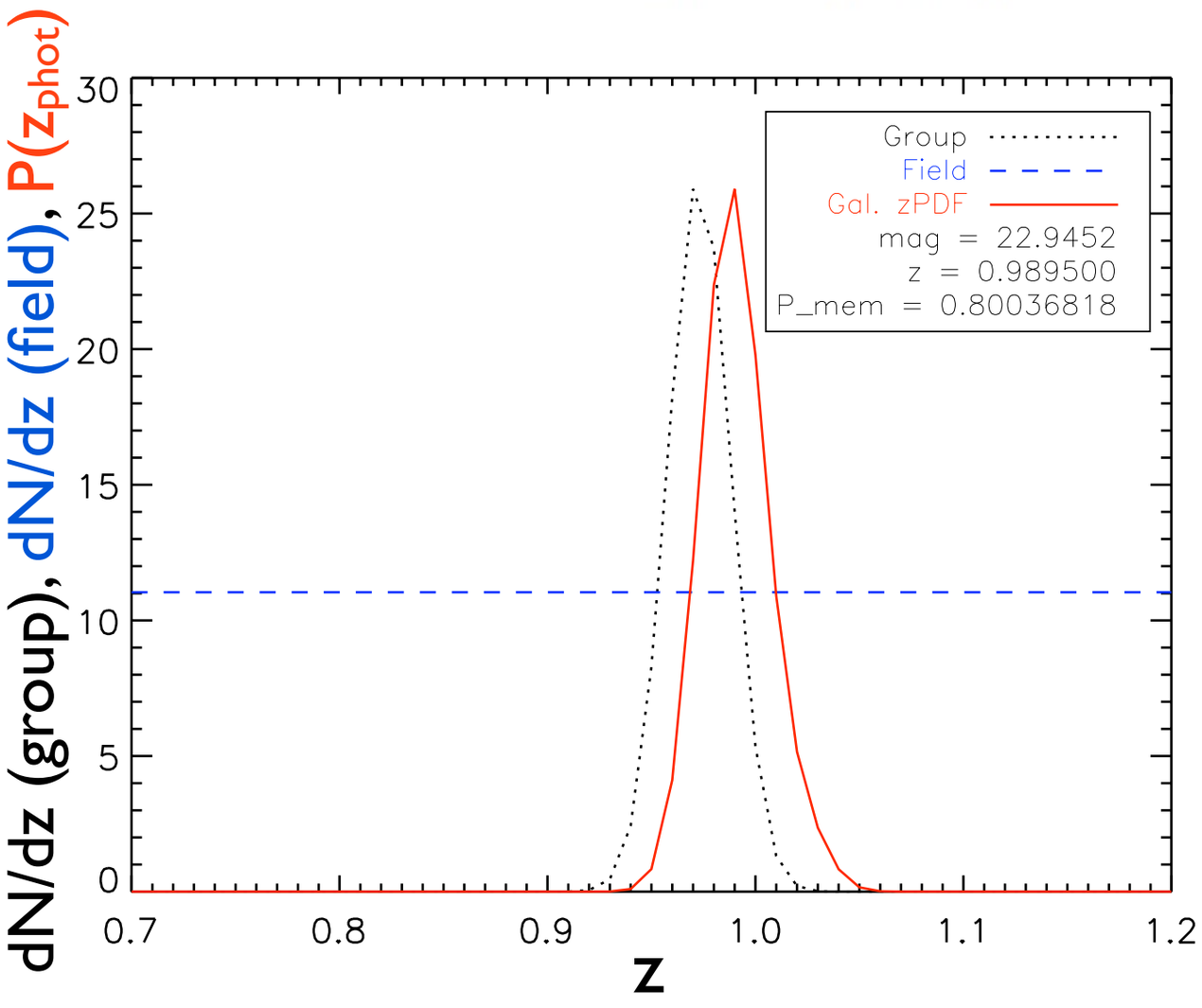


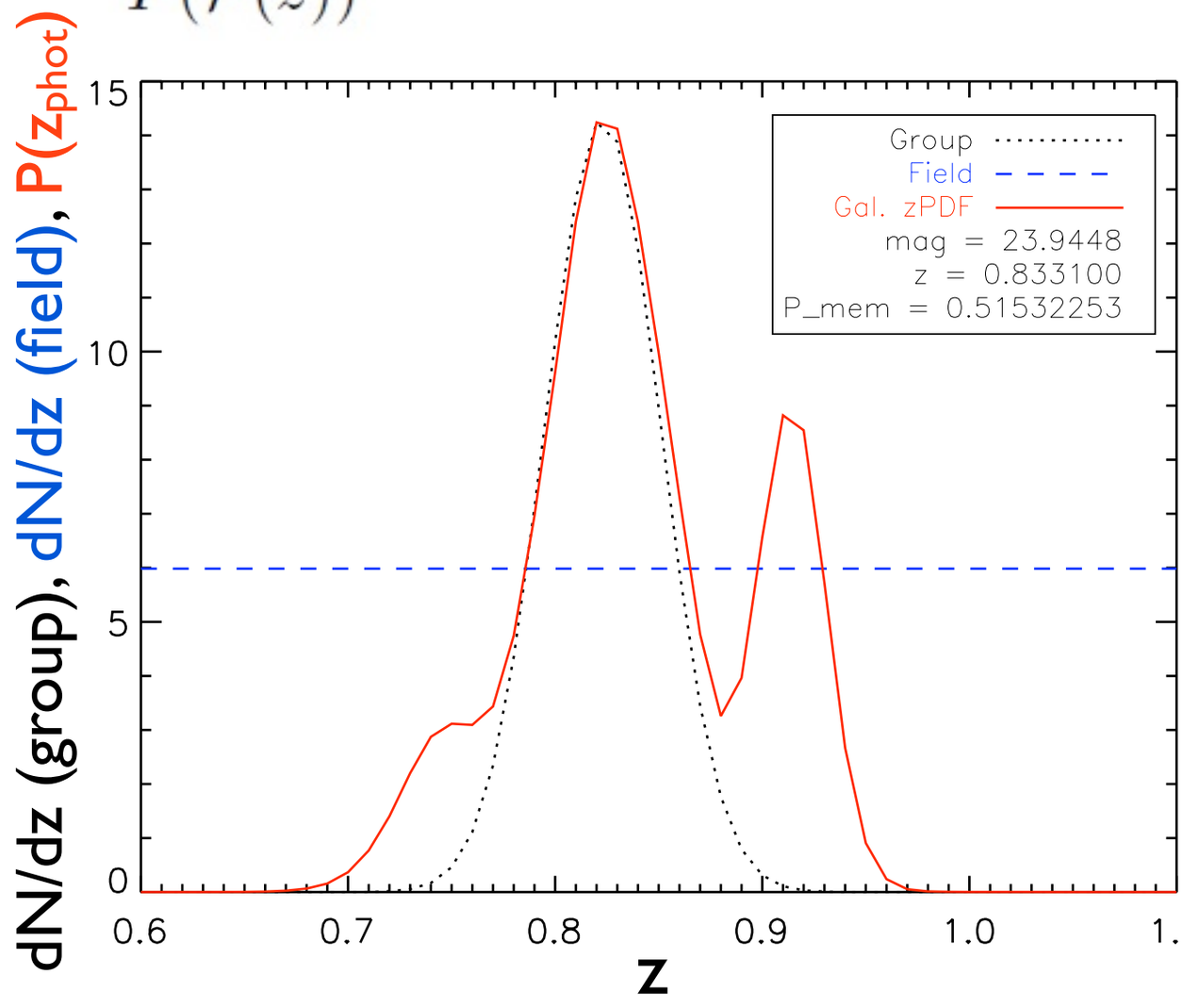
Leauthaud et al. 2010

- X-ray position gives RA, Dec (uncertain by up to 32")
- Red sequence overdensity gives z, refined w/ spectroscopic z
- M_{WL}-L_X relation gives radius assuming a mass-conc. relation
- Remove groups with possible projections or overlap

Member Selection with Photometric Redshifts

$$P(g \in G|\mathcal{P}(z)) = \frac{P(\mathcal{P}(z)|g \in G)P(g \in G)}{P(\mathcal{P}(z))}$$

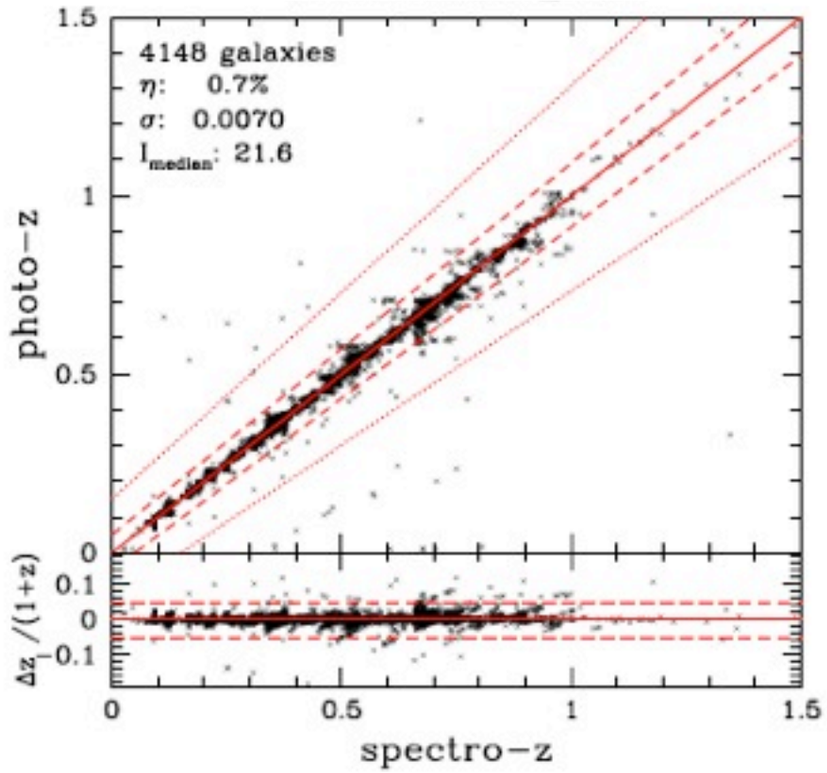




Identify members using photoz probability distribution
+ measured field/group densities

Photometric Redshifts

- Photometry in 31 UV/Opt/IR bands
- $\sigma(z_{spec}\text{-}z_{phot}) \approx 0.01$ for $m_i < 24$
- ~94000 galaxies with $0<z<1$, $m_{F814W} < 24.2$
- ~3500 total members in 120 groups
- PDF gives good estimate of redshift uncertainty



Ilbert et al. 2009

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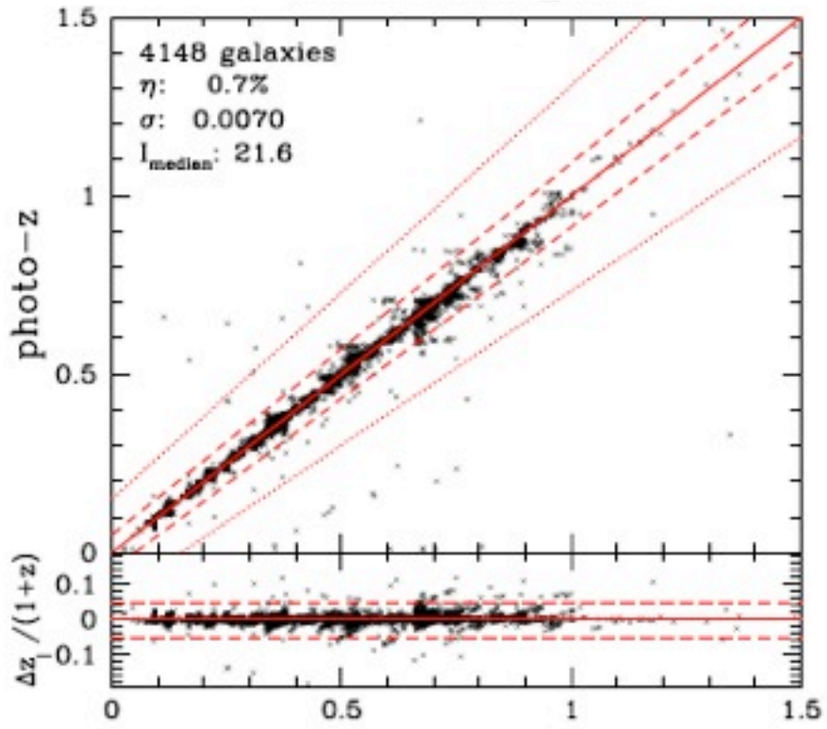
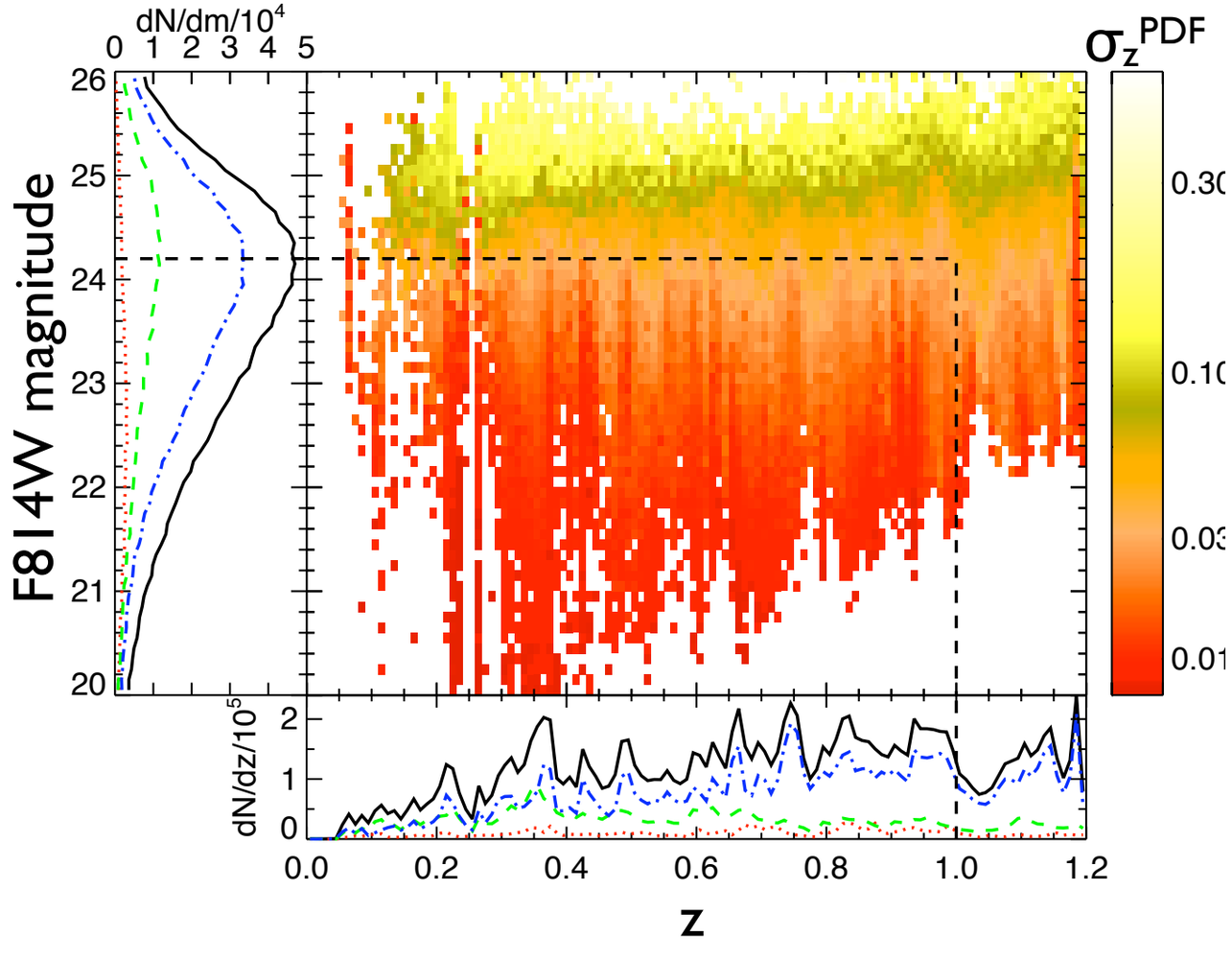
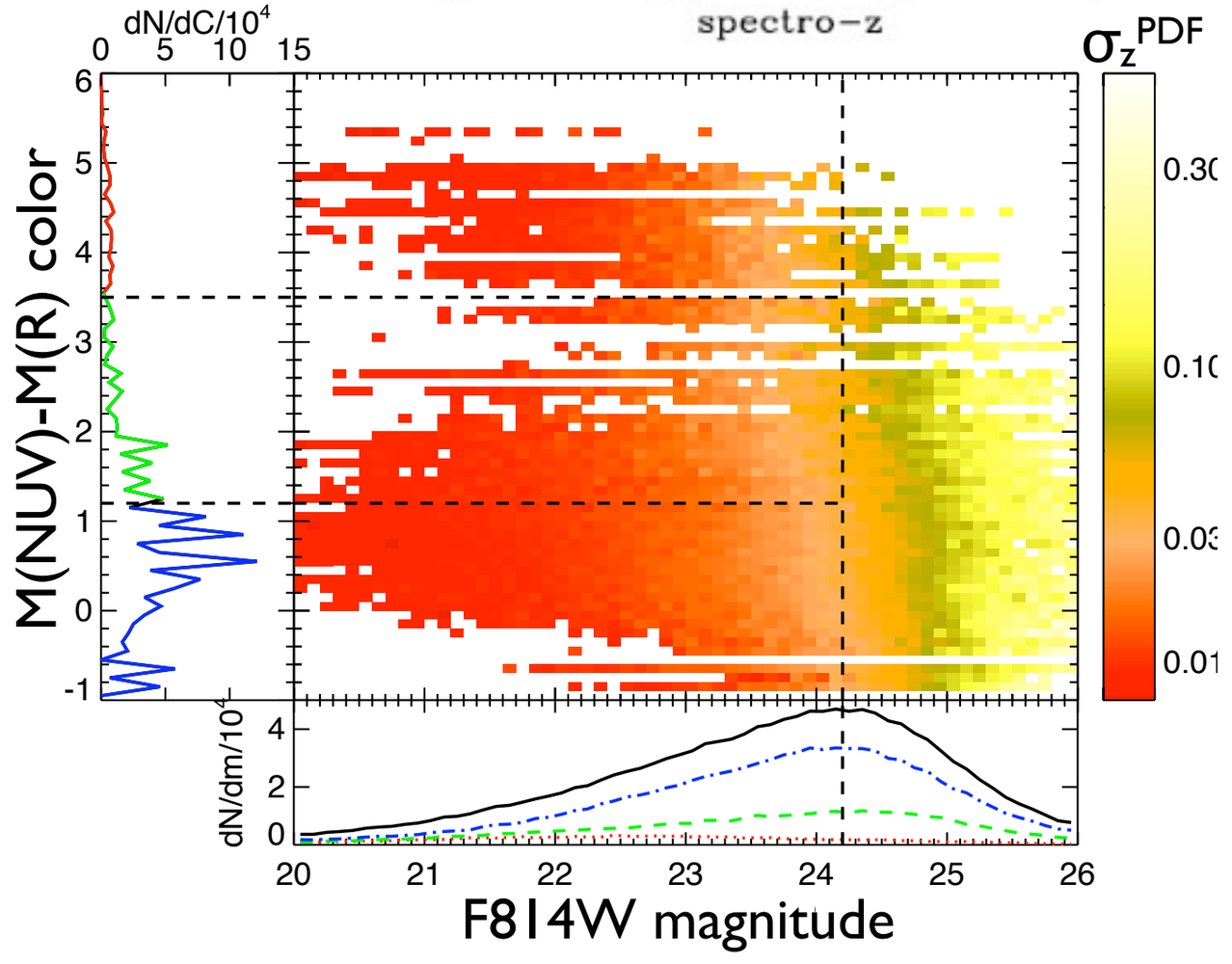


Ilbert et al. 2009





Characterizing the Member Selection

Test purity and completeness using spectroscopic redshifts

~20% of photoz-selected members have spectra

"Spectroscopic member" ≡ $|z_{gal}-z_{group}| < 0.005(1+z_{group})$

Purity = fraction of selected objects that are "members"

Completeness = fraction of "members" that are selected

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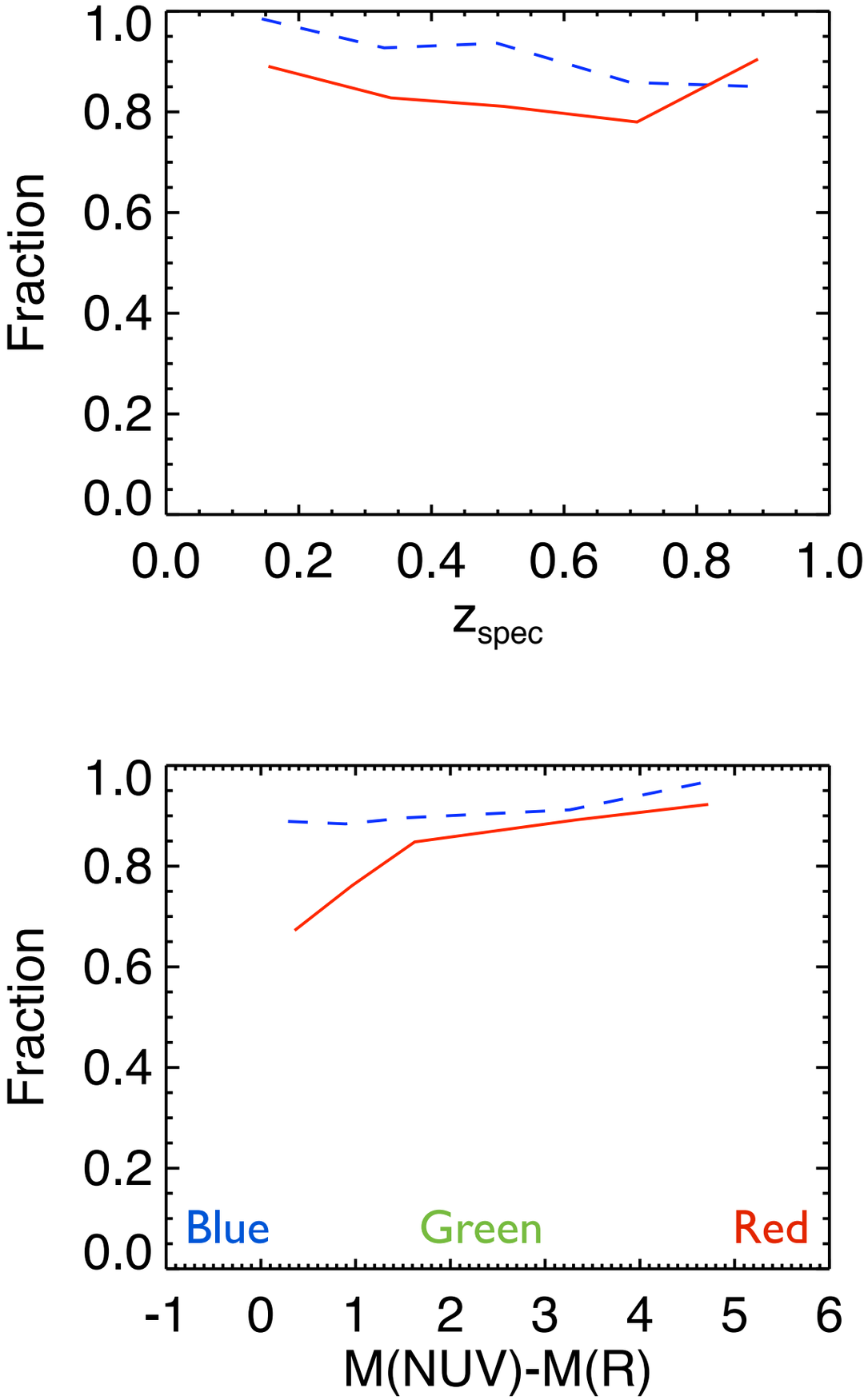
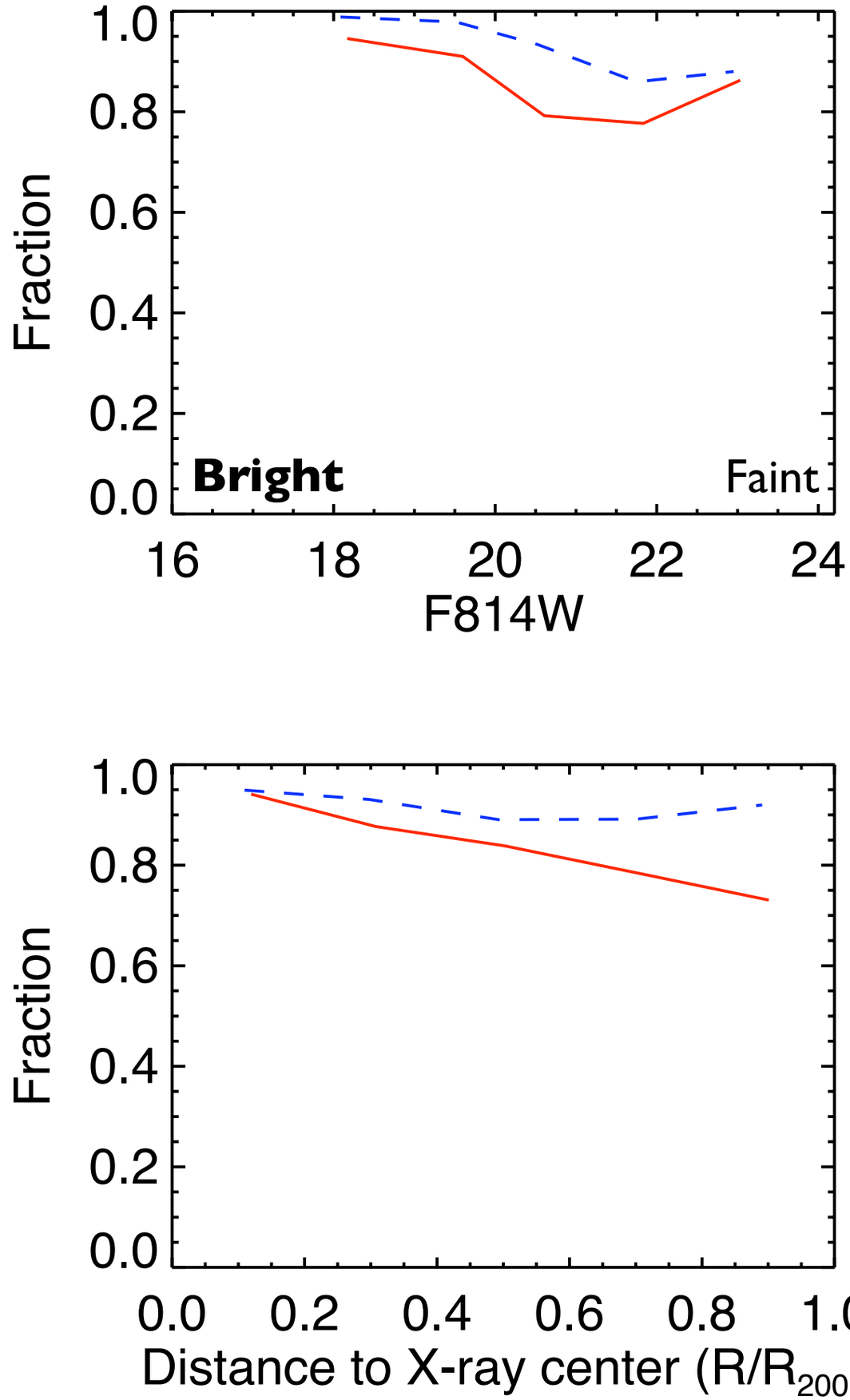
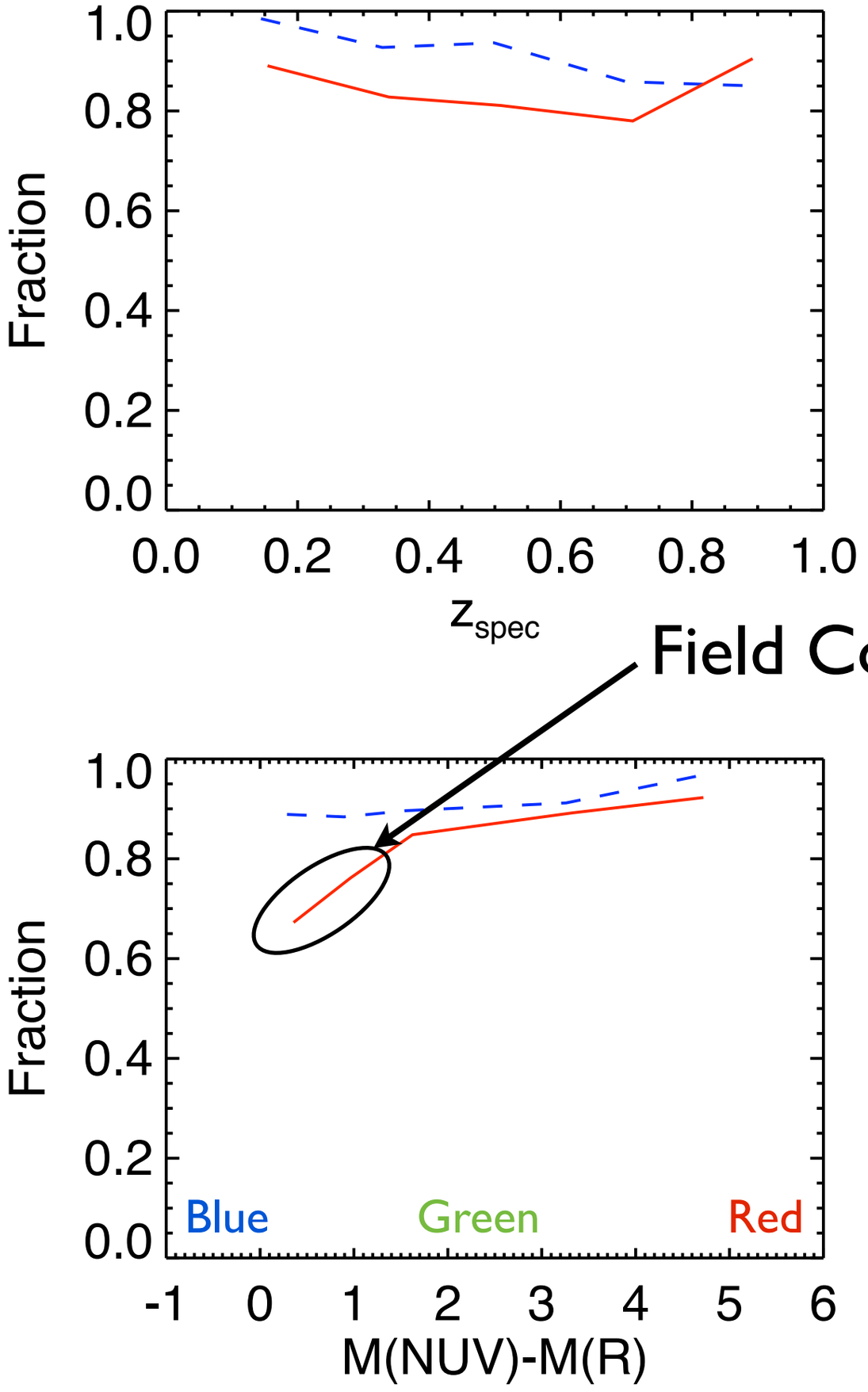
Caveats: membership criterion is ~3-5σ_v for groups
varying uncertainties for z_{gal} and z_{group}
mocks will improve our characterization of selection
(Peter Behroozi, Michael Busha, Risa Wechsler)

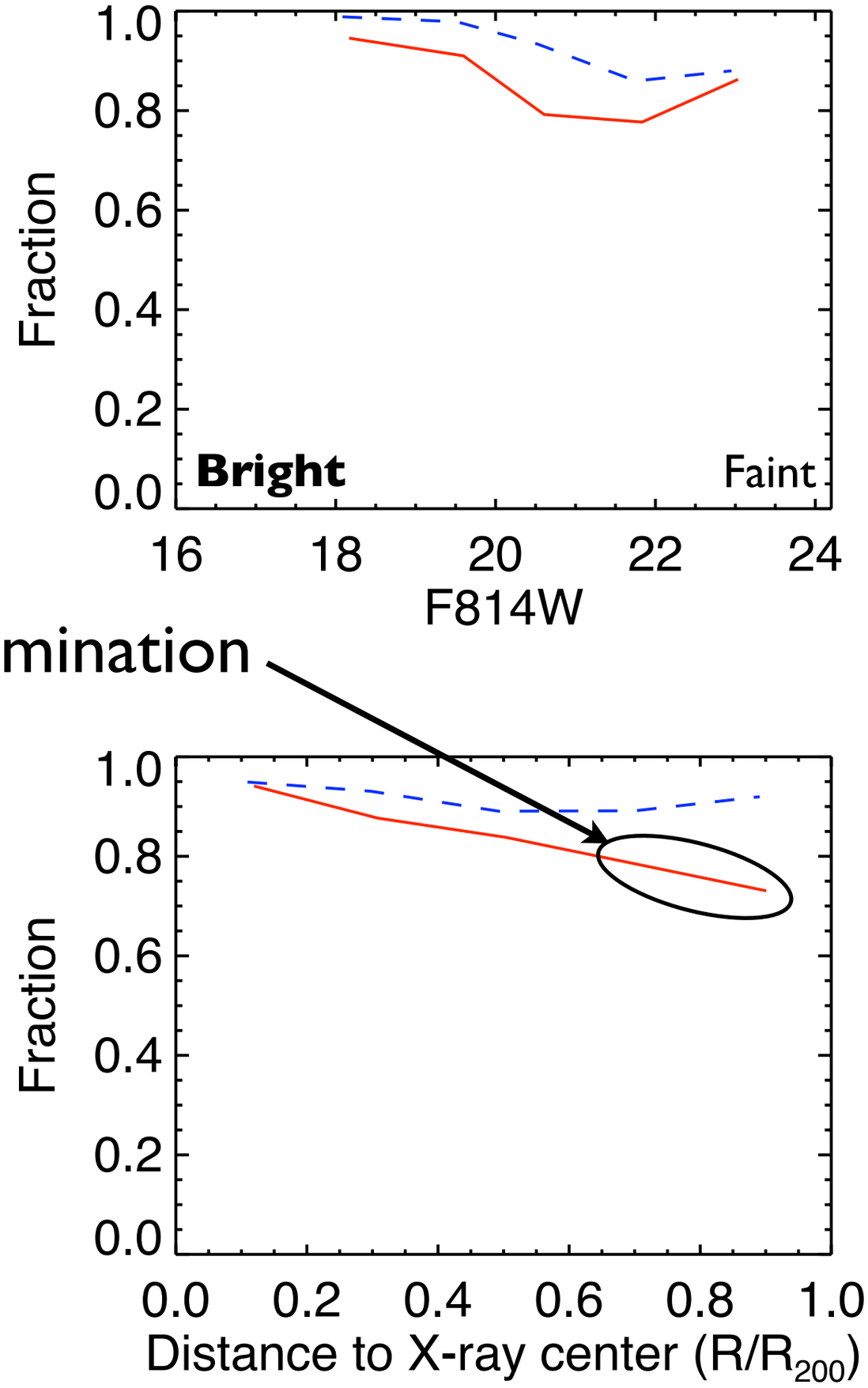
Purity and Completeness





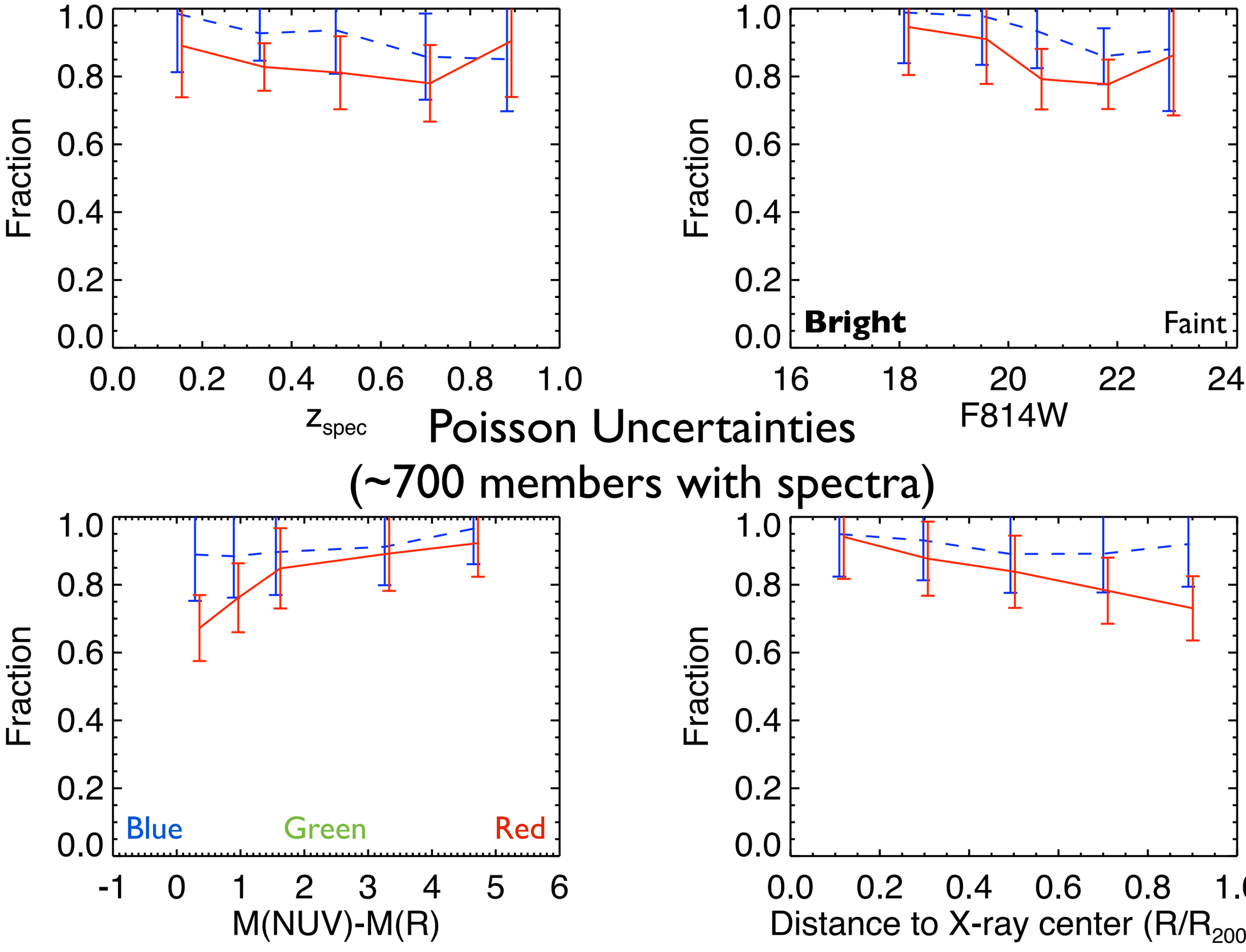
Purity and Completeness





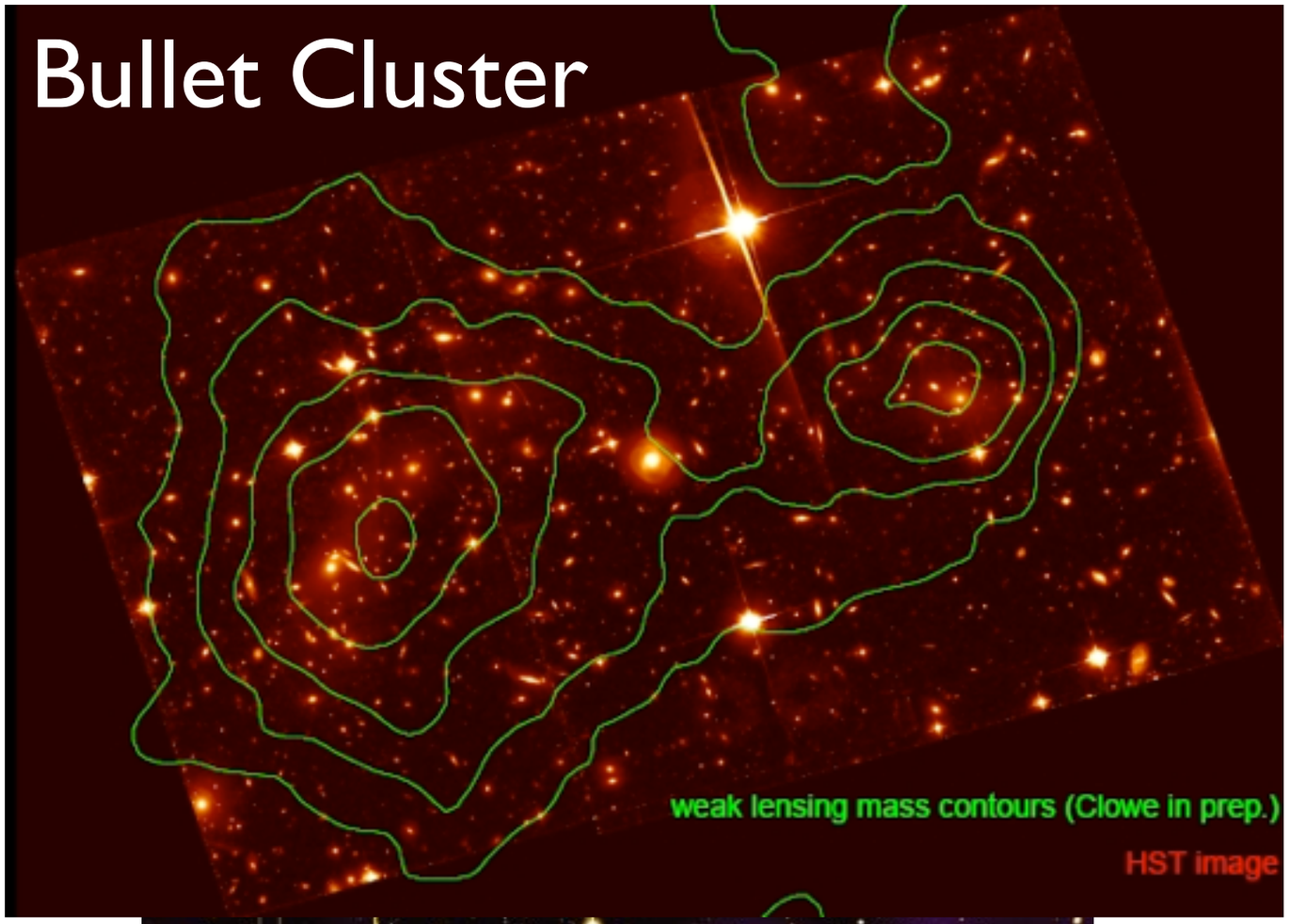
Field Contamination

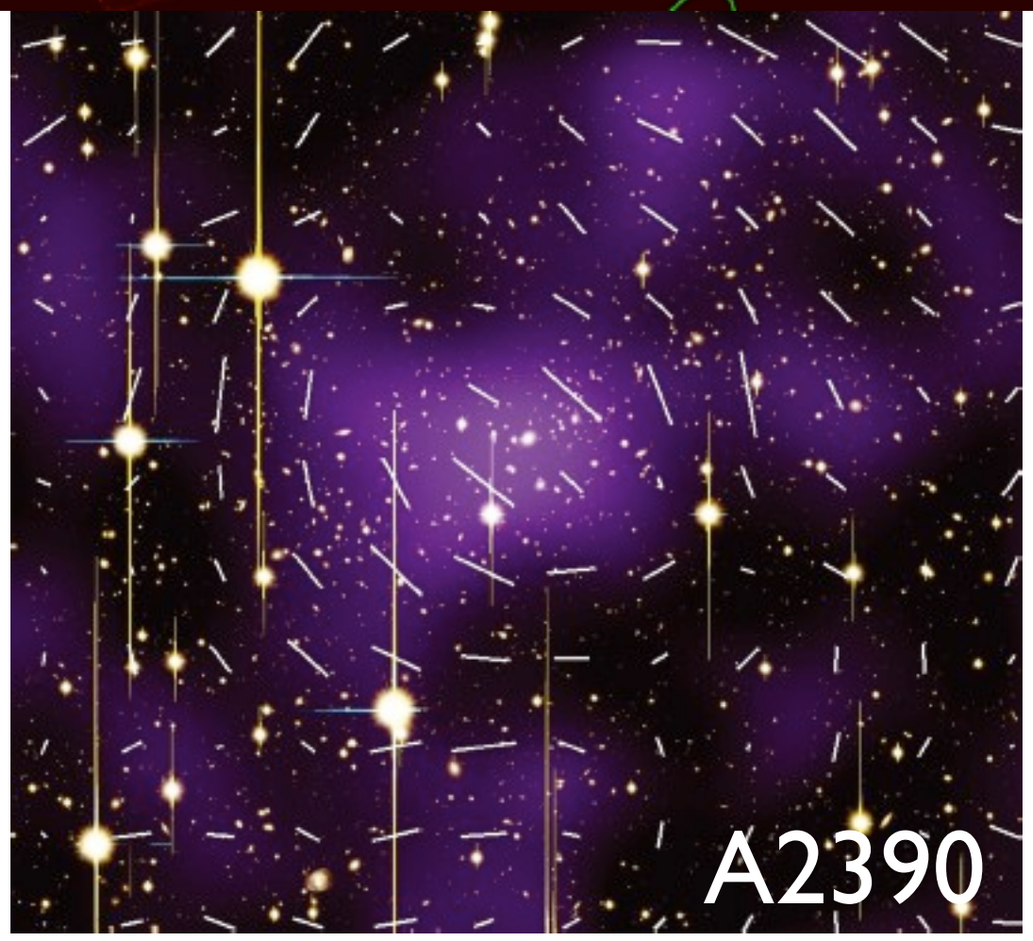
Purity and Completeness



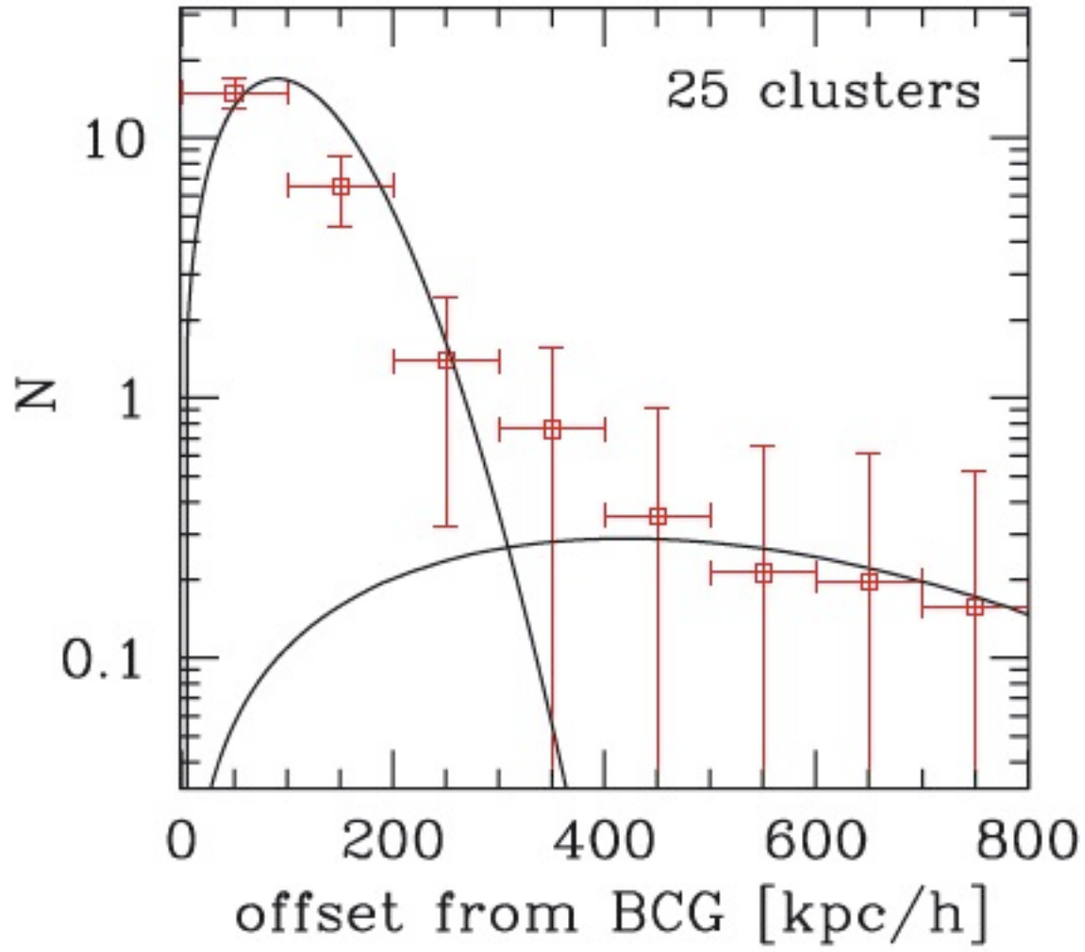
Poisson Uncertainties

(~700 members with spectra)





Finding Group Centers



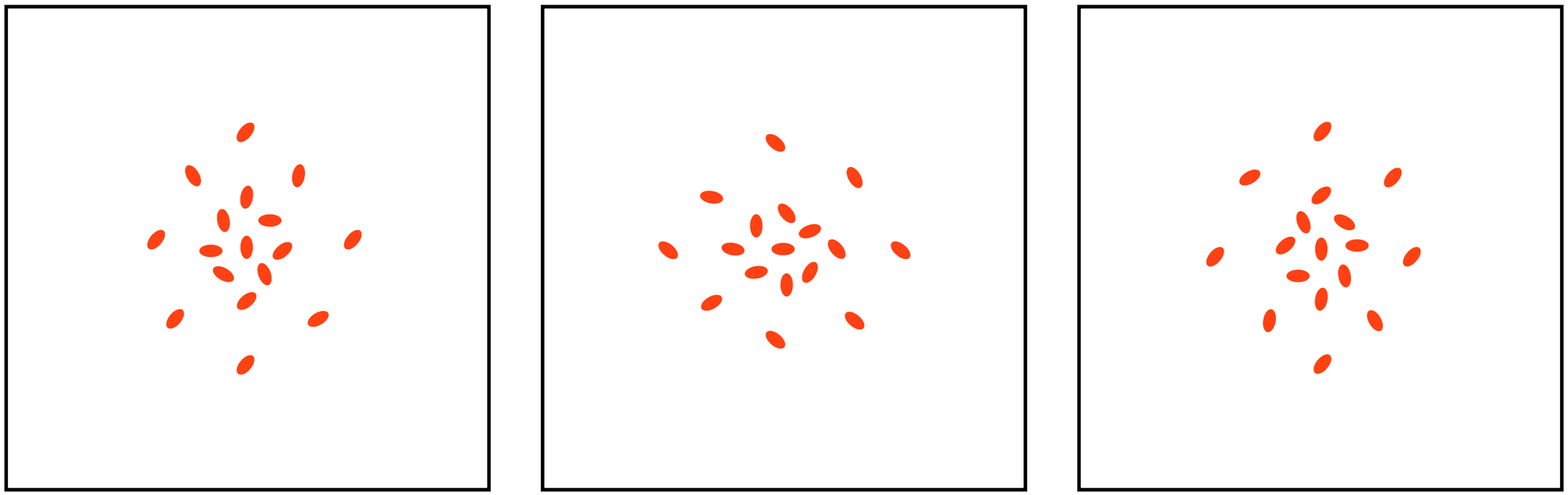
Oguri et al. 2010

Stacked Weak Lensing

Cluster 1

Cluster 2

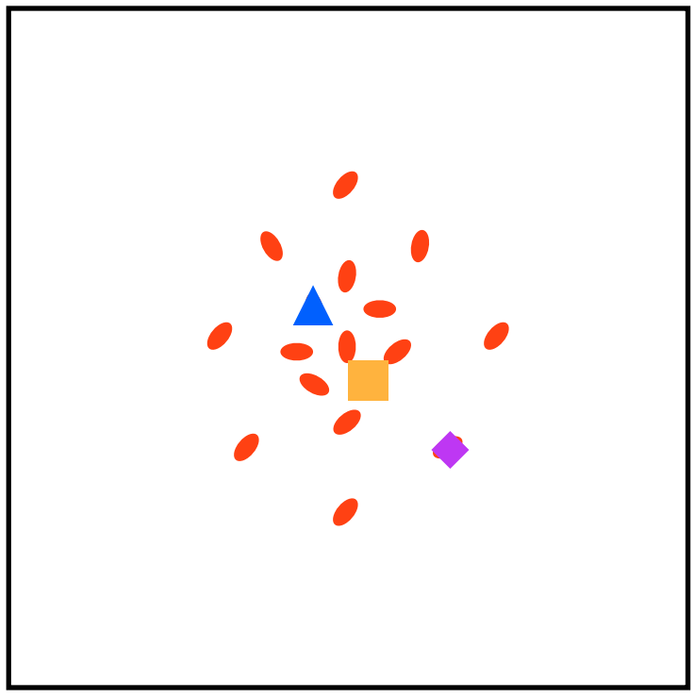
Cluster 3



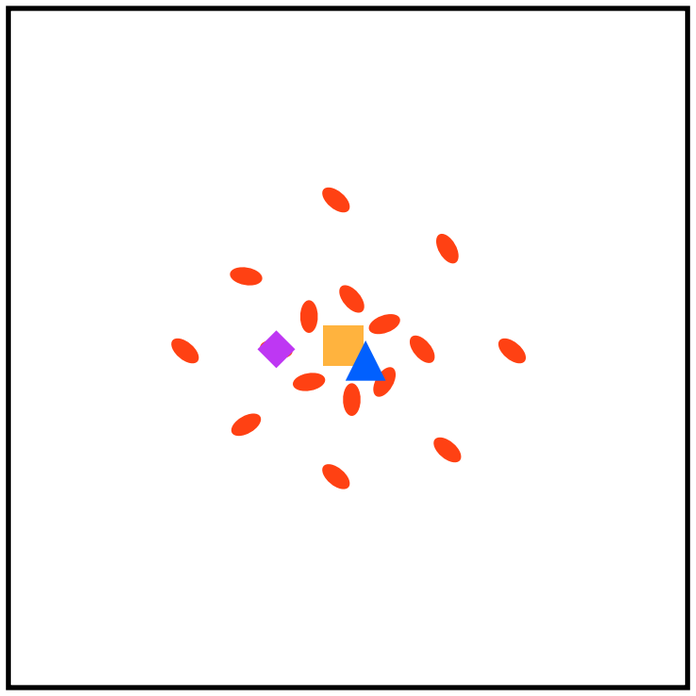
1. Find members ...

Stacked Weak Lensing

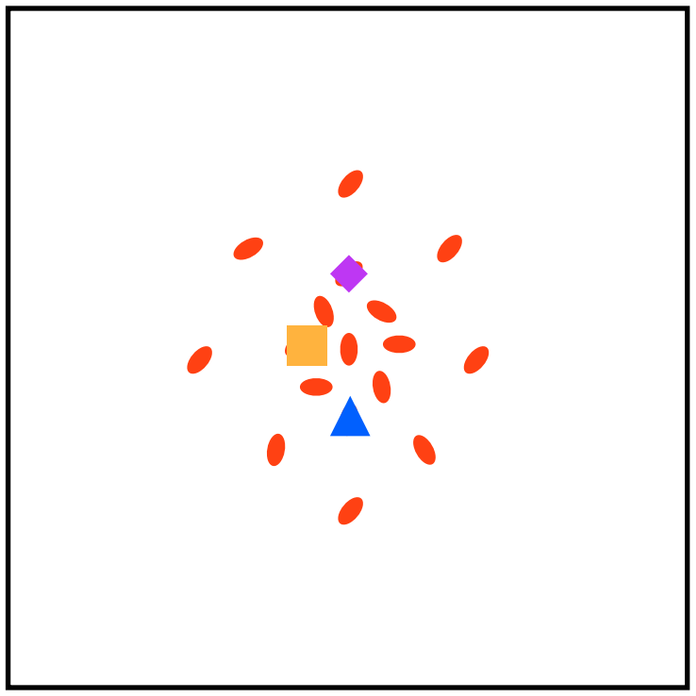
Cluster 1



Cluster 2



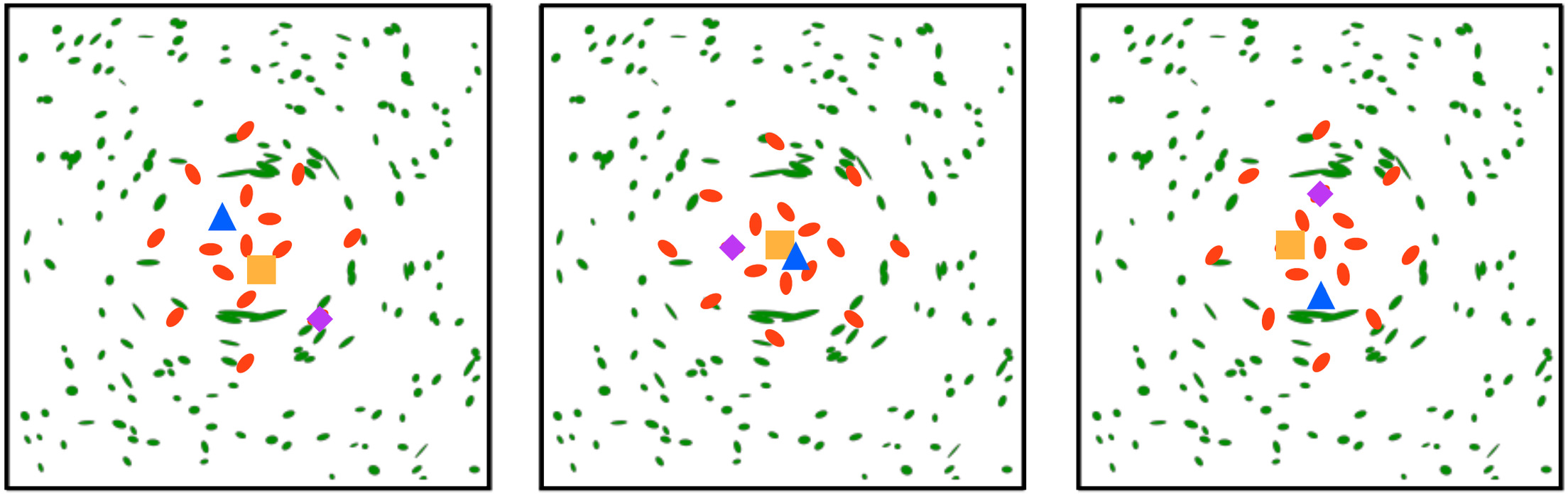
Cluster 3



1. Find members
2. Determine centers

Stacked Weak Lensing

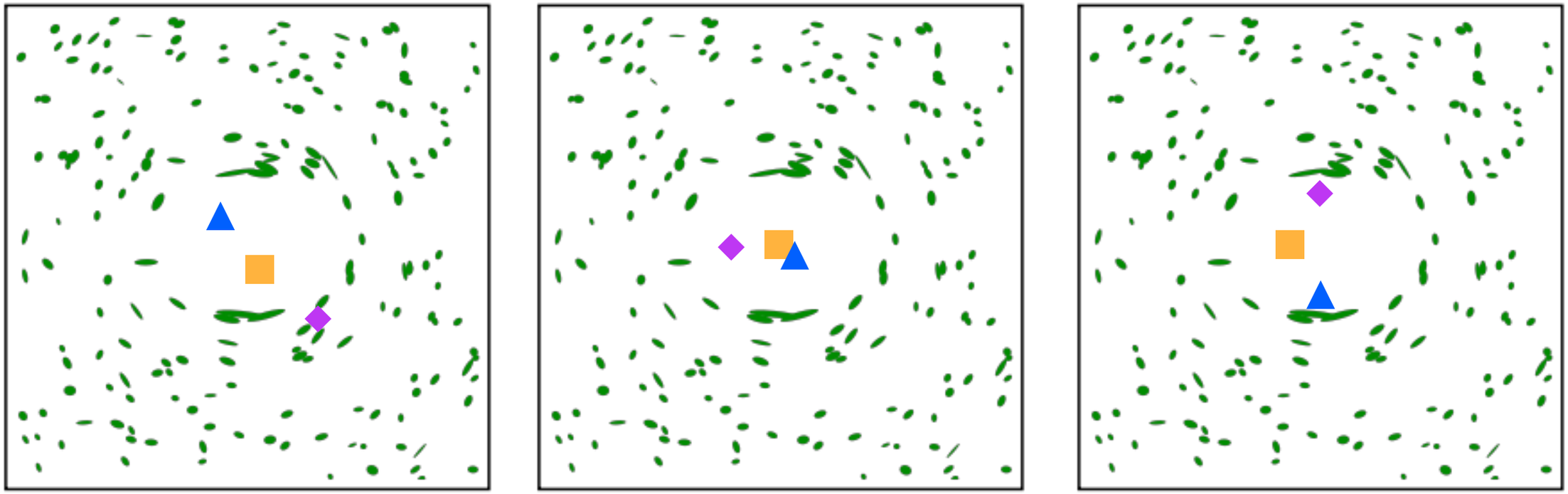
Cluster 1 | Cluster 2 | Cluster 3



1. Find members
2. Determine centers
3. Measure shapes of background sources

Stacked Weak Lensing

Cluster 1 | Cluster 2 | Cluster 3



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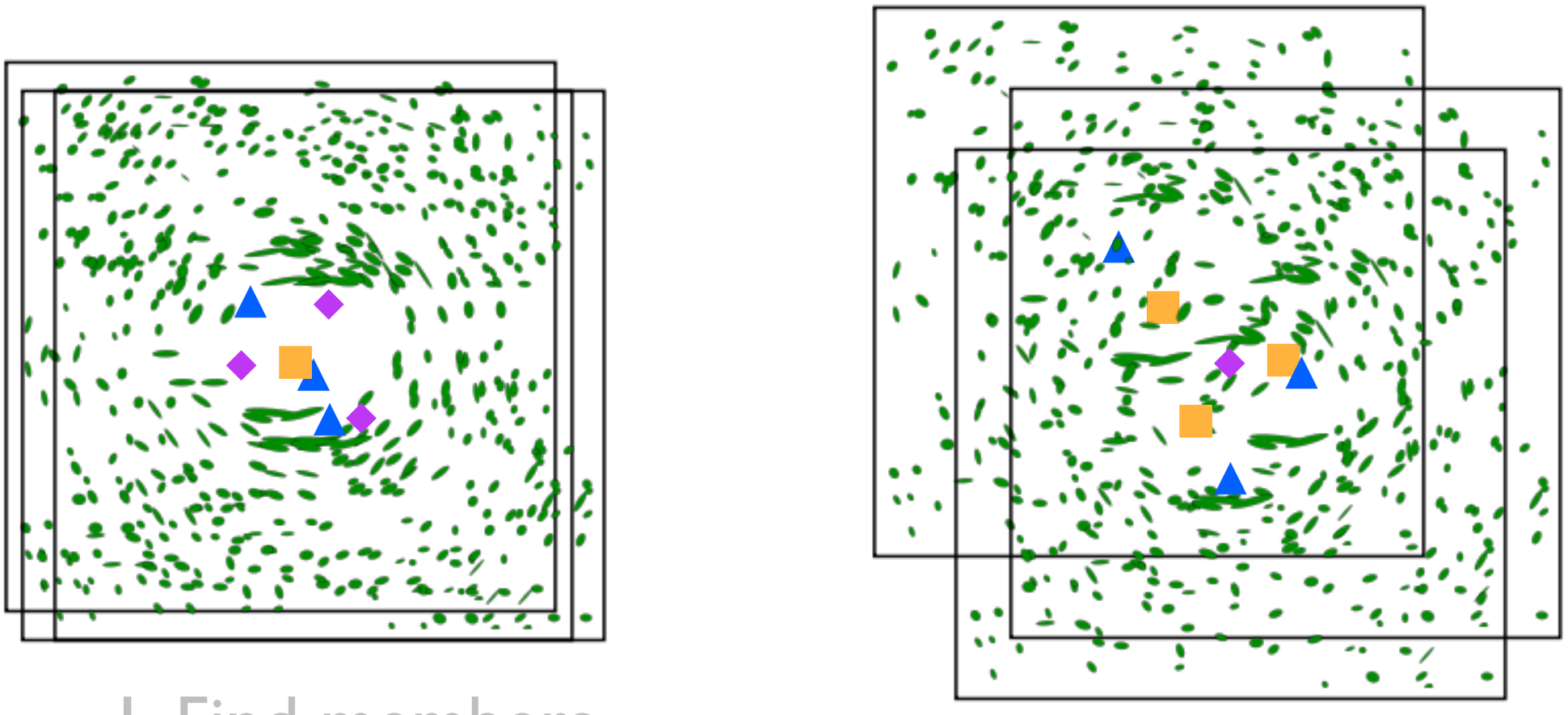
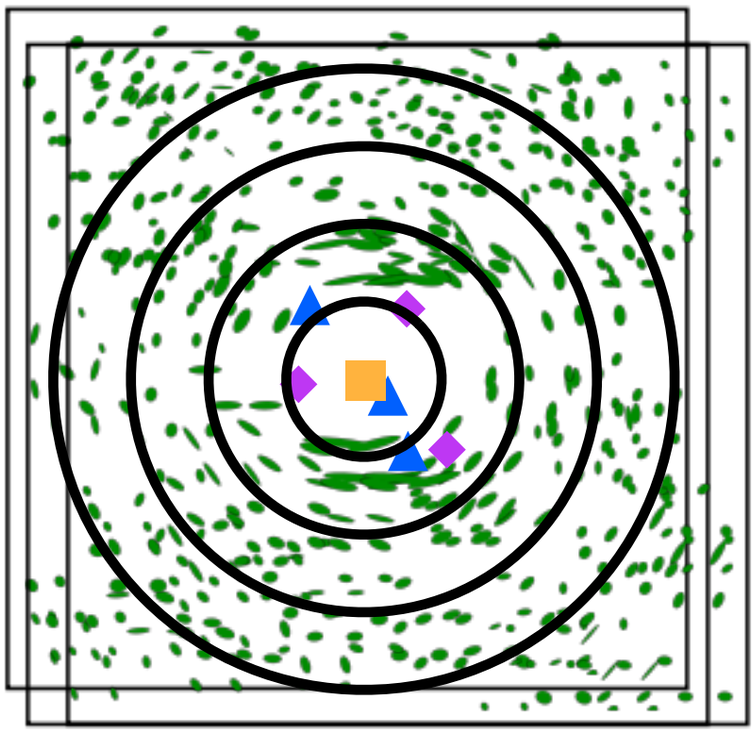


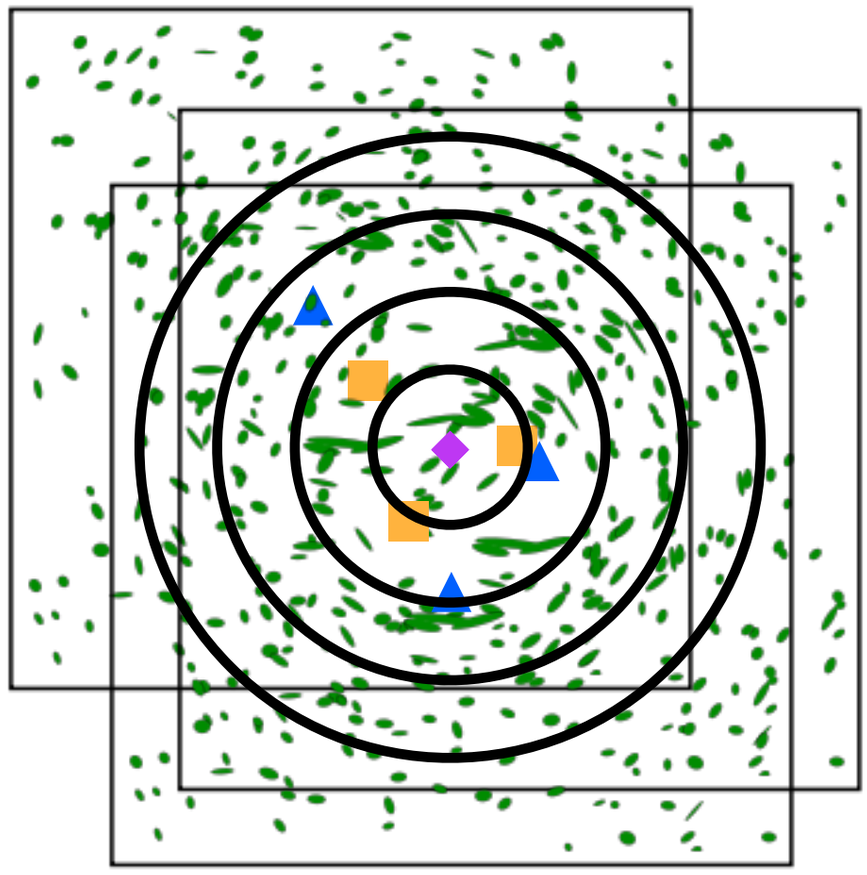
1. Find members
2. Determine centers
3. Measure shapes of background sources
4. Stack on centers

Stacked Weak Lensing

Good center



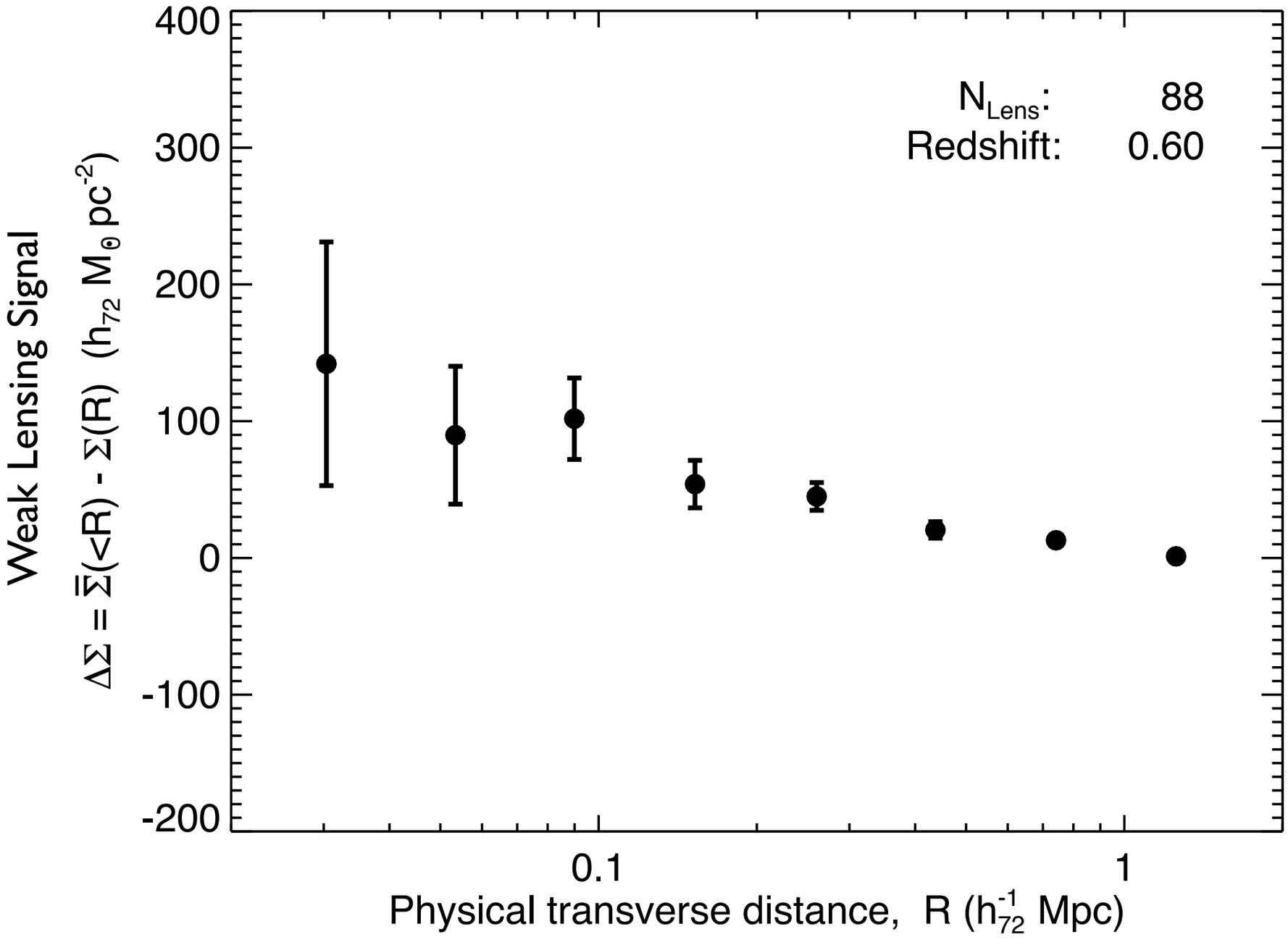
Bad center



1. Find members
2. Determine centers
3. Measure shapes of background sources
4. Stack on centers
5. Measure tangential shear in radial bins

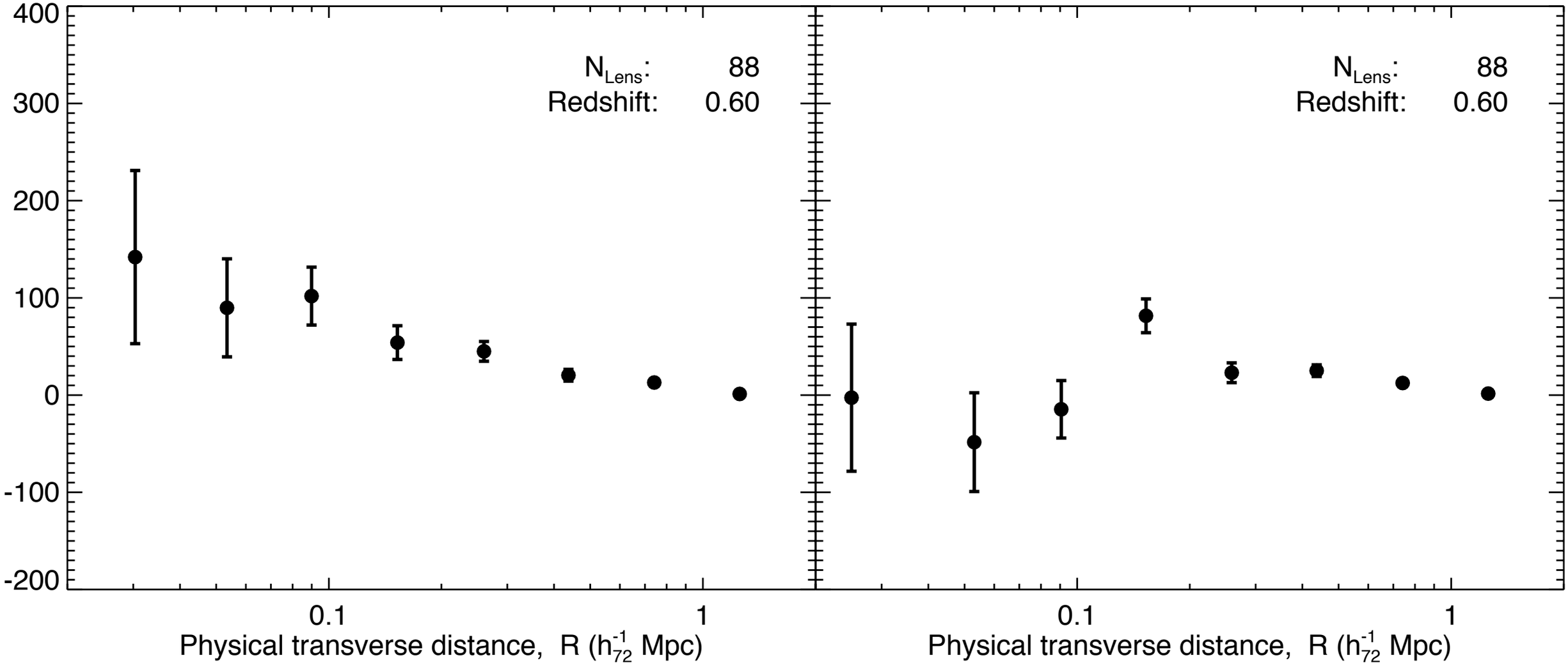
Preliminary Results

"BCG" ≡ galaxy with largest stellar mass within NFW scale radius of X-ray center



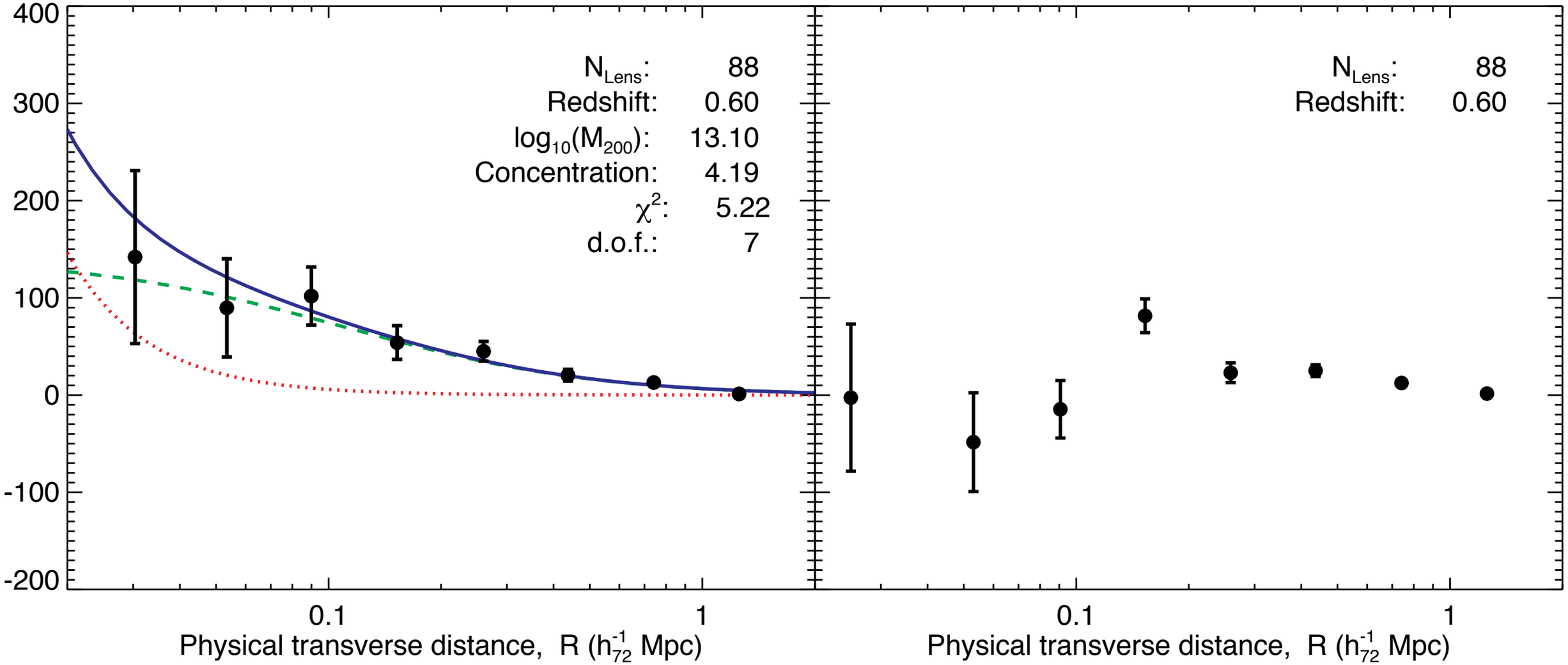
"BCG"

X-ray


N_Lens: 88
Redshift: 0.60
ΔΣ = Σ̄(<R) - Σ(R) (h_72 M_⊙ pc^-2)
400
300
200
100
0
-100
-200
0.1
1
Physical transverse distance, R (h_72^-1 Mpc)
N_Lens: 88
Redshift: 0.60
0.1
1
Physical transverse distance, R (h_72^-1 Mpc)

"BCG"

X-ray



NFW

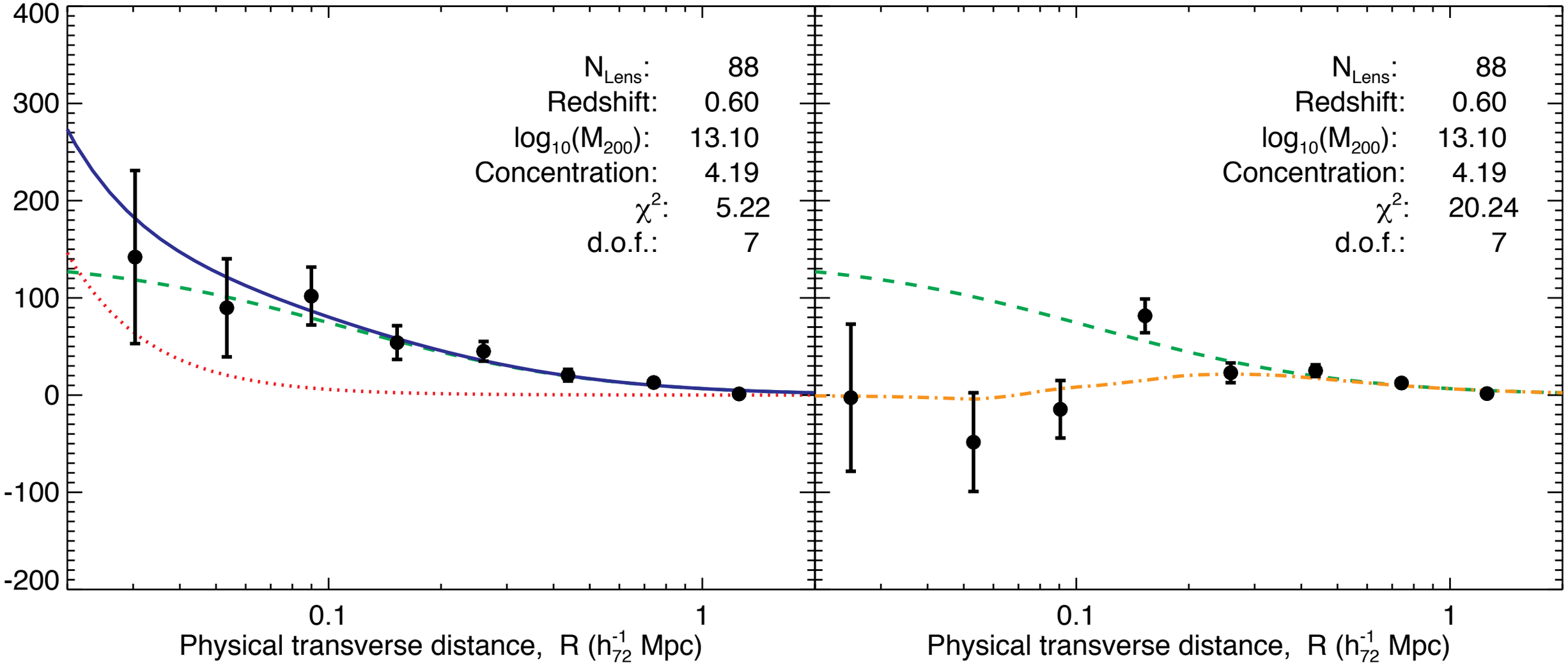
Central Galaxy

Offset NFW

Total

"BCG"

X-ray

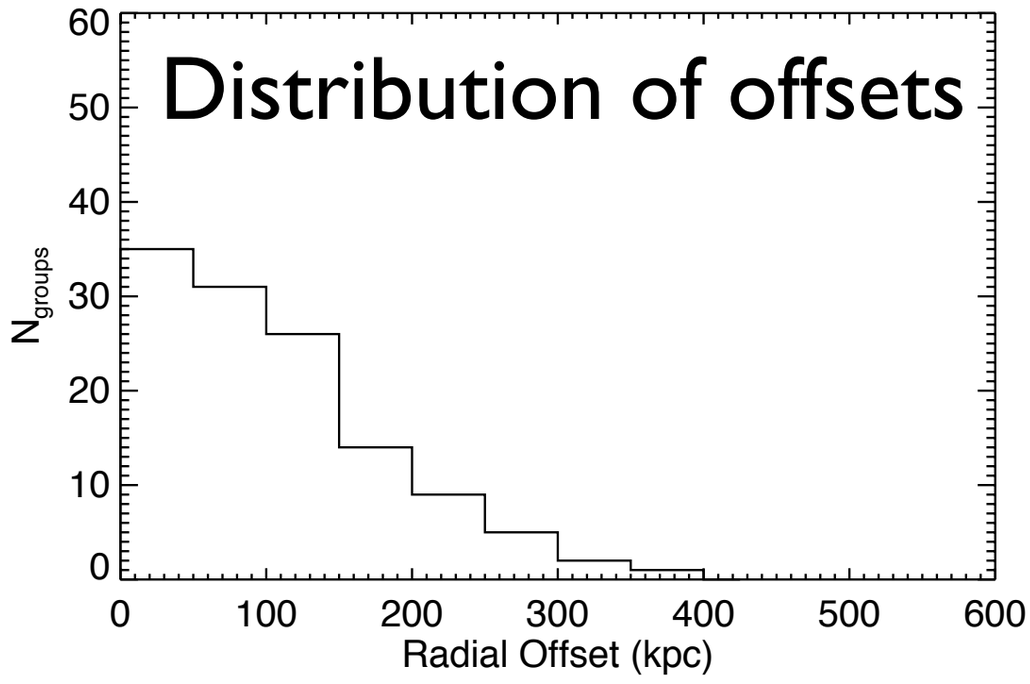


NFW

Central Galaxy

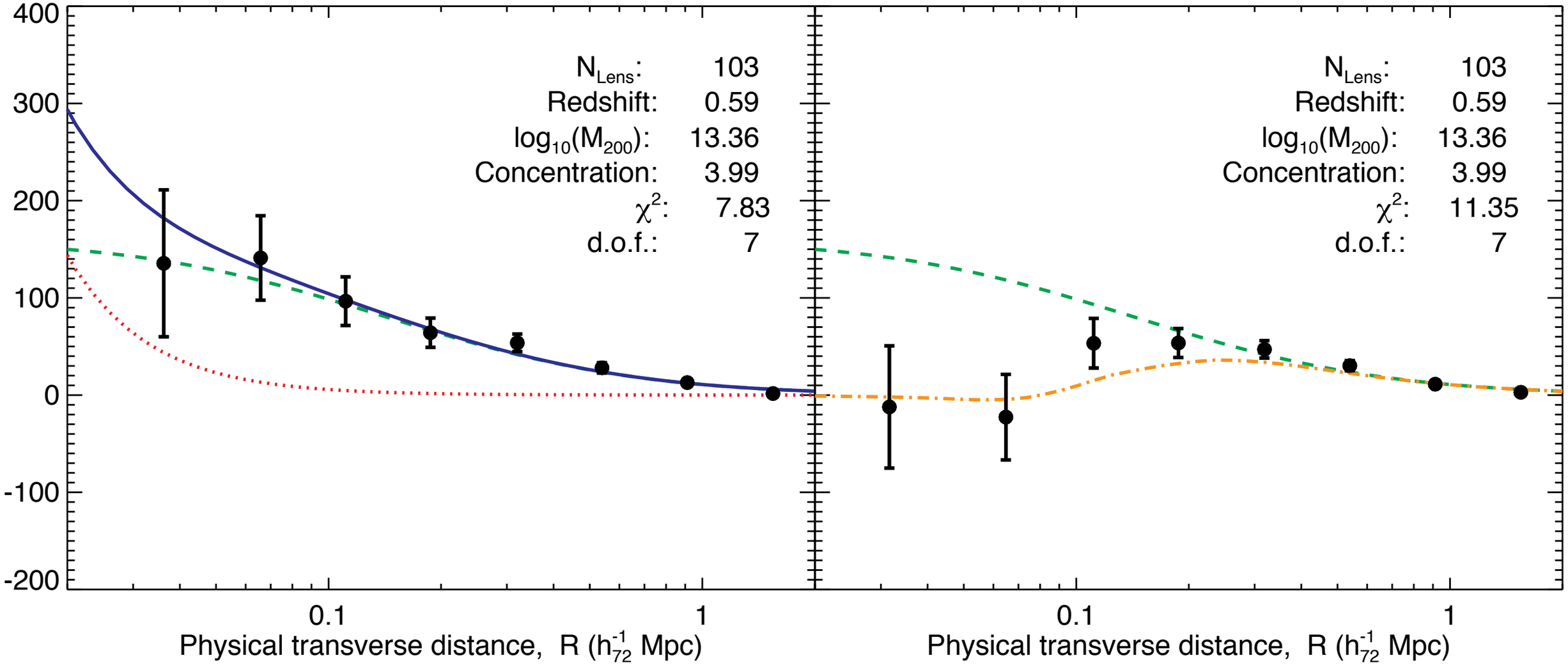
Offset NFW

Total



"BCG"

Luminosity-Weighted Centroid

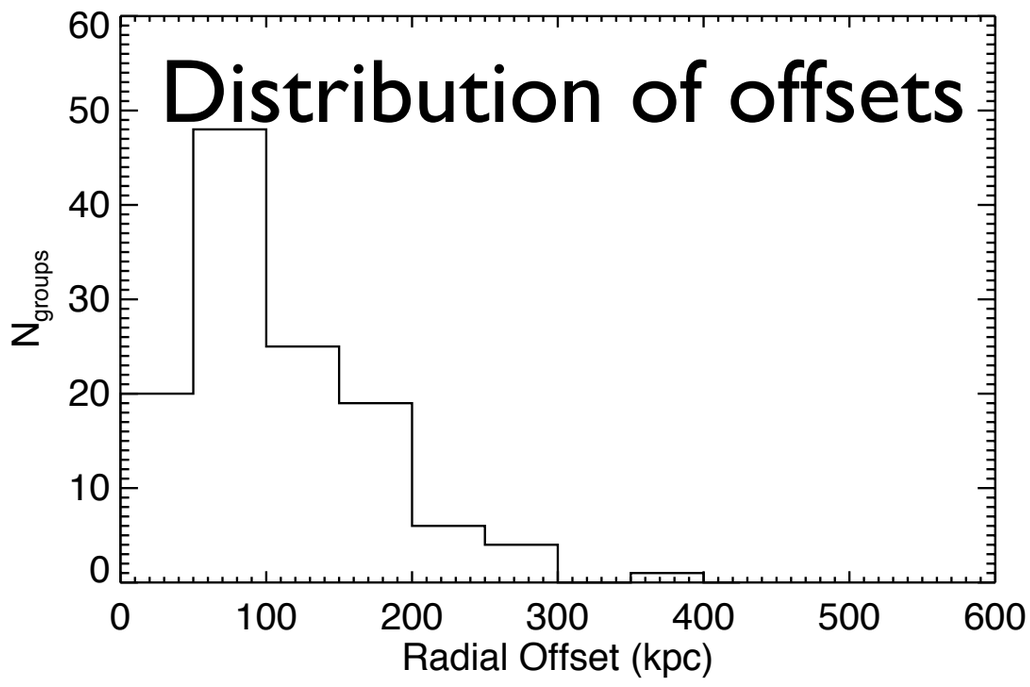


NFW

Central Galaxy

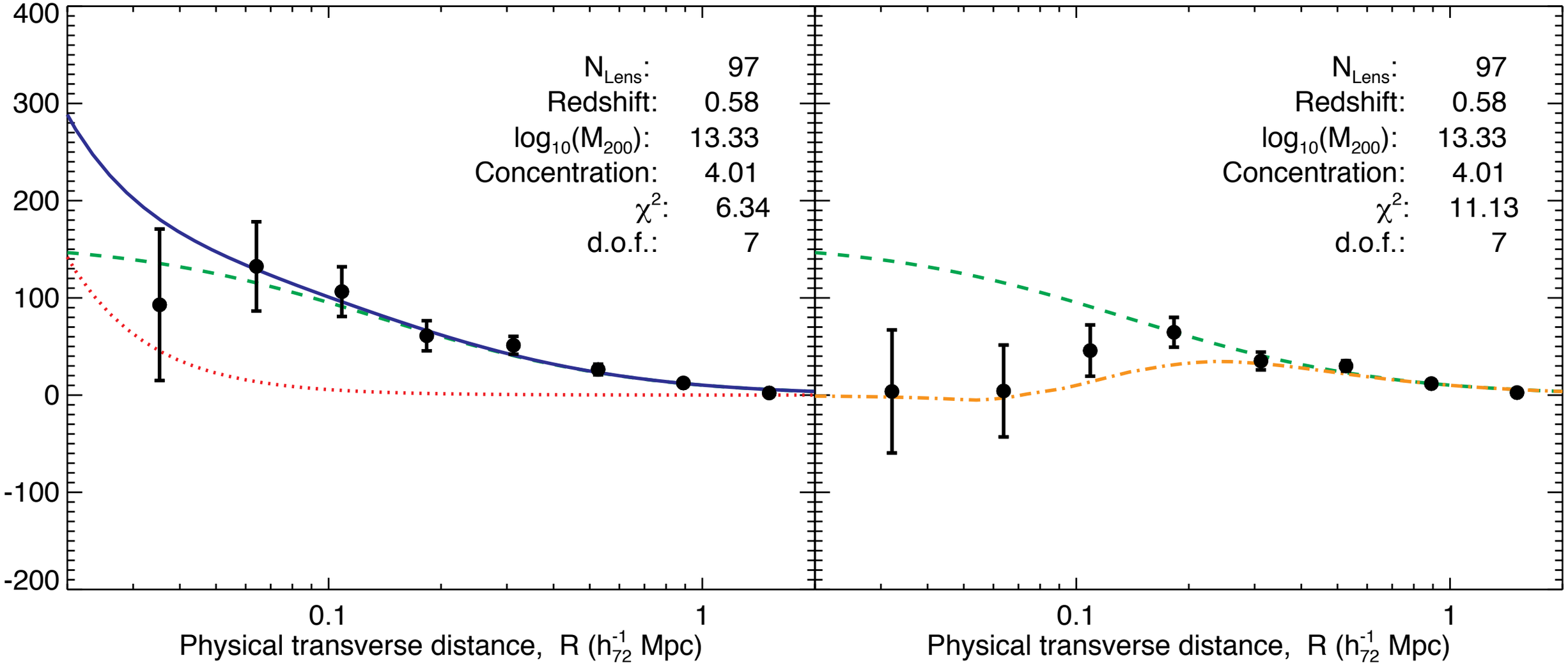
Offset NFW

Total



"BCG"

SM-Weighted Centroid

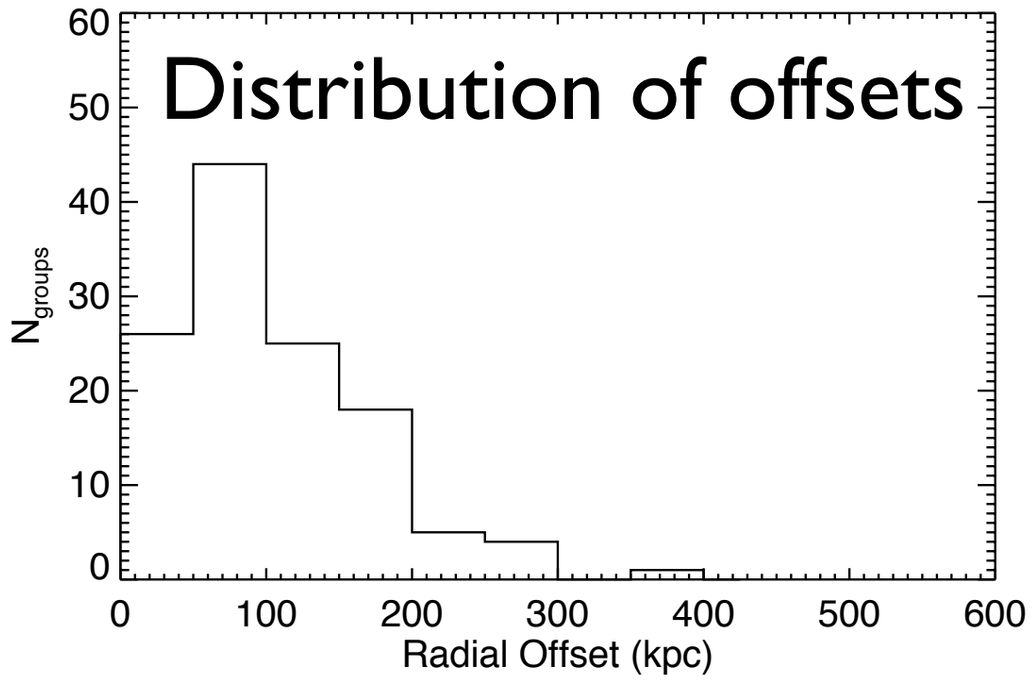


NFW

Central Galaxy

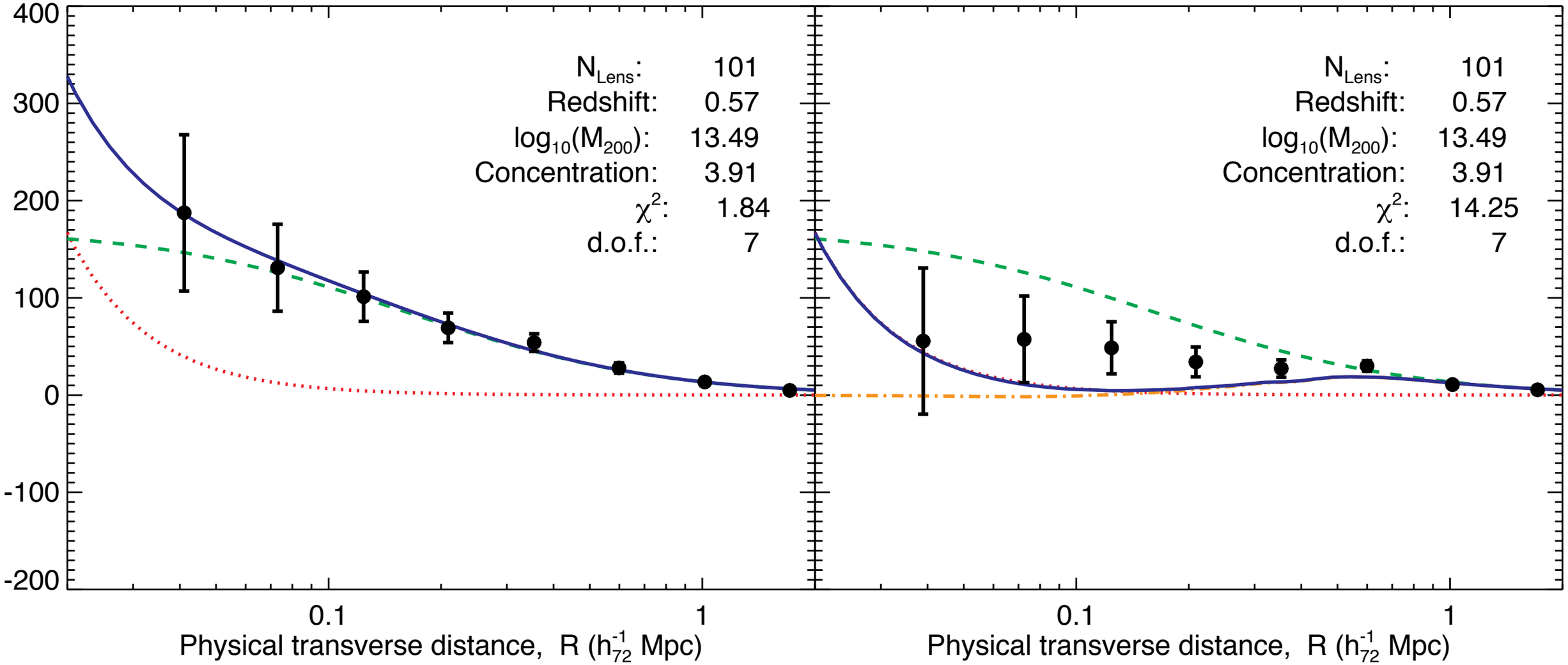
Offset NFW

Total



"BCG"

2nd Most Massive Member

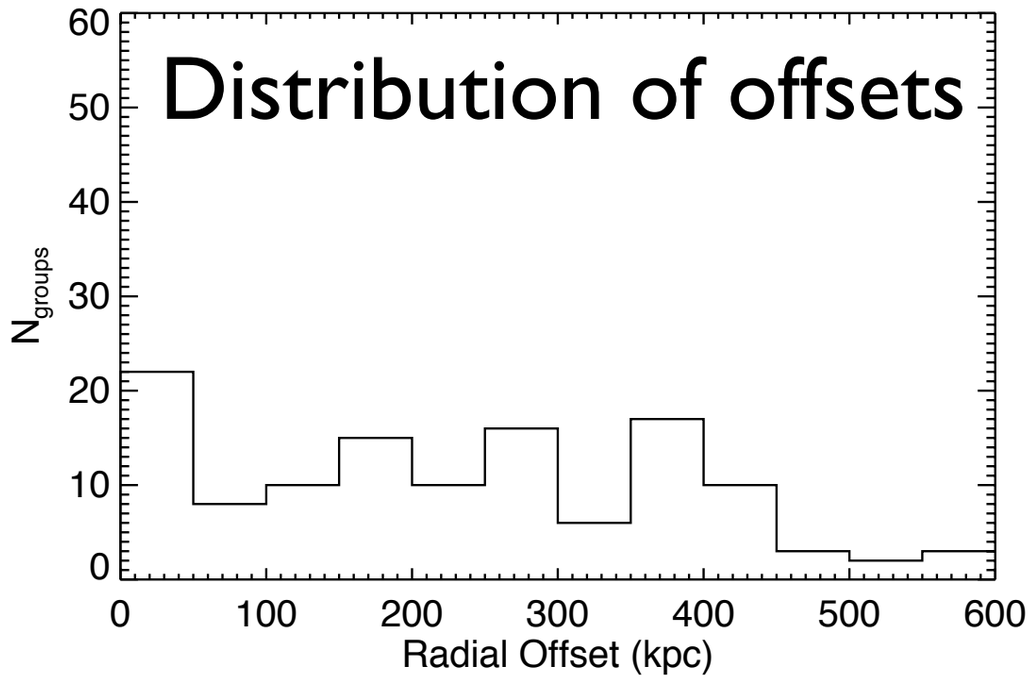


NFW

Central Galaxy

Offset NFW

Total



Summary

- Galaxy with highest stellar mass near X-ray center appears to be the best tracer of CM for this catalog
- Other tracers can be offset by ~few hundred kpc
- Offsets can be due to:
  - interlopers and incompleteness
  - scatter in observables
  - intrinsic separation?
- To do:
  - study offset-dependent properties
  - satellite and halo concentration