Weak lensing of SZ clusters

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with S. Seitz, R. Kosyra, F. Brimioulle, J. Koppenhoefer, C.-H. Lee,
R. Bender, A. Riffeser, T. Eichner, T. Weidinger, M. Bierschenk, A. Mana,
O. Friedrich (all LMU/MPE), M. Becker, E. Rozo, E. Rykoff (Stanford)

Contents

- Introduction

- A medley of projects:
  - Weak lensing analysis of 12 SPT/Planck clusters
  - Projected environment of Planck SZ clusters
  - Cosmic variance of cluster weak lensing

- Summary


RXC J2248.7-4431, z=0.35
0.1 deg
1.5 Mpc
Introduction

What we're after

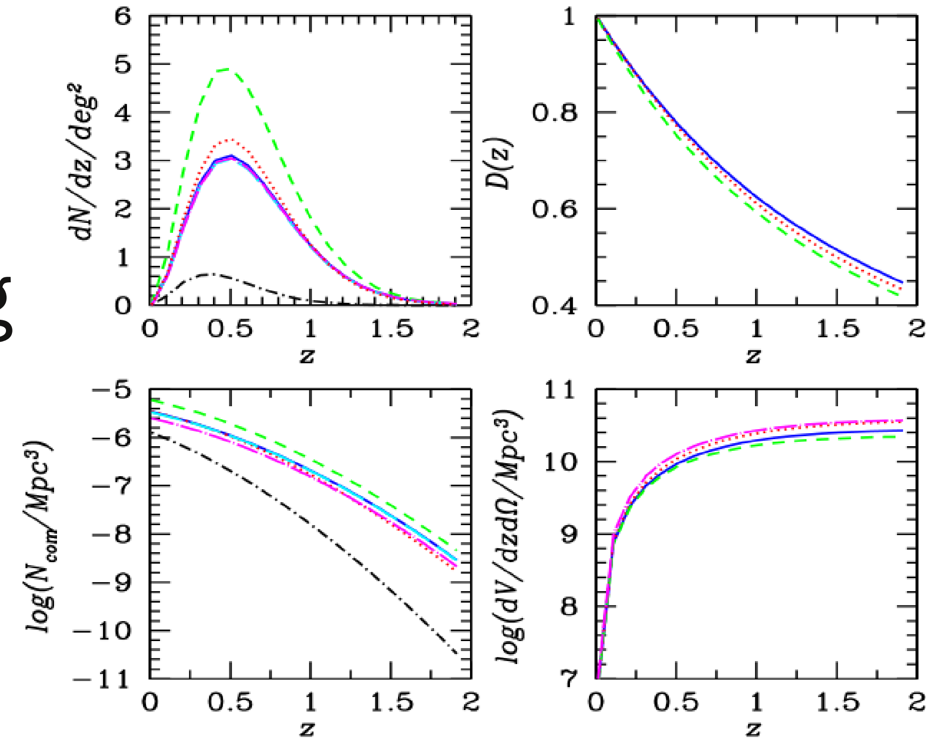
- Cosmology from comparing cluster mass function to observations

But: e.g. Majumdar & Mohr (2004), Lima & Hu (2005)

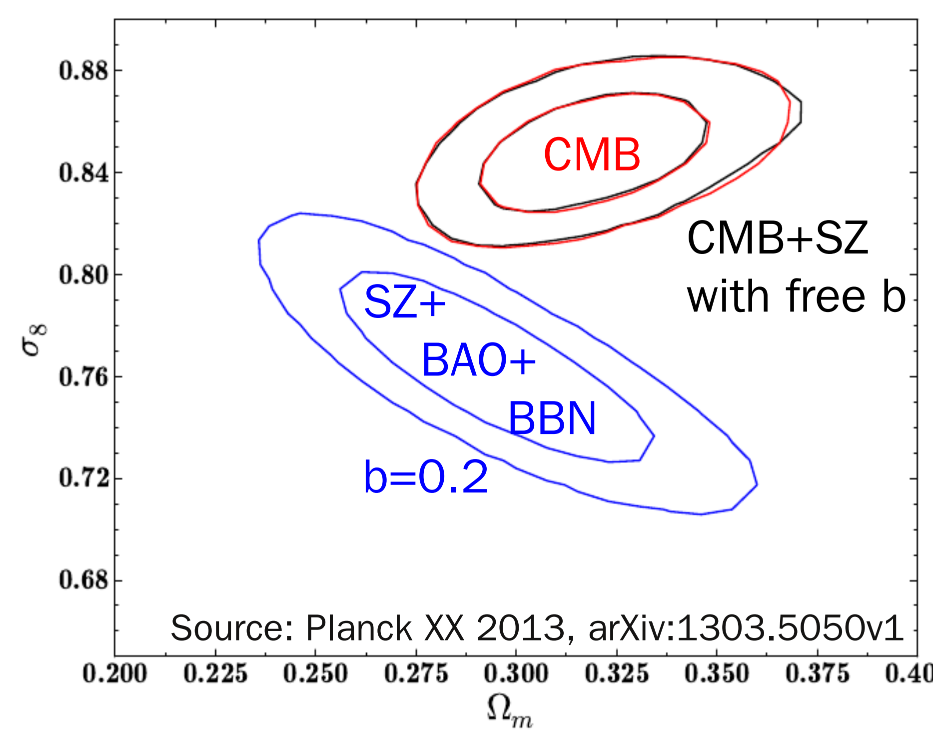
- need mass-observable relation (MOR)

$$E(z)^{-2/3} \times \left(\frac{D_A^2 \times Y_{500c}}{\mathrm{Mpc}^2}\right) = 10^A \times \left(\frac{M_{500c} \times (1-b)}{6 \times 10^{14} h_{70}^{-1} M_\odot}\right)^B$$

- hydrostatic bias $M_{500}^{\mathrm{HE}} = (1-b)\, M_{500}$
- sensitive to intrinsic scatter
- self- vs. external calibration
- MOR uncertainty dominates

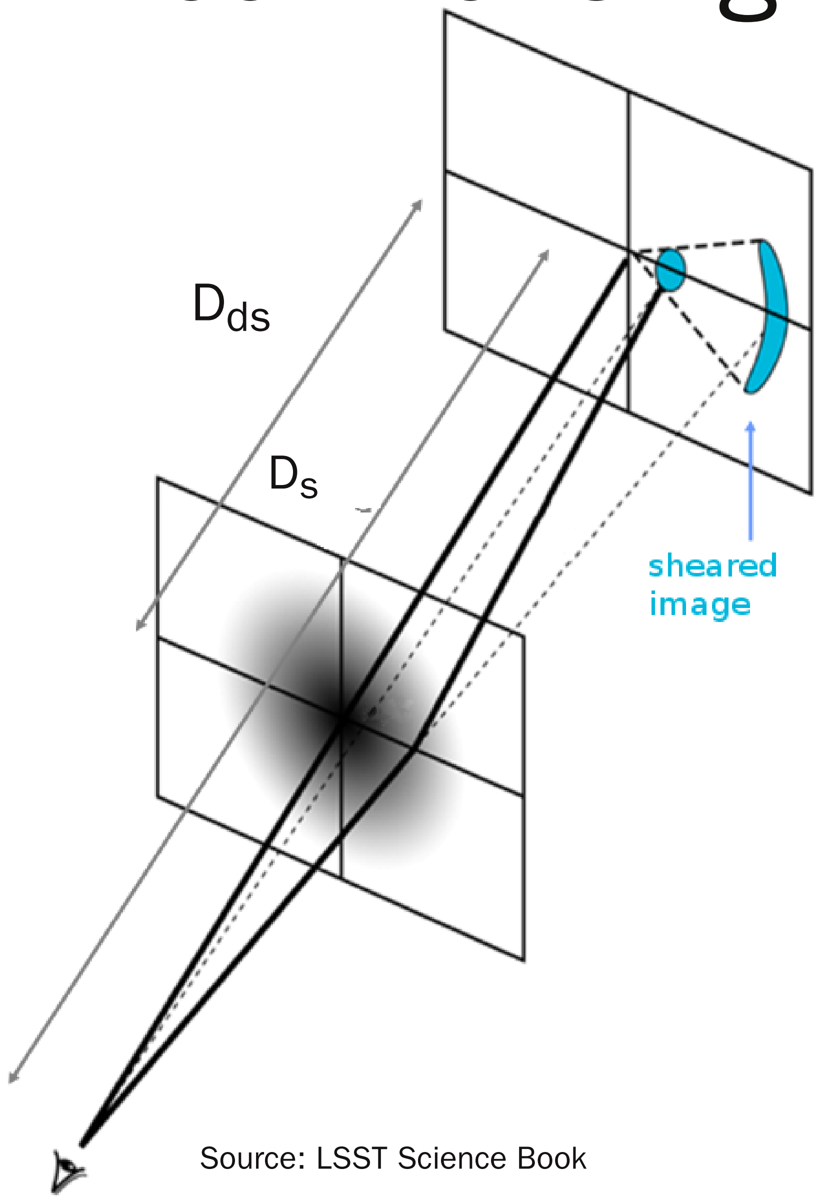


Source: Battye & Weller 2008



Source: Planck XX 2013, arXiv:1303.5050v1

Weak Lensing



Source: LSST Science Book

- Matter (also dark) bends space-time (and therefore light rays)
- Weak effect: % distortion
- Tangential distortion ~ overdensity

$$\gamma_t(\theta) = \langle\kappa(\theta')\rangle_{\theta'<\theta} - \kappa(\theta)$$

$$\kappa = \Sigma / \left[\frac{c^2}{4\pi G}\frac{D_\mathrm{s}}{D_\mathrm{d} D_\mathrm{ds}}\right]$$

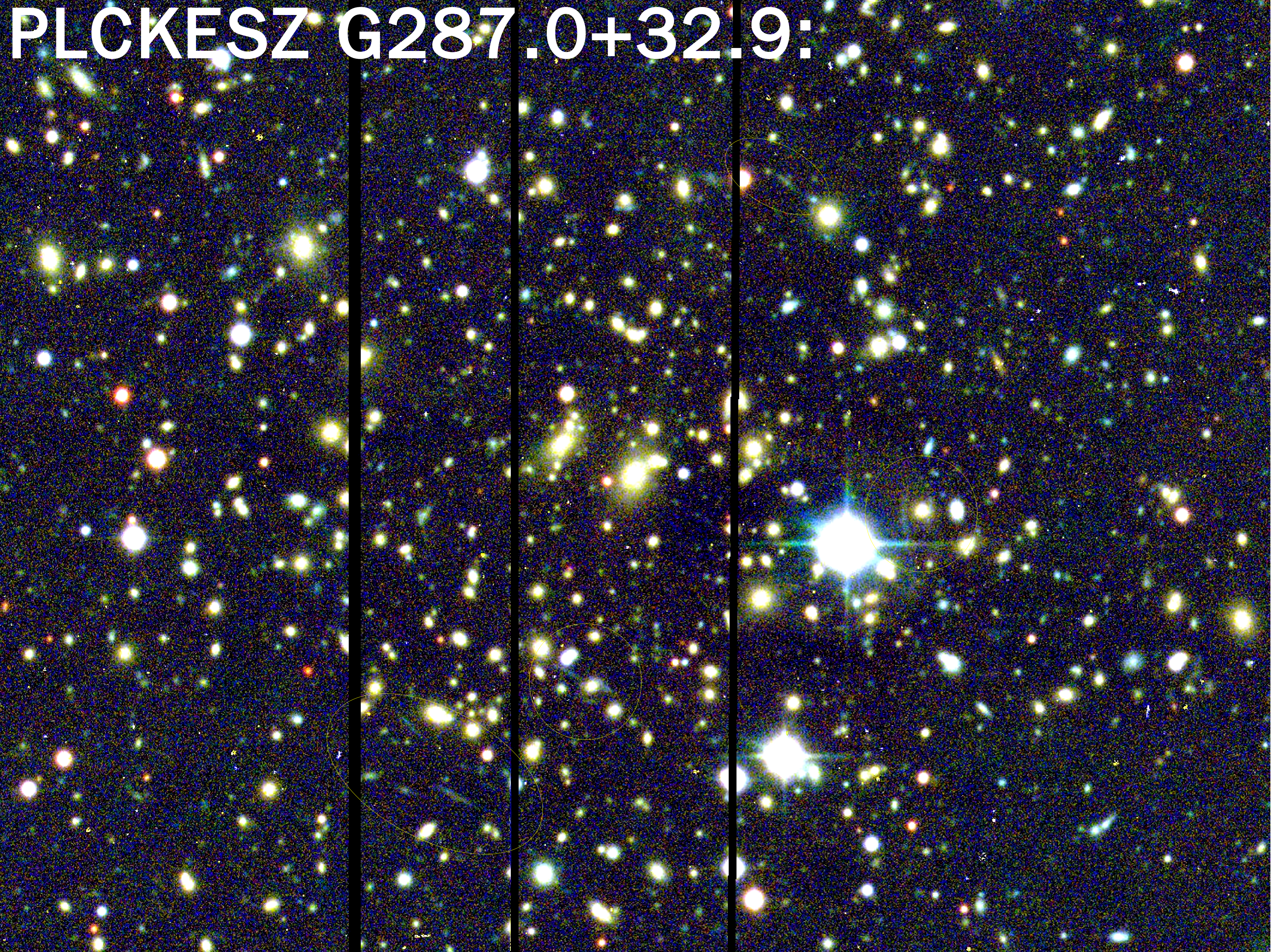
Part 1:

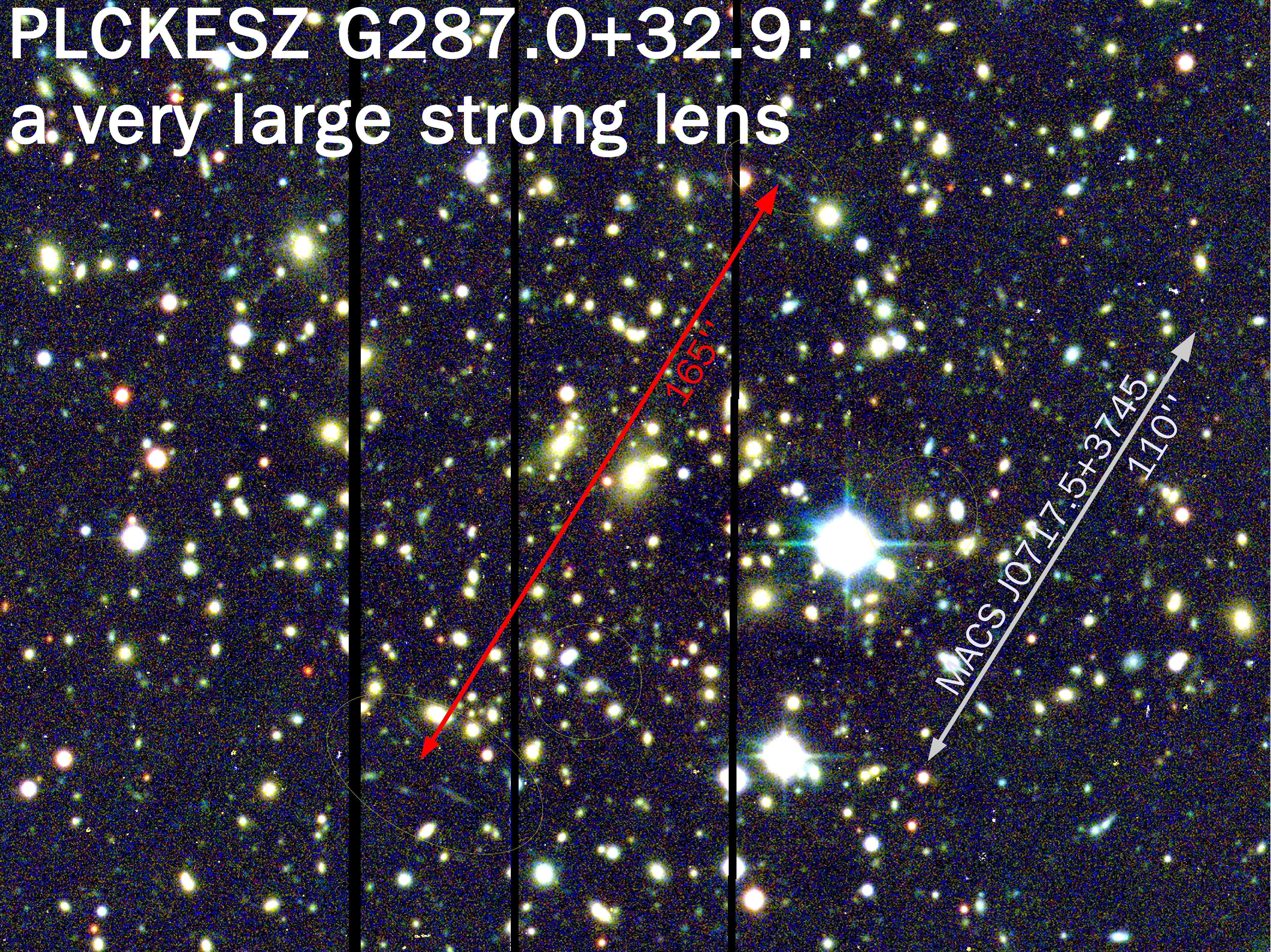
Weak lensing analysis of SZ-selected clusters of galaxies from the SPT and Planck surveys

DG, S. Seitz, R. Kosyra, F. Brimioulle, J. Koppenhoefer, C.-H. Lee,
R. Bender, A. Riffeser, T. Eichner, T. Weidinger, M. Bierschenk

arXiv:1310.6744


MACS J0416.1-2403
CLASH, z=0.42
WFI
SPT J2355-5056
SPT, z=0.32
WFI
PSZ1 G099.48+55.62
Planck, z=0.11
CFHT
PSZ1 G230.73+27.70
Planck, z=0.29
CFHT
SPT J2332-5358
SPT, z=0.40
WFI
RXC J2248.7-4431
CLASH/SPT/Planck, z=0.35
WFI
PSZ1 G292.5+22
Planck, z=0.39
WFI
PSZ1 G287+33
Planck, z=0.30
WFI
CFHT
PSZ1 G168.0+60.0
Planck, z=0.15
CFHT
PSZ1 G099.8+58.5
Planck, z=0.68
WFI
SPT J0509-5342
SPT, z=0.46
WFI
SPT J0551-5709
SPT, z=0.42


PLCKESZ G287.0+32.9:


PLCKESZ G287.0+32.9:
a very large strong lens
165"
MACS J0717.5+3745
110"

From photons to cluster cosmology

- Observing
- De-biasing
- Flat-fielding
- De-fringing
- Background level subtraction
- Astrometry
- Photometry
- Artifact removal
- Co-Addition
- Point-spread function modelling
- Galaxy shape measurement
- Background galaxy selection
- Mass likelihood estimation
- Mass-observable relation estimation
- Cosmology!

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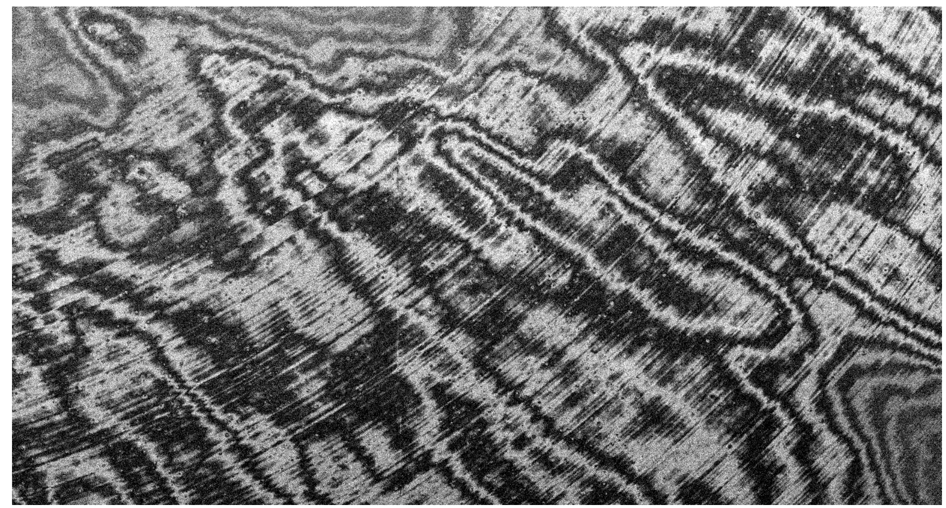
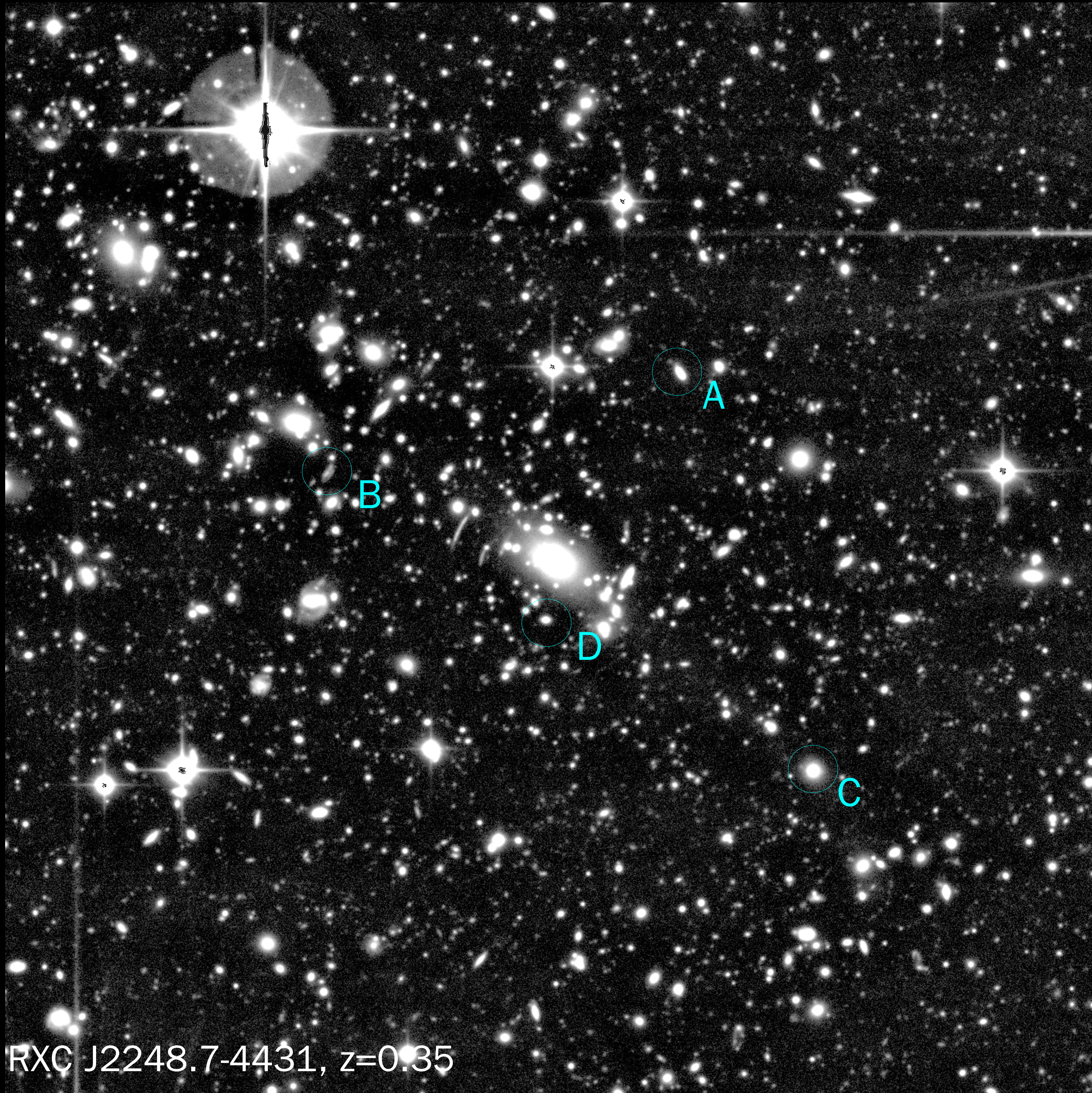
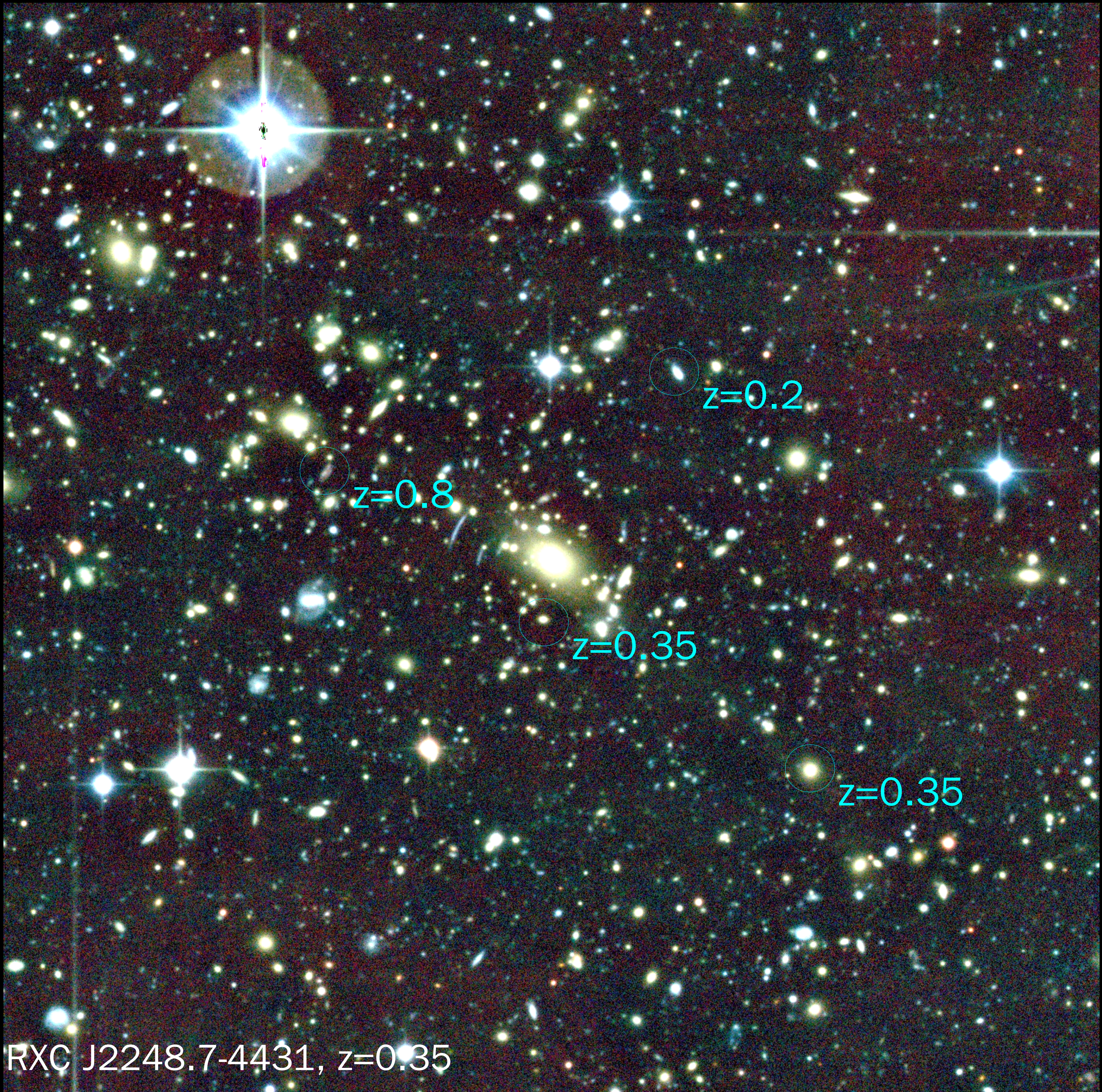


WFI fringe pattern



R

VRI



VRI

Background selection

What we want to know:

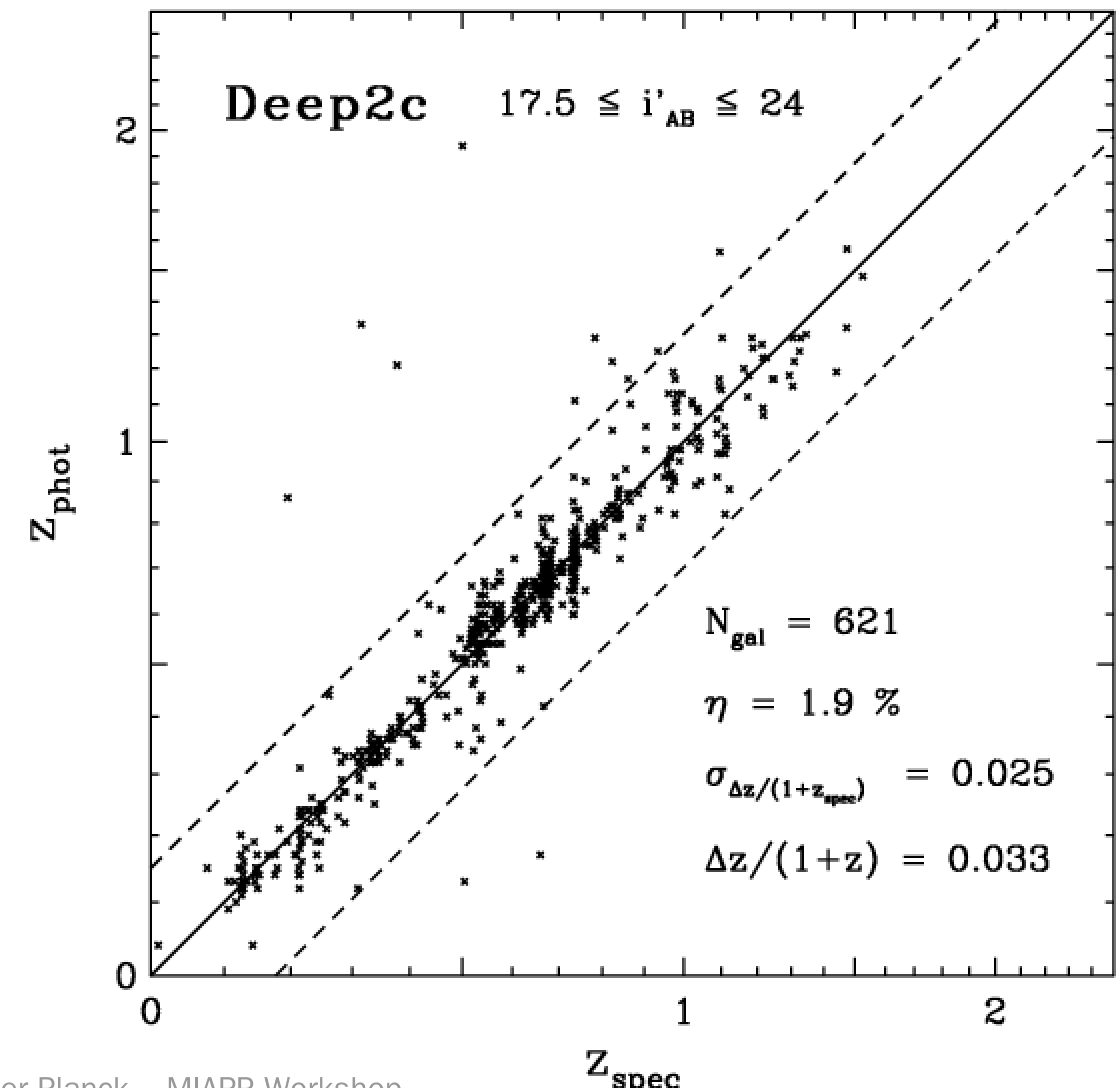
$$\frac{D_d(z_d) D_{ds}(z_s, z_d)}{D_s(z_s)} = D_d(z_d) \times \beta(z_s, z_d)$$

Galaxy information we can use:

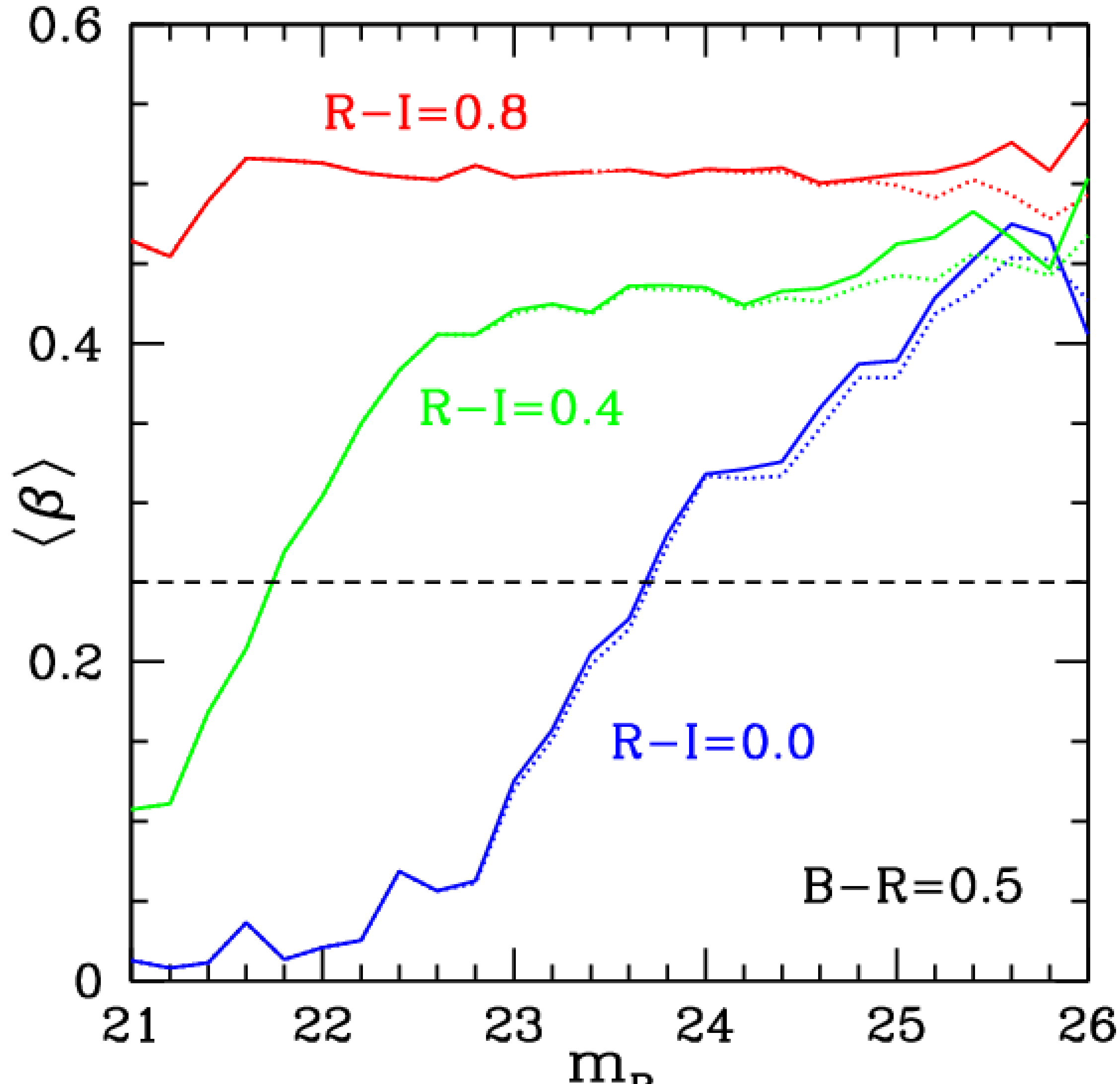
- Color
- Magnitude
- Vicinity to the cluster center
- Size

Background selection: General idea

- reference catalog of galaxies with known redshifts and magnitudes: ESO DPS, 2 sq. deg. UBVRIJK (Erben+2005, Hildebrandt+2006, Olsen+2006)
- Estimate $\beta(z_s, z_d)$ at magnitude-space position



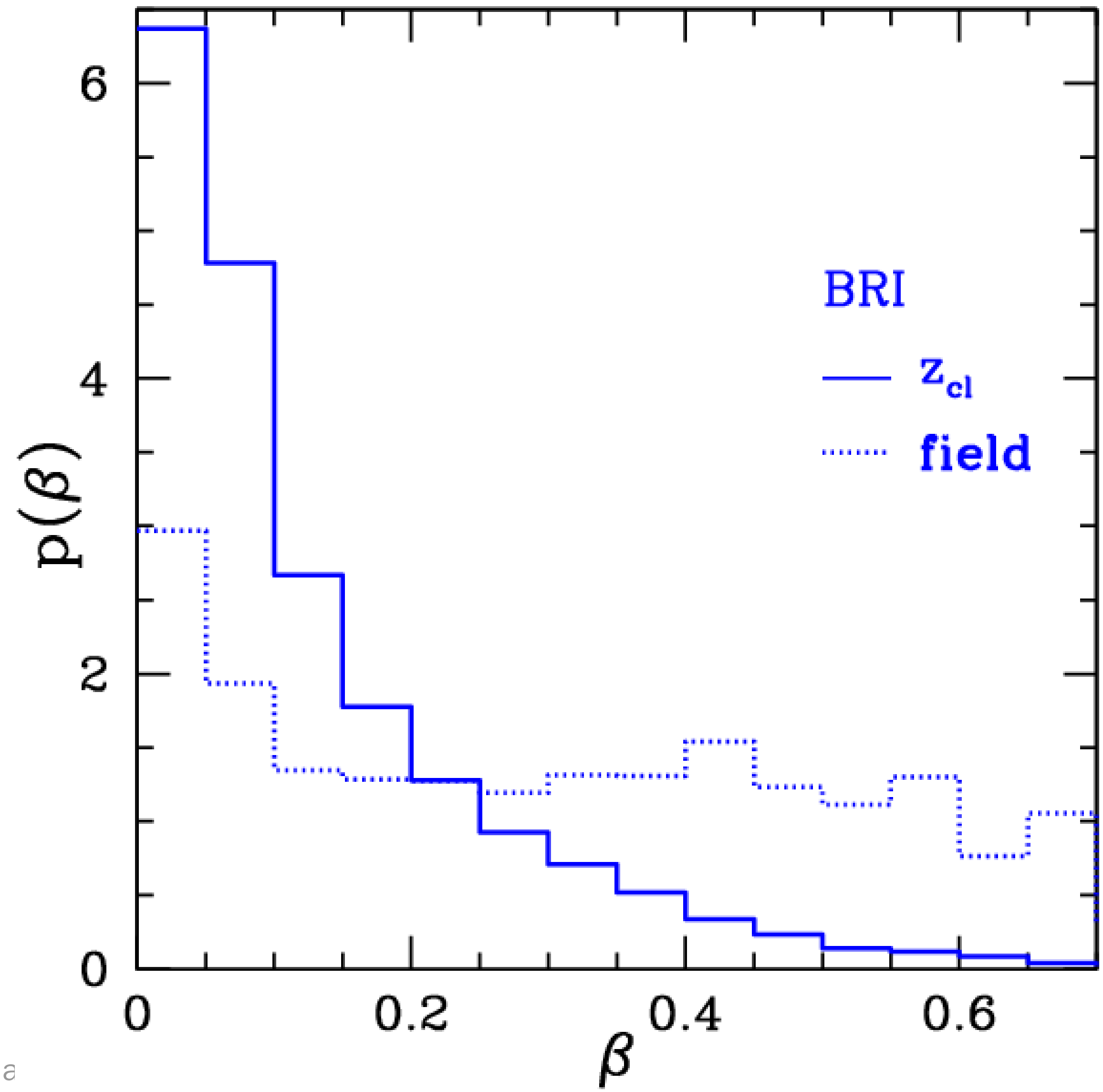
Background selection: color/magnitude dependence



z_{cl}=0.4

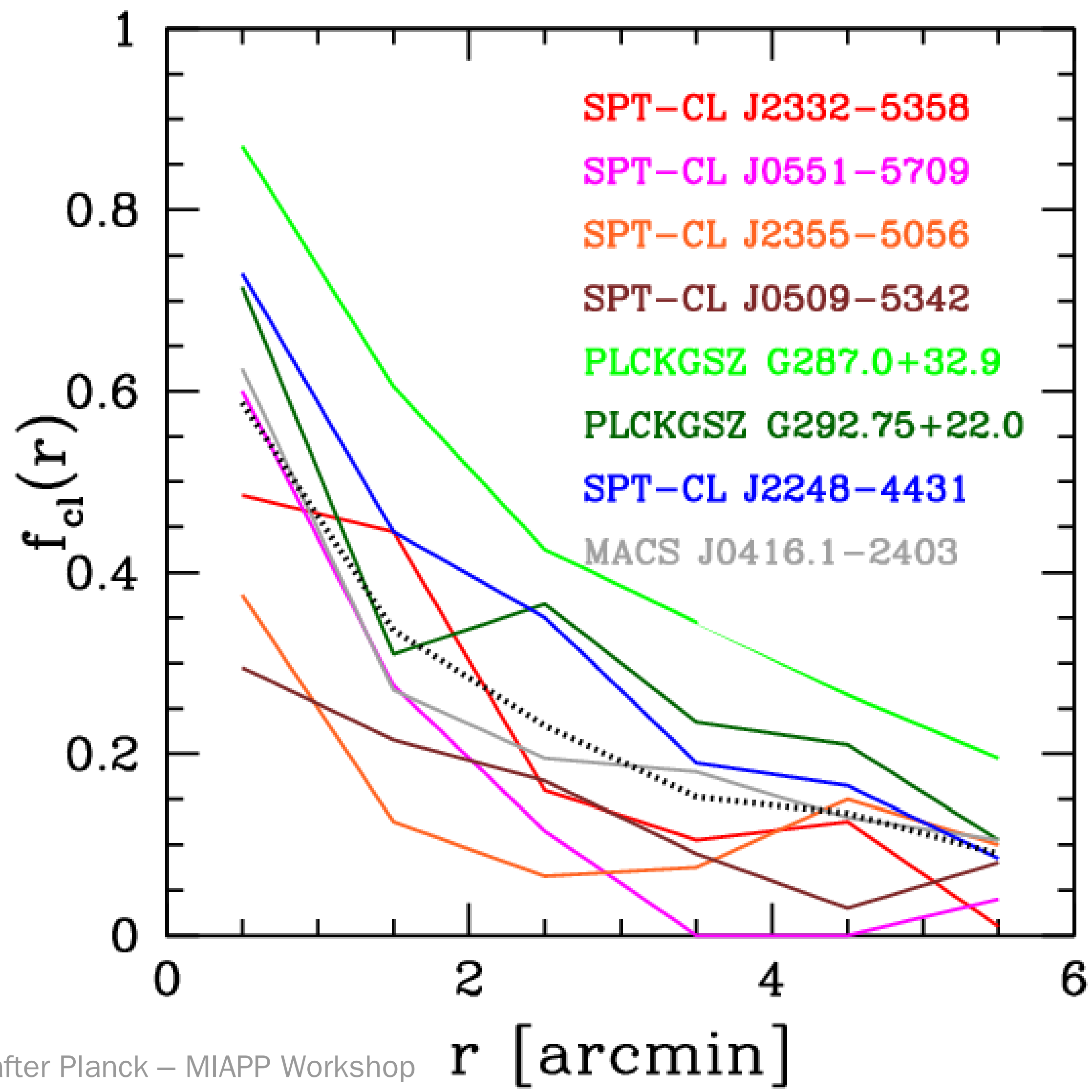
Background selection: cluster member correction

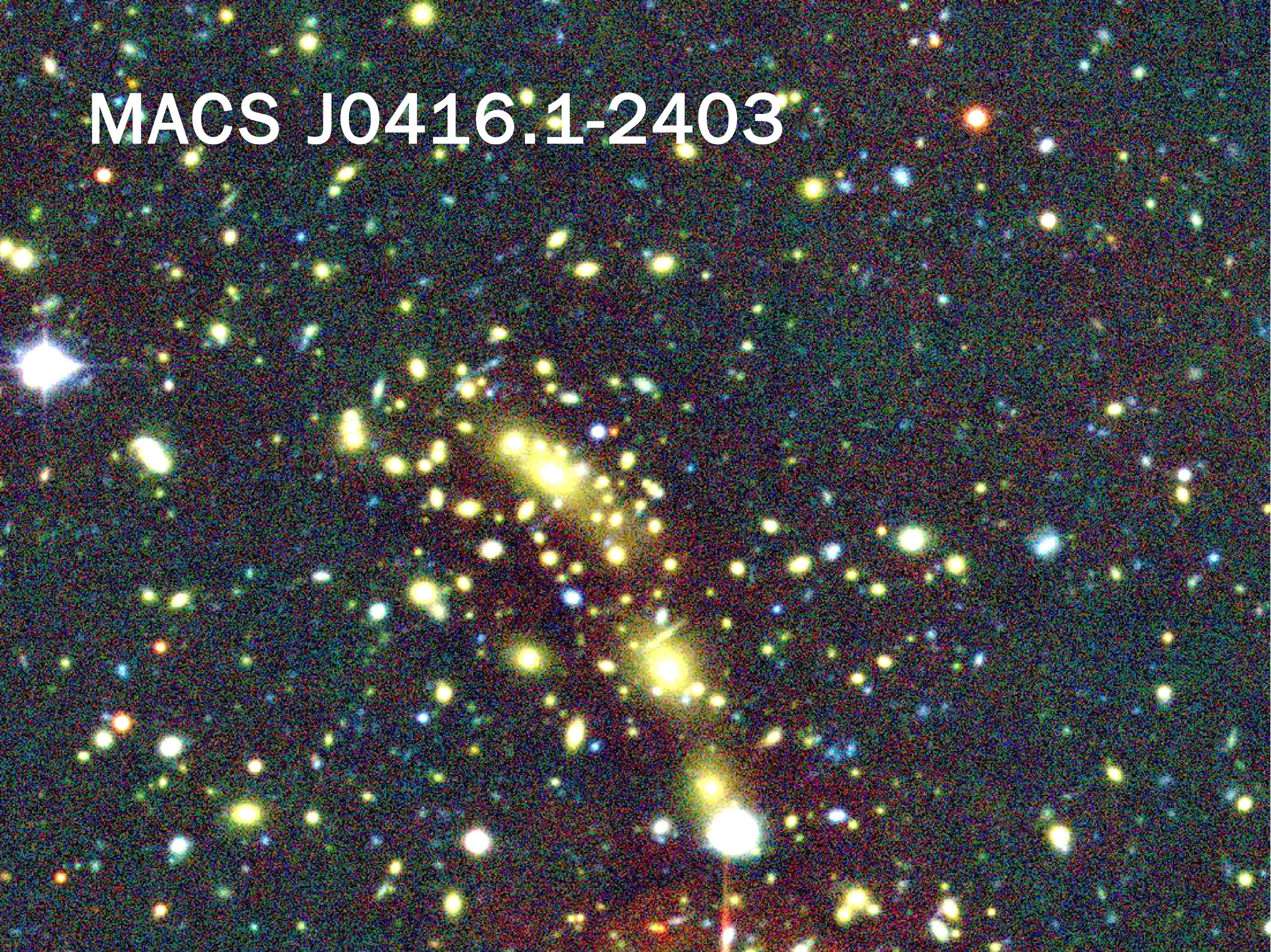
- Field galaxies have a distribution p(β) (dotted)
- Galaxies at cluster redshift have a different p(β) (solid)
- Decompose observed p(β) as a function of radius!



Background selection: cluster member correction

- Result:
  member number density profile
- Roughly NFW
- Used to correct β estimate for galaxies that could be at z_{cl}

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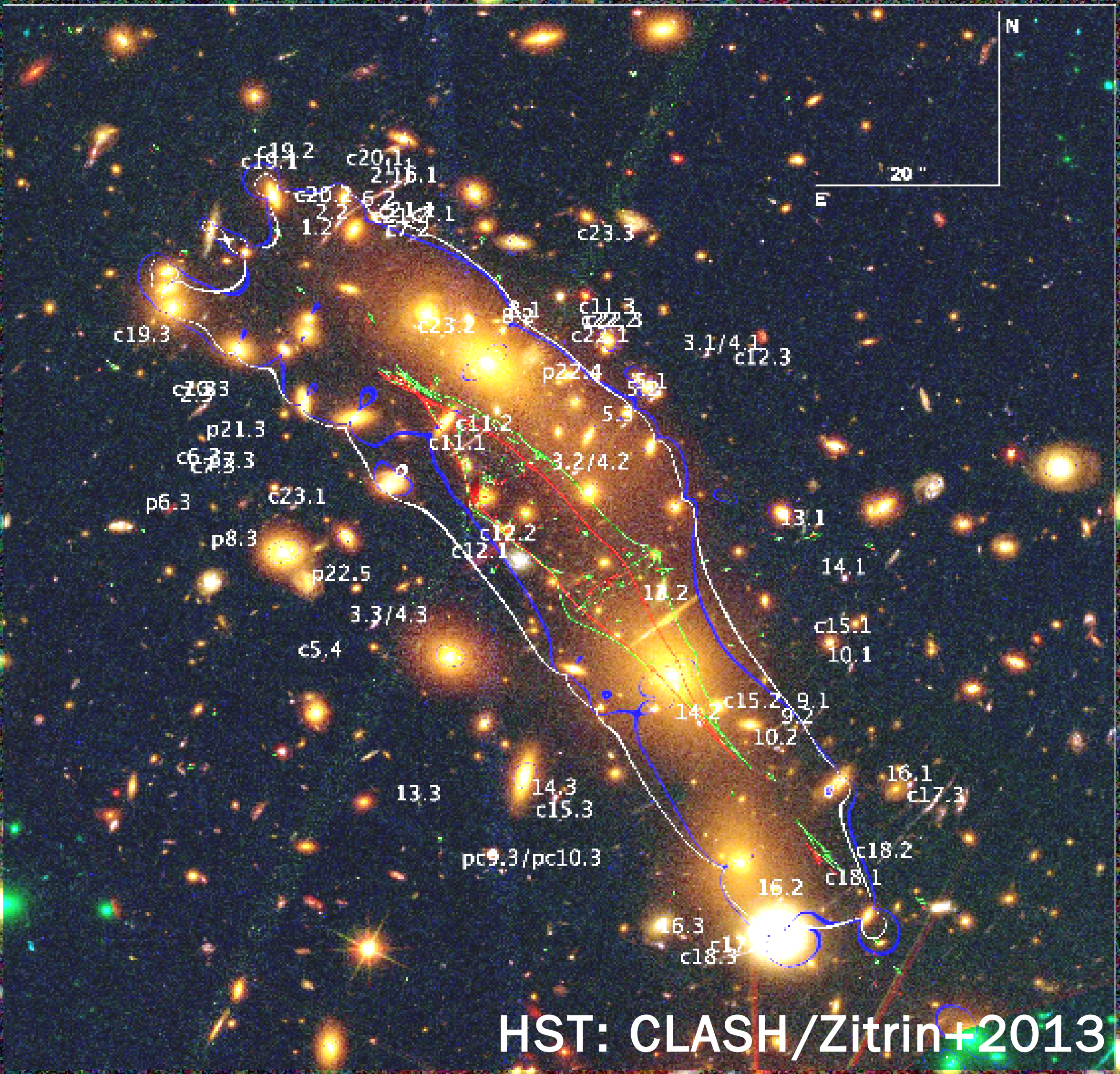
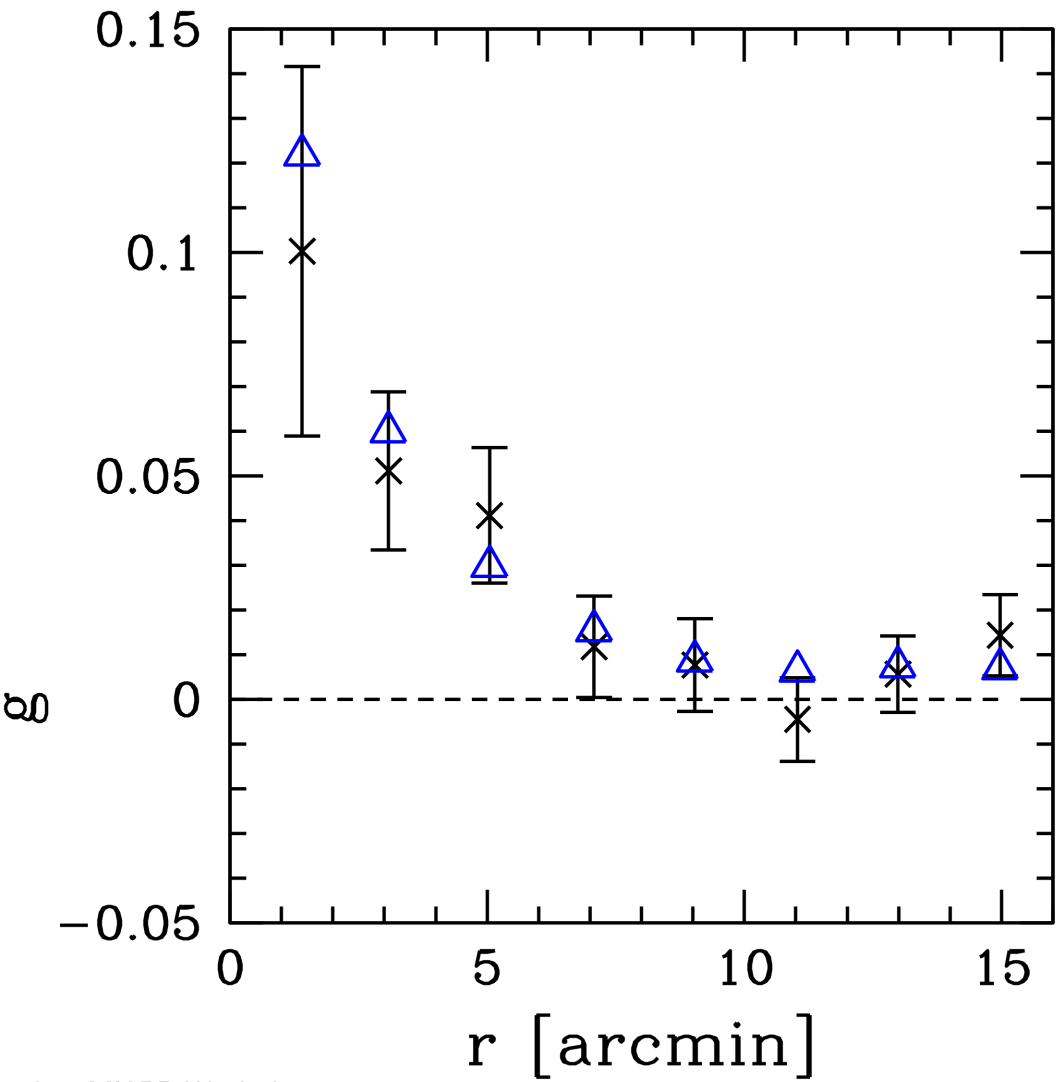


HST: CLASH/Zitrin+2013

MACS J0416.1-2403

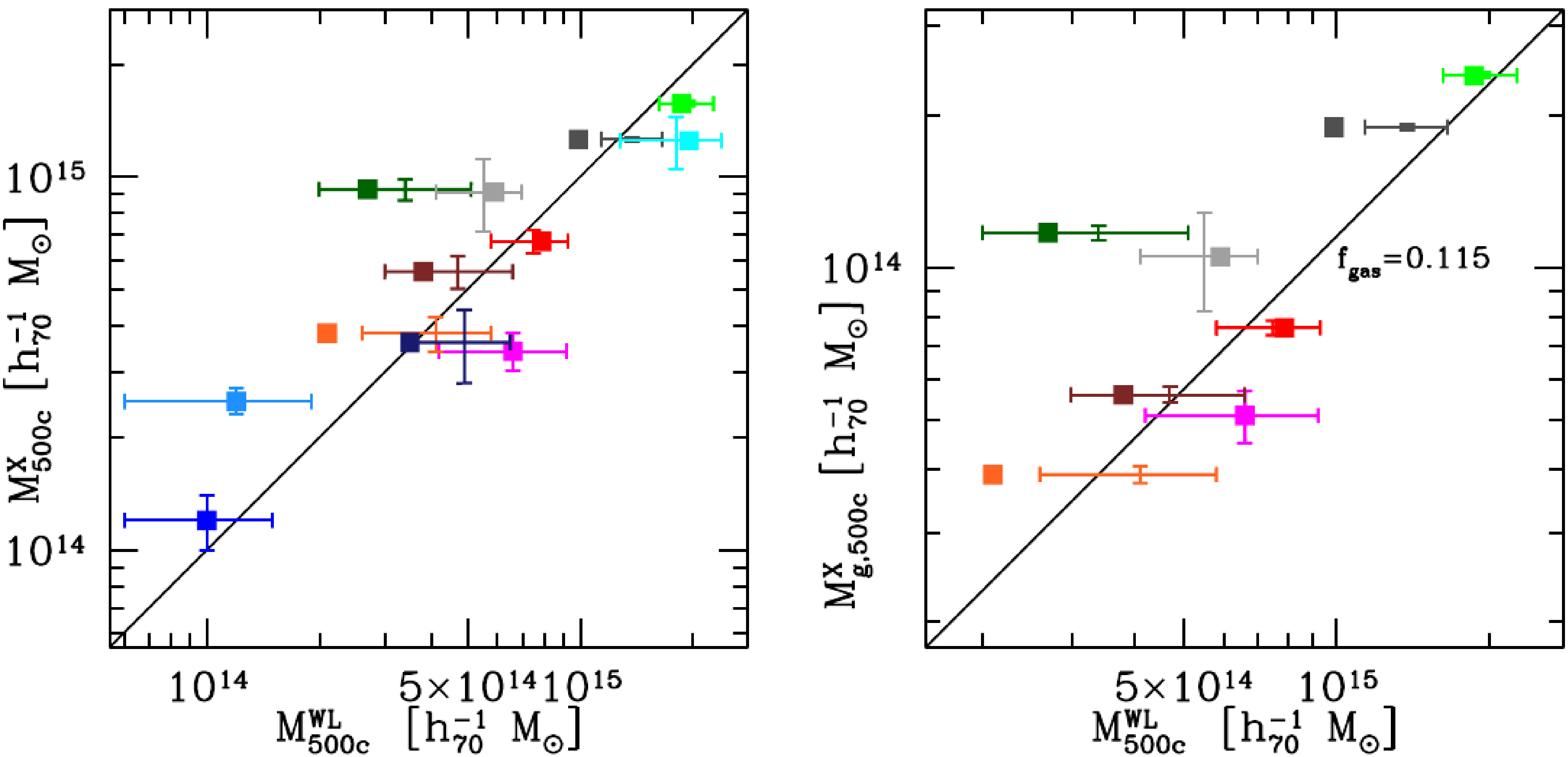
- Comparison with SL+WL model (**blue**, Zitrin+2013) confirms our measurement (**black**)
- No conflict with non-detection in Planck at

$$M_{200m} = (10.0^{+2.9}_{-2.6}) \times 10^{14} h_{70}^{-1} M_{\odot}$$



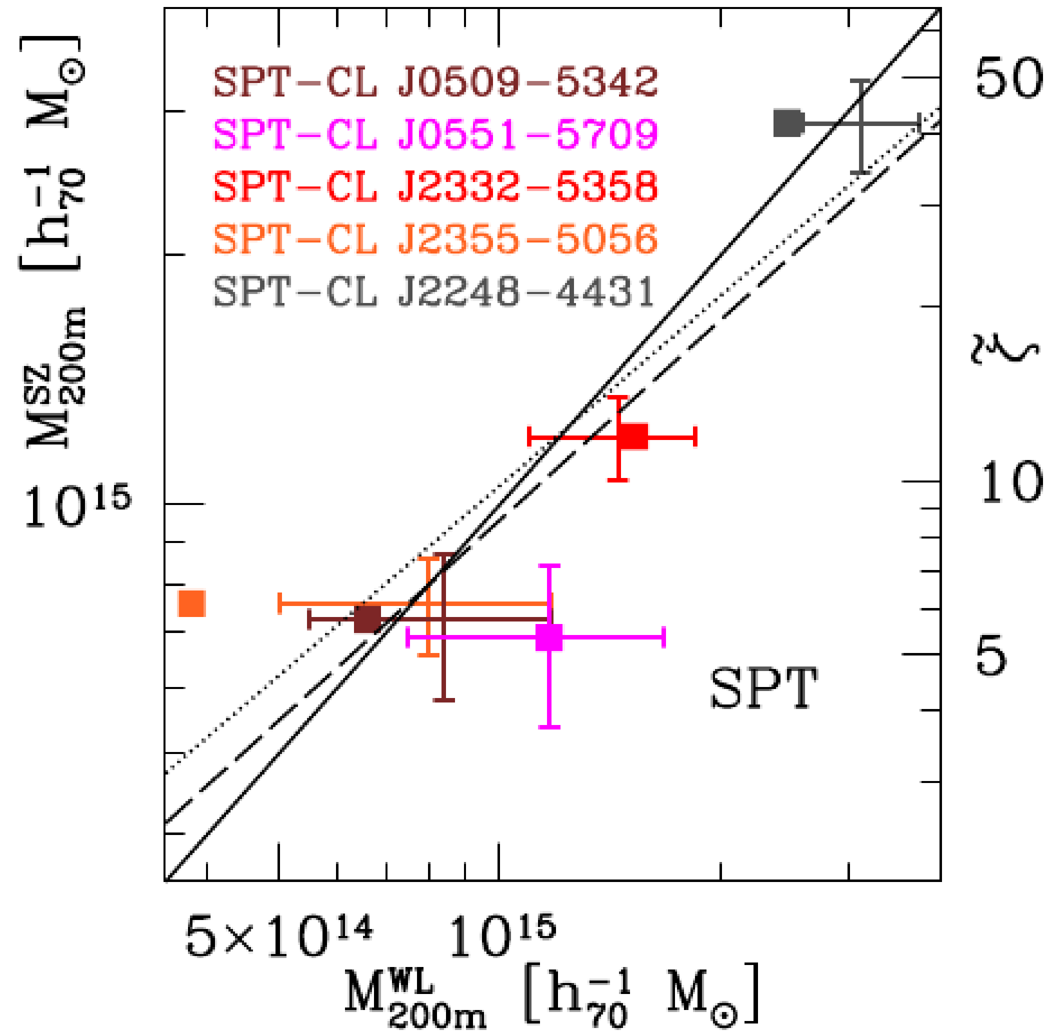
X-ray vs. weak lensing

- Consistent with $M^{WL}=M^{X}$, $0.115M^{WL}=M^{gas}$
- 20% hydrostatic bias is outside 68% confidence

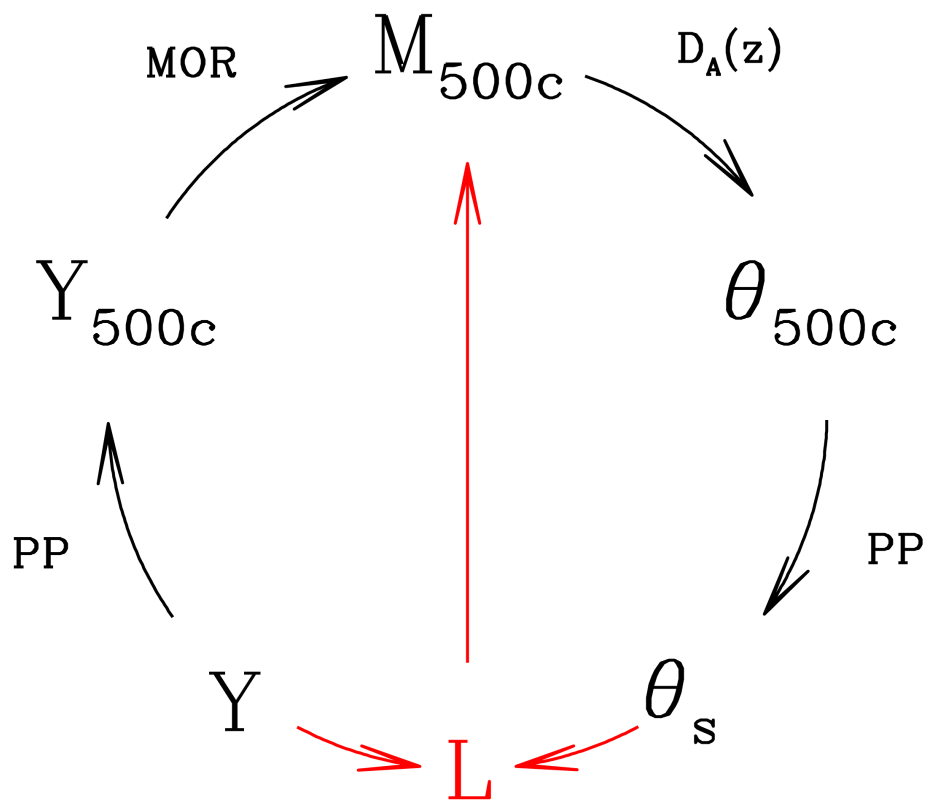


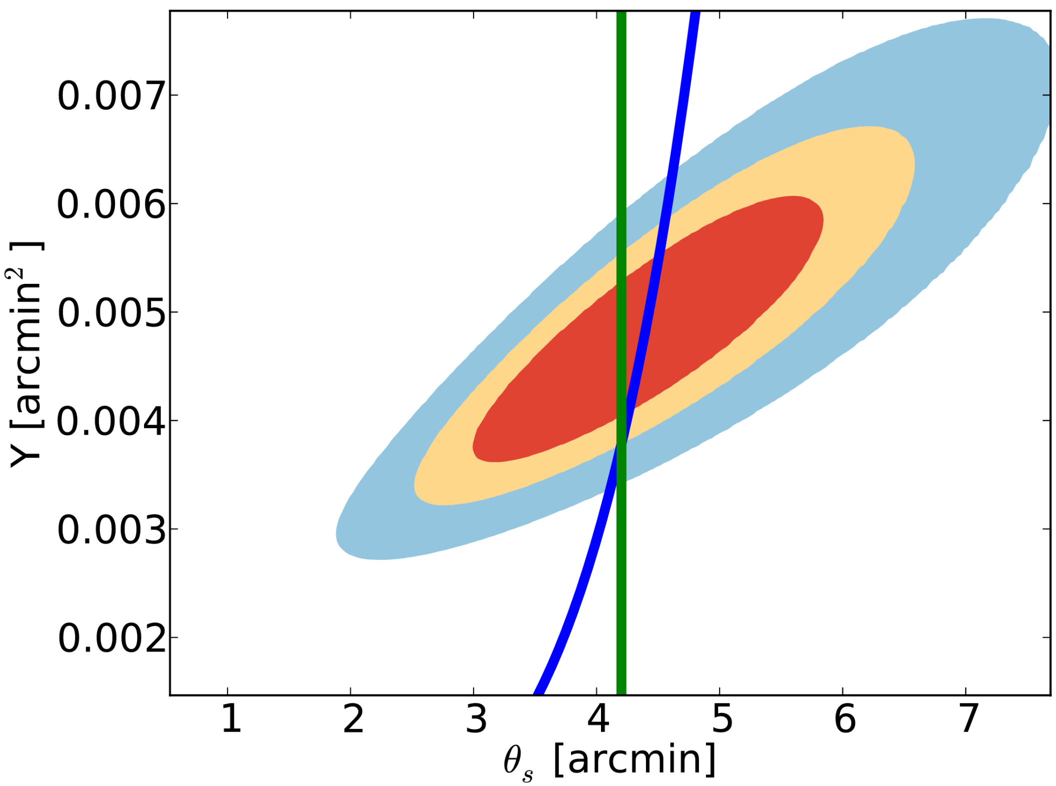
SPT SZ vs. weak lensing

- SPT uses mass-significance relation
- Consistent within 68% confidence with MOR of Vanderlinde+2011 (mock survey), Benson+2013 (SZ, X-ray+CMB cosmology)



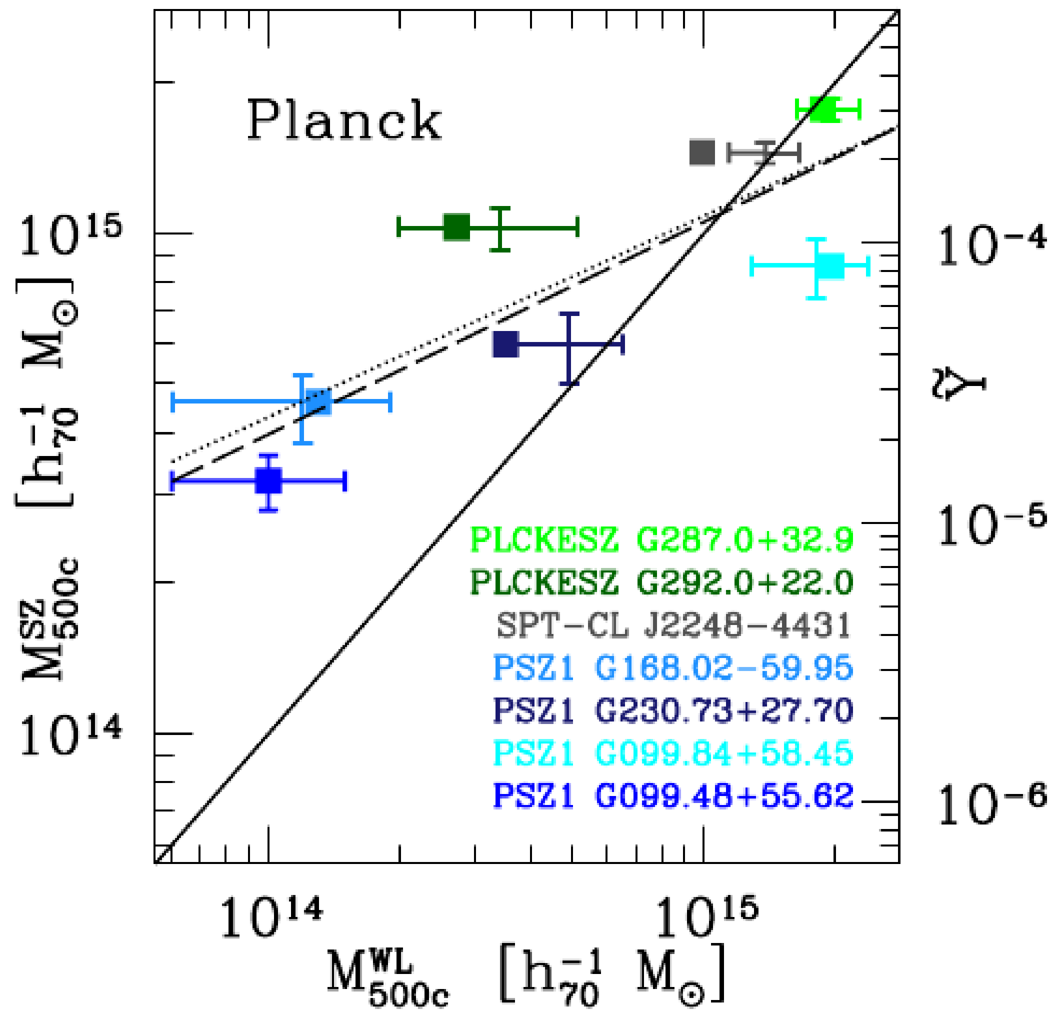
Planck SZ mass estimation





Planck SZ vs. weak lensing

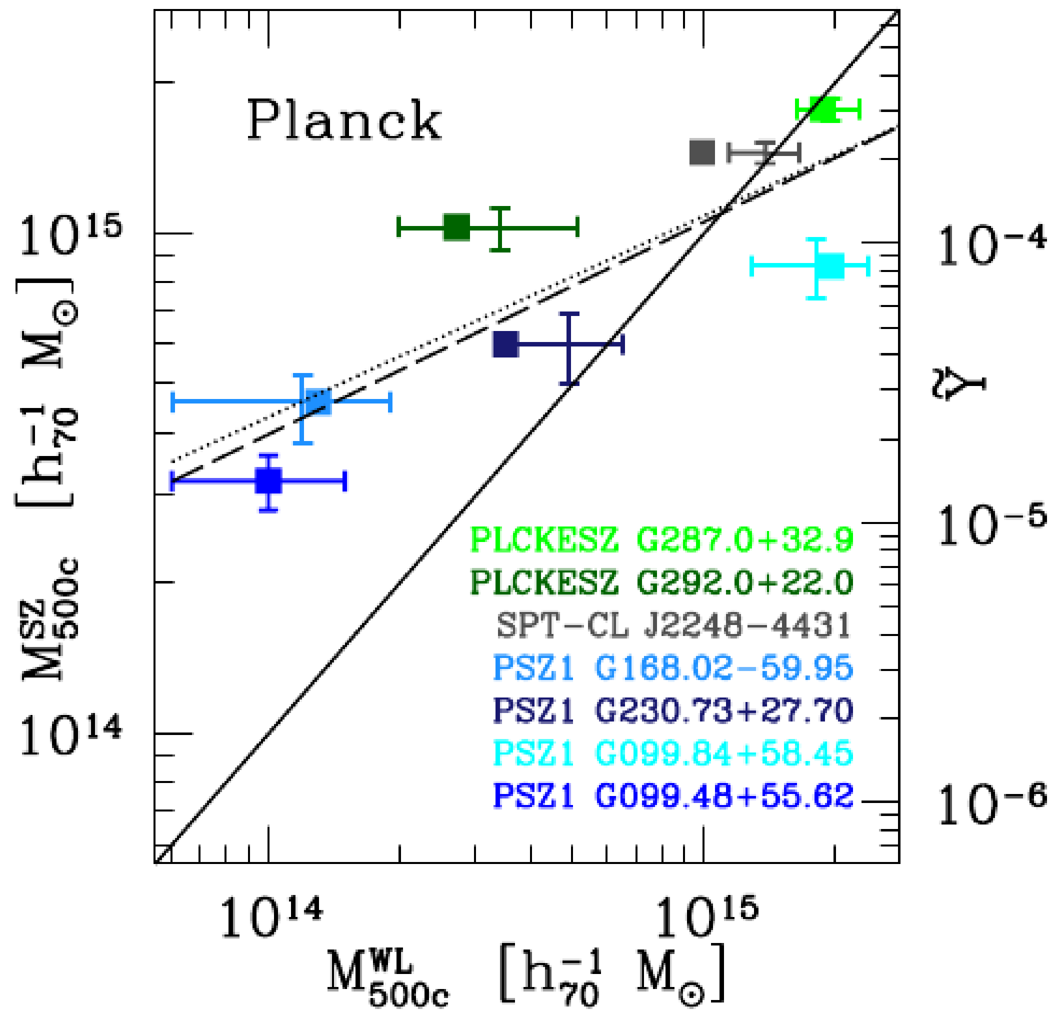
- At face value, Planck XX 2013 MOR excluded at 3σ



Planck SZ vs. weak lensing

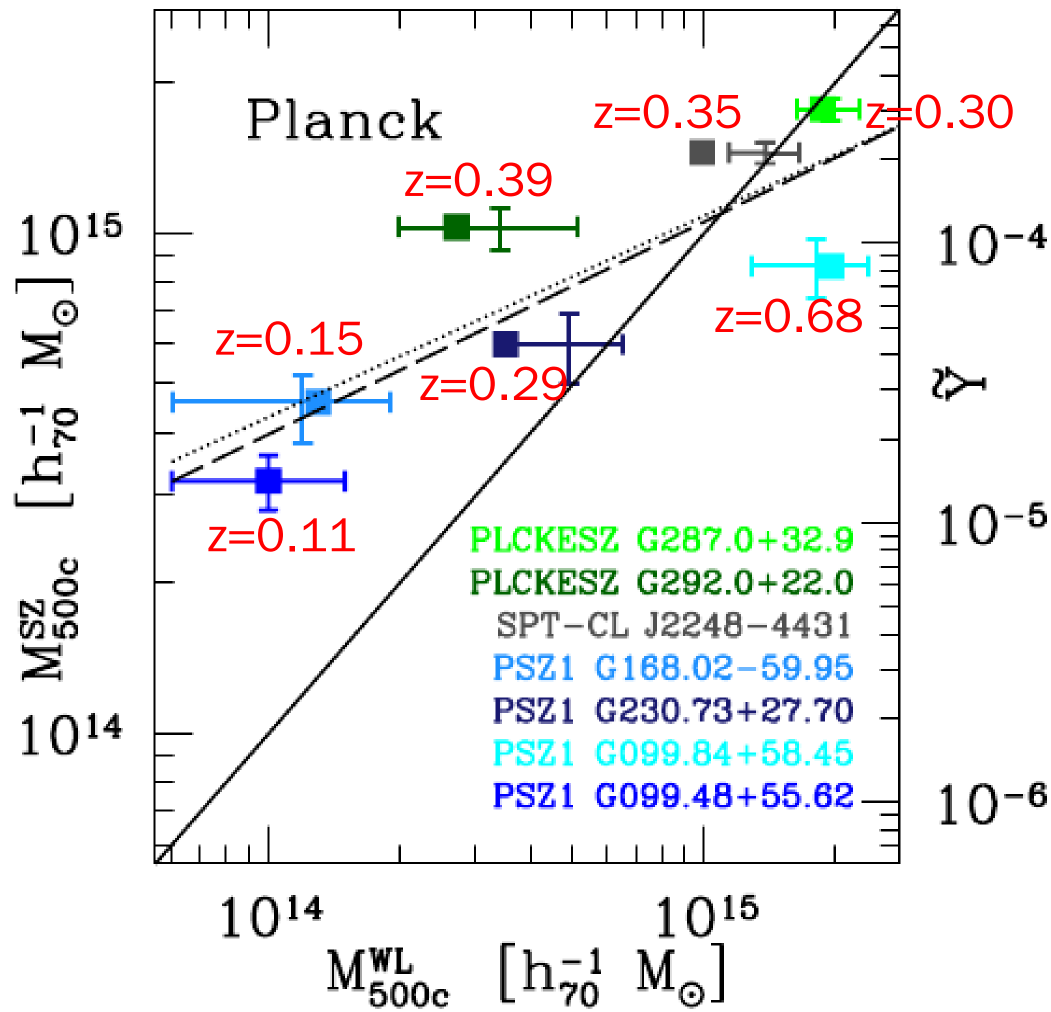
- At face value, Planck XX 2013 MOR excluded at 3σ
- Could this be
  - shallower MOR slope

(see also von der Linden+2014; Sereno, Ettori & Moscardini 2014)



Planck SZ vs. weak lensing

- At face value, Planck XX 2013 MOR excluded at 3σ
- Could this be
  - shallower MOR slope
  - redshift / size effect



Planck SZ vs. weak lensing

- At face value, Planck XX 2013 MOR excluded at 3σ
- Could this be
  - shallower MOR slope
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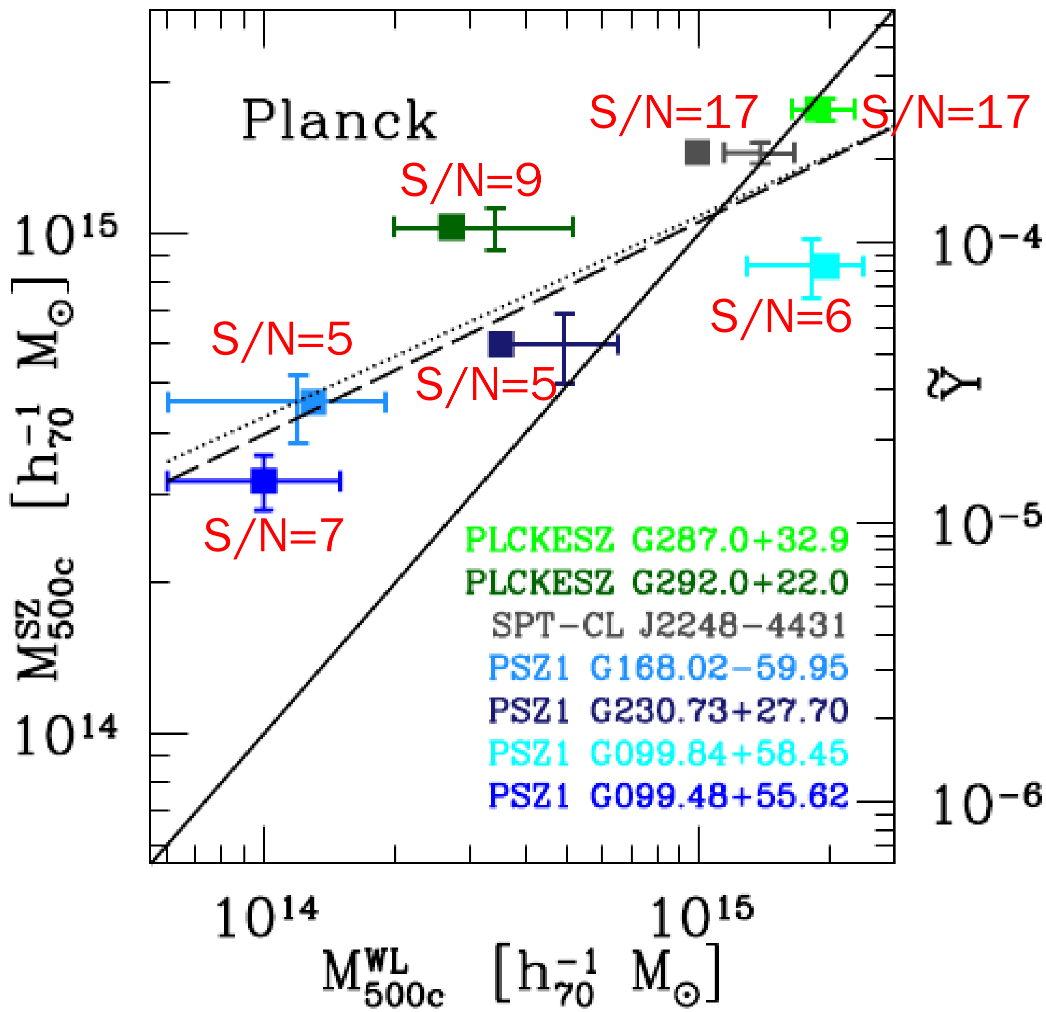
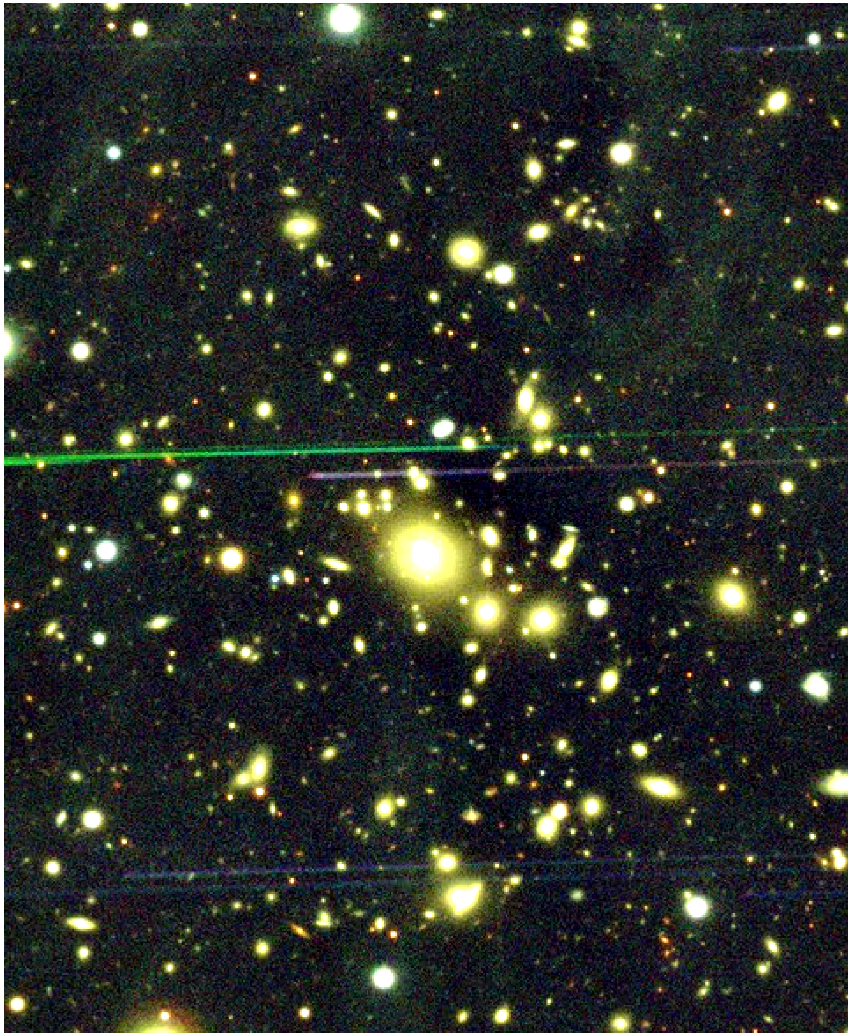
  - noise (bias)



Planck SZ vs. weak lensing

- At face value, Planck XX 2013 MOR excluded at 3σ
- Could this be
  - shallower MOR slope
  - redshift / size effect
  - noise (bias)
  - chance (N=7) ?



PSZ1G118.58+28.57 (85° N) seen by the Wendelstein 2m telescope

Summary:
Weak lensing of Planck/SPT clusters

Analysis of 12 clusters shows

- consistency with published hydrostatic X-ray mass
- consistency with SPT mass-significance relation
- disagreement with Planck MOR
  - hydrostatic bias, shallow slope, size/noise effect?
  - larger sample to be analyzed

Part 2:

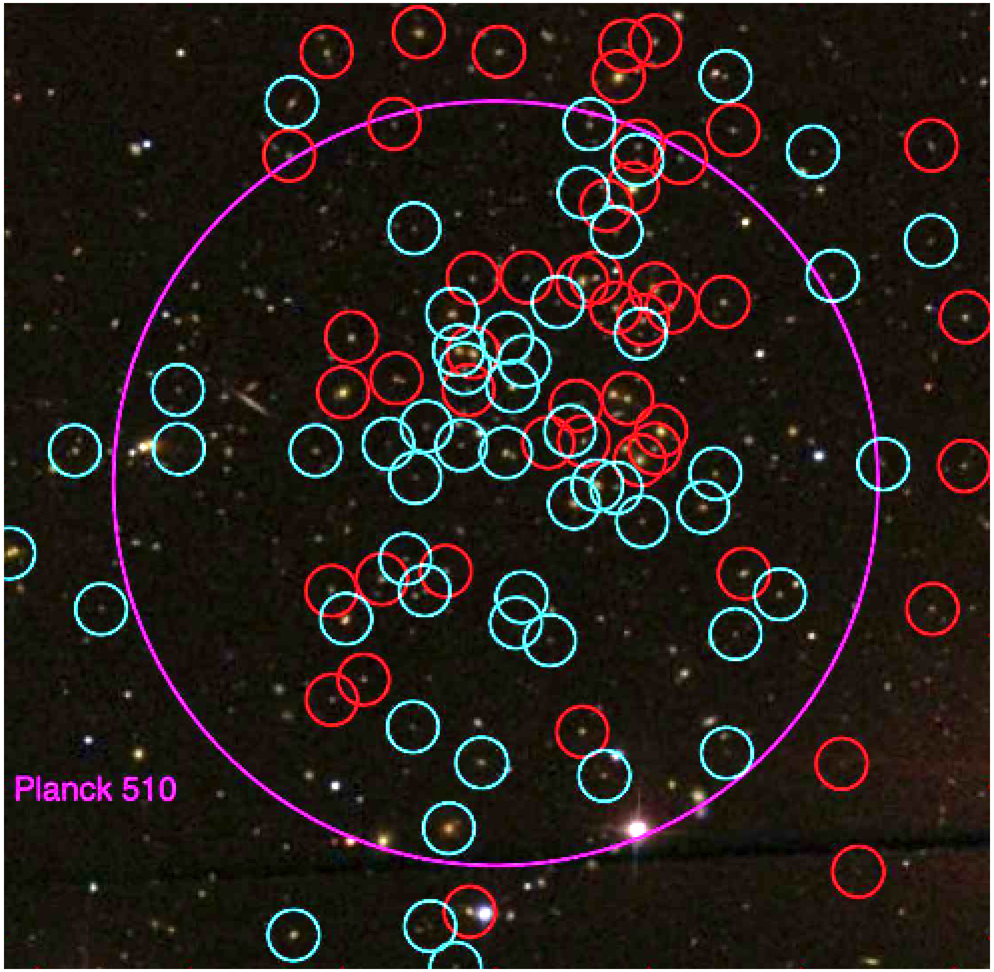
The (projected) group environment of Planck SZ detections

Ralf Kosyra, DG, S. Seitz, A. Mana, E. Rozo, E. Rykoff

work in progress, comments/suggestions very welcome

Motivation

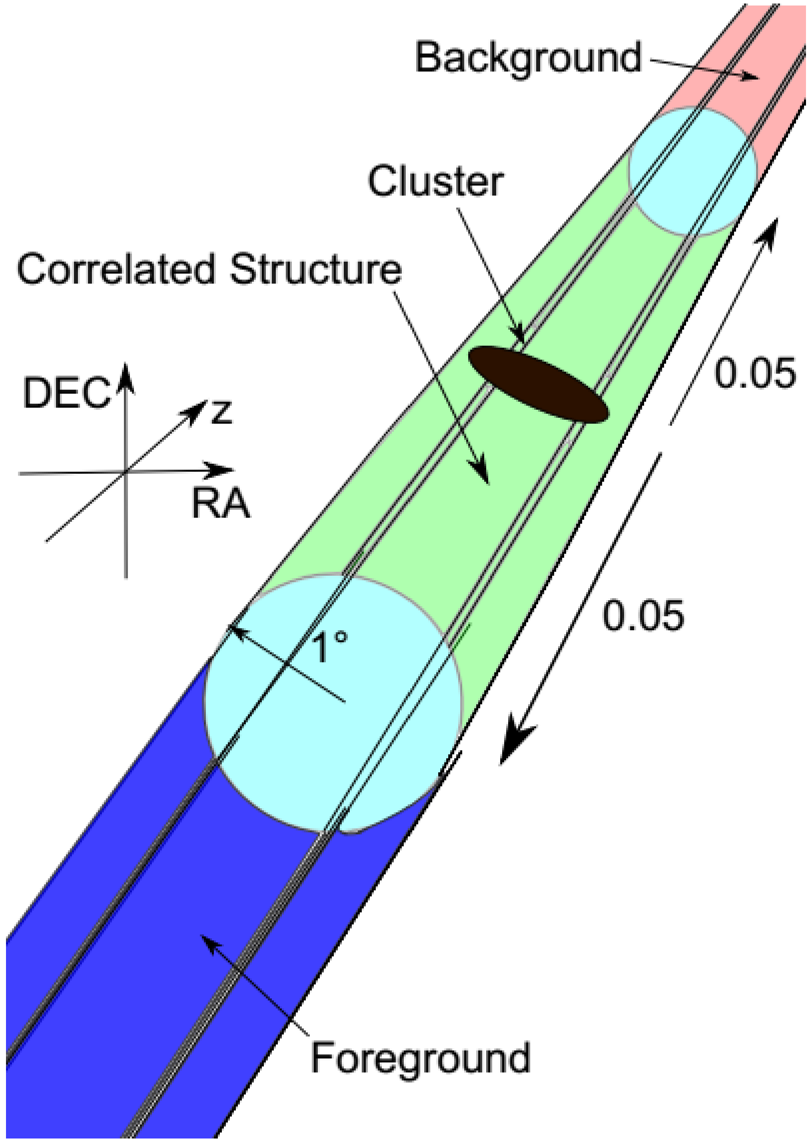
- Planck beam size makes blending a potential issue
- Idea: cross-correlate SDSS redMaPPer groups (Rozo+, Rykoff+2014) and Planck clusters



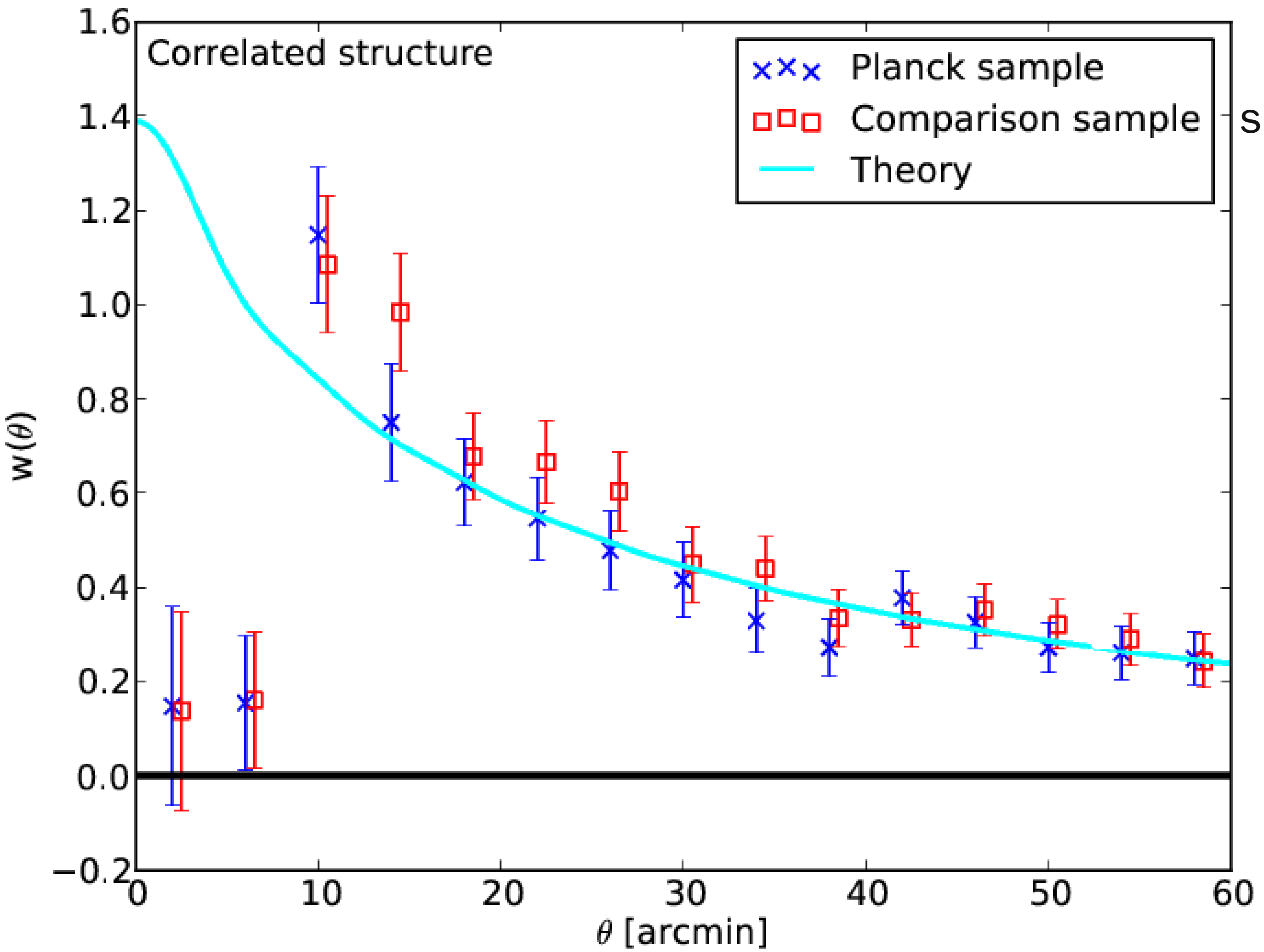
Source: Rozo+2014, z_1=0.27, z_2=0.37

Data and methods

- SDSS DR 8 (~10,000 sq. deg)
- Planck 2013 XXIX SZ catalog
  - ~300 clusters in SDSS, z<0.5
- RedMaPPer catalog (Rykoff+2014)
  - ~400,000 groups with richness >5
- foreground, background and correlated groups
- Jackknife errors



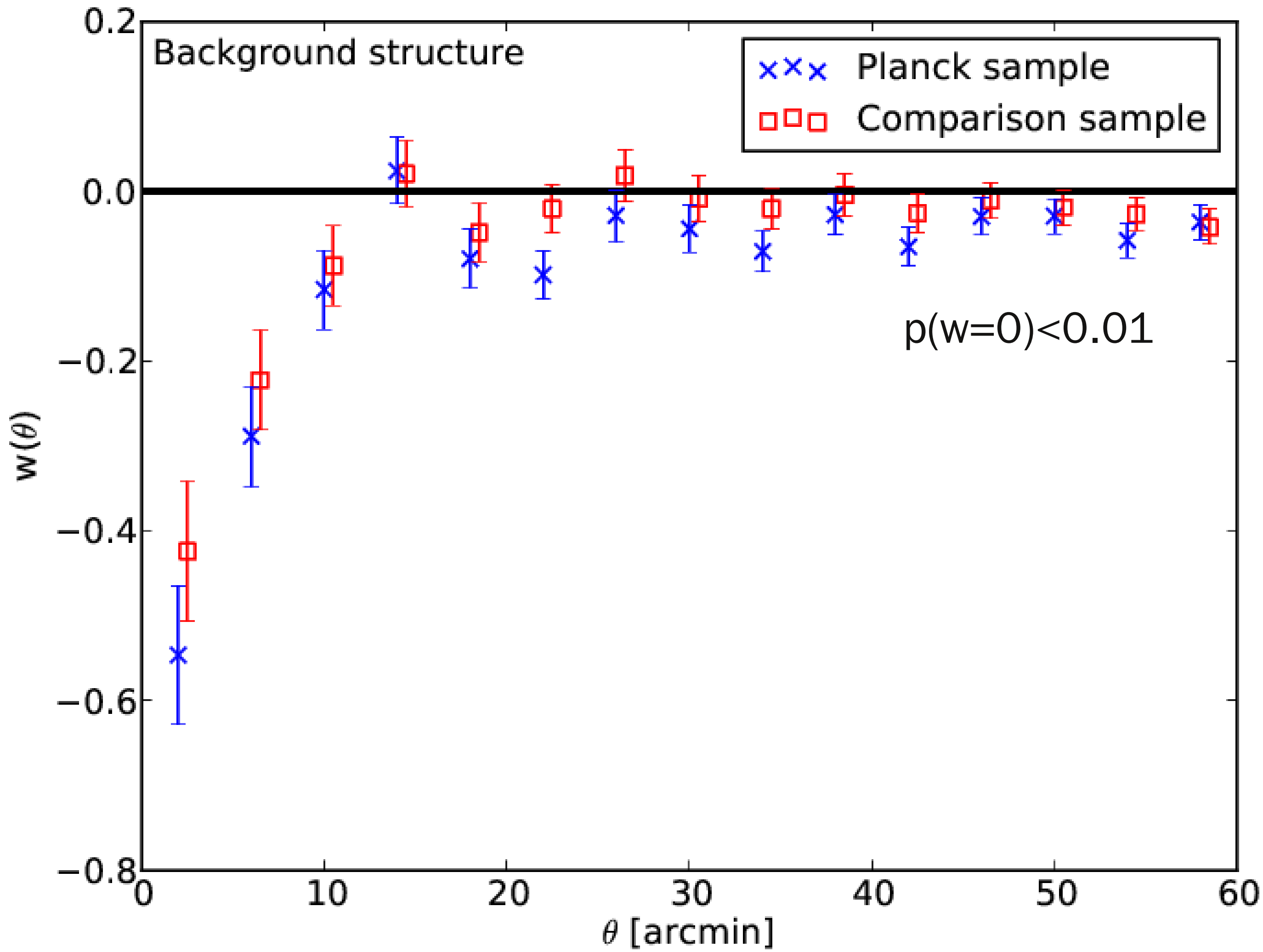
Preliminary results: correlated group density as expected



similar to Planck in richness / redshift

Kosyra et al. in prep

Preliminary results: small defect of background groups

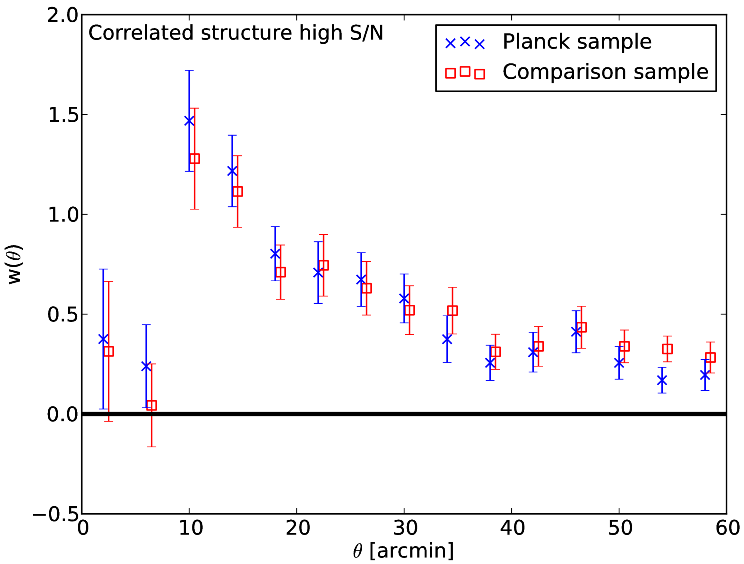


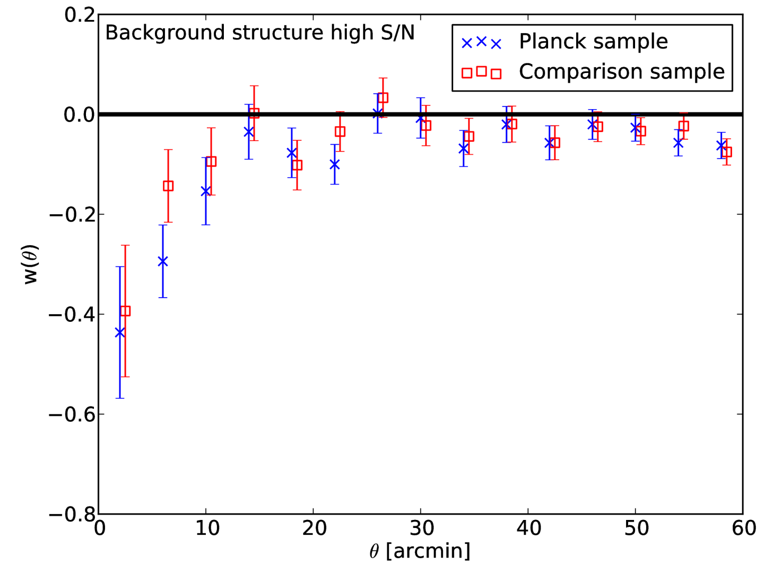
Kosyra et al. in prep

Preliminary results: problem is limited to low SZ S/N

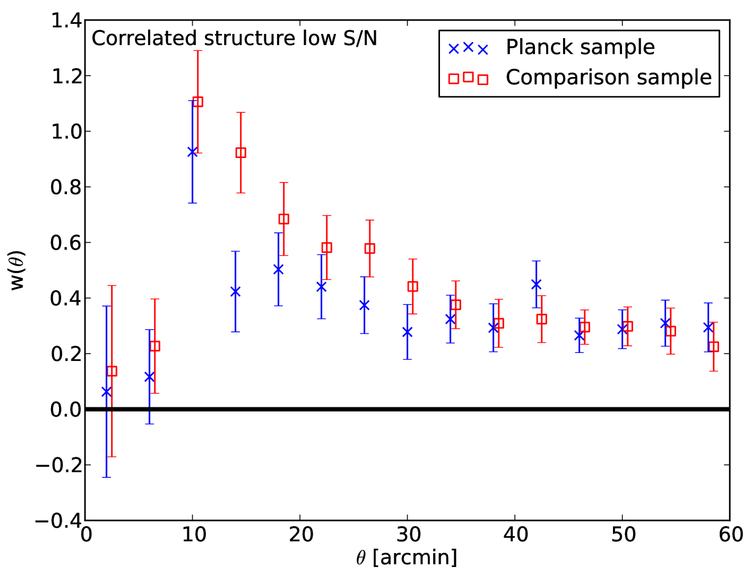
S/N>5.4

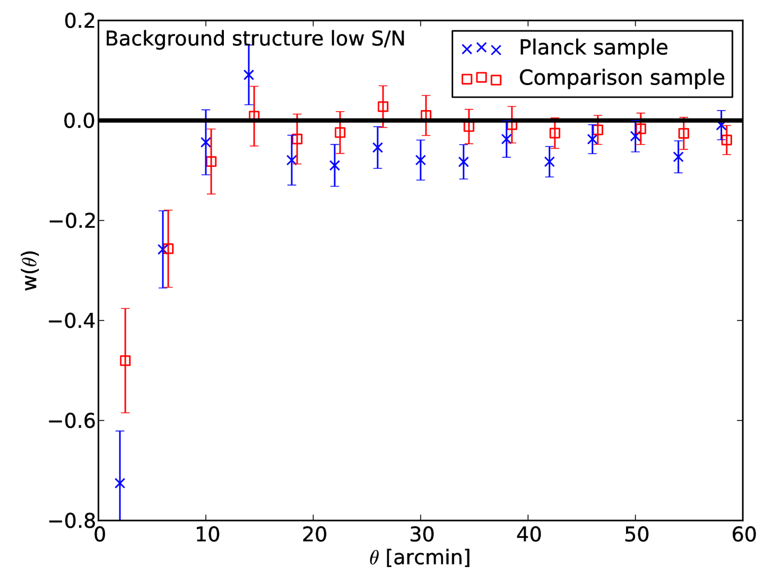
Planck XX uses S/N>7





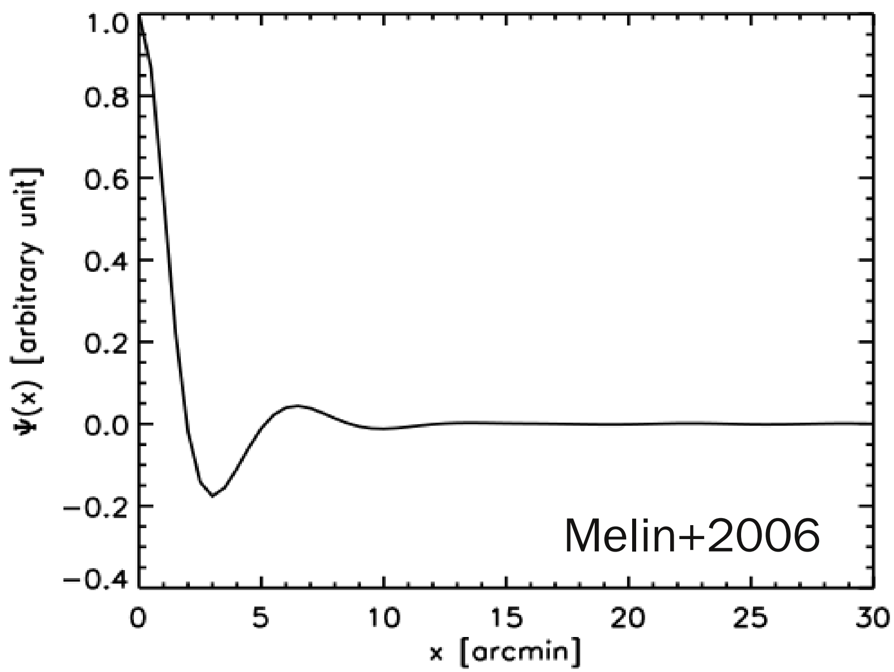
S/N<5.4





What could be the cause?

- High frequency filter? But:
  - multi-band information
  - SZ signal of groups weak
- Point source contamination?
  - Confusion by radio/sub-mm sources (e.g. Lin+2002)
- ?



A problem for mass calibration?

SZ / X-ray:

- groups contribute little
- typical cluster: $\Delta Y_{SZ}/Y_{SZ} < 10^{-3}$ inside Planck beam

Lensing

- 5% missing matter between z_l=0.2, z_s=1 causes $\Delta\kappa$~0.003
- Comparable to mean κ of cluster WL
- but: mass-sheet degeneracy

Summary:
Planck SZ projected environment

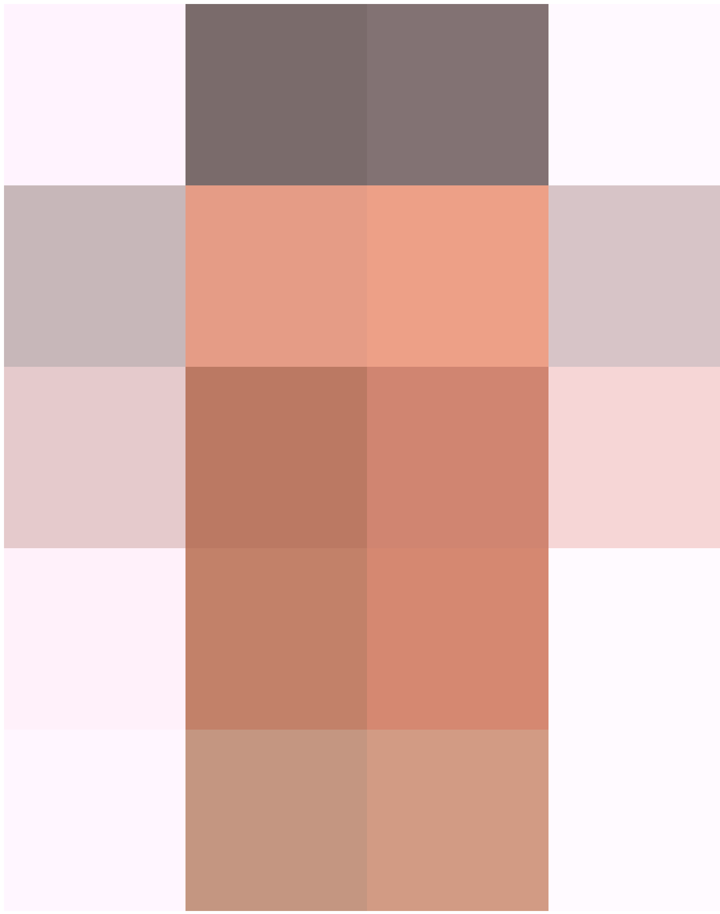
- Evidence for preferential selection of clusters with low background density
- Systematic effect on SZ measurement small, especially at large SZ S/N
- Systematics on lensing potentially larger

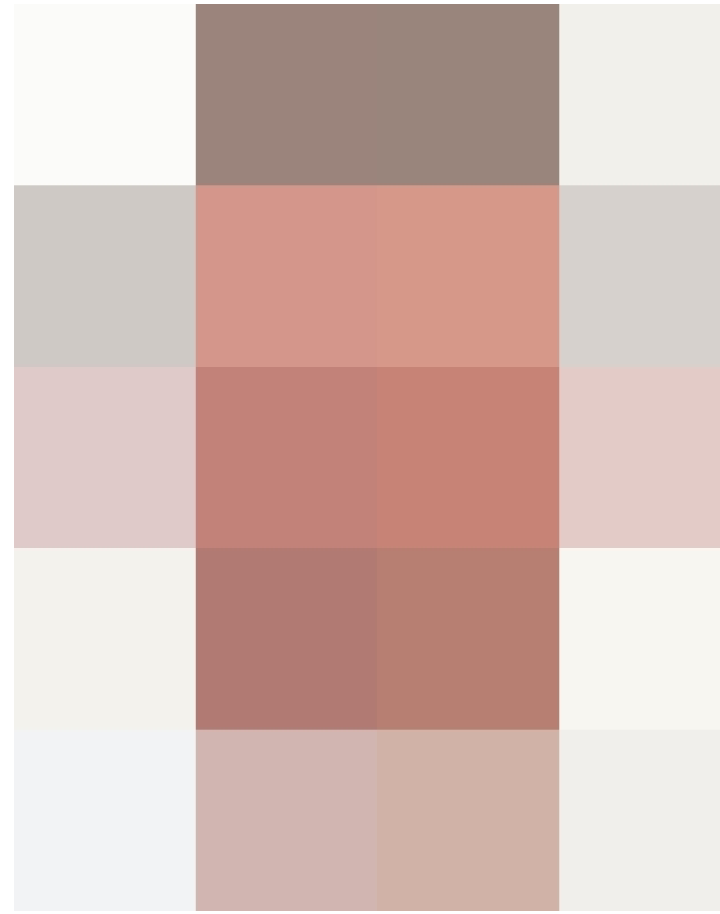
Part 3:

The cosmic variance of the cluster weak lensing signal

DG, S. Seitz, M. Becker, O. Friedrich

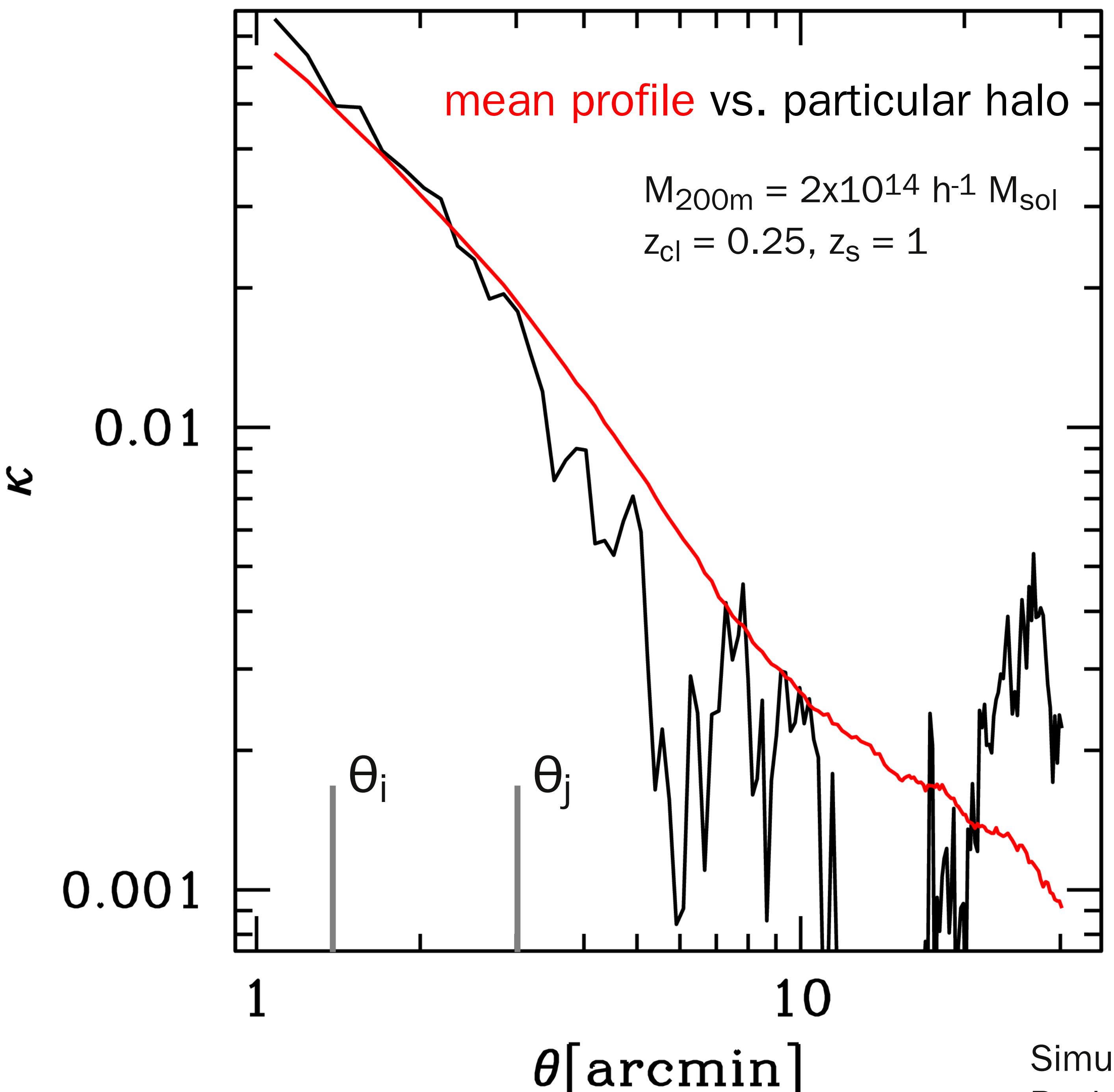
work in progress, comments/suggestions very welcome





Source: M. Gruendl, Institute for Psychology, Regensburg University



Goal:
model the covariance of $(\kappa\text{-}K)_i$, $(\kappa\text{-}K)_j$

Test against 15,000 simulated clusters

Simulated cluster profiles: M. Becker
Becker & Kravtsov 2011

Why bother?

- We want to interpret shear / magnification signal as a likelihood of cluster mass
- Confidence interval and minimum variance estimation depends on full covariance at fixed mass, including intrinsic variability
- Systematic underestimation of uncertainty leads to bias in derived MOR parameters, particularly intrinsic scatter
- Ignoring or self-calibrating this in cluster surveys yields biased / relaxed cosmology constraints

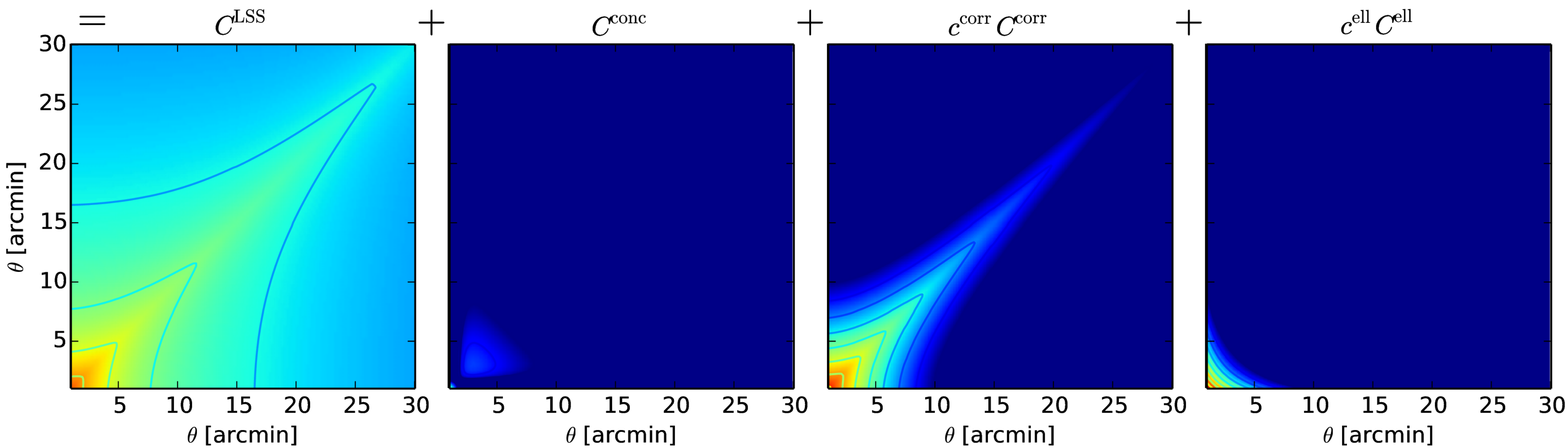
Covariance model for κ(r)

The κ data vectors for two clusters of same mass could differ due to

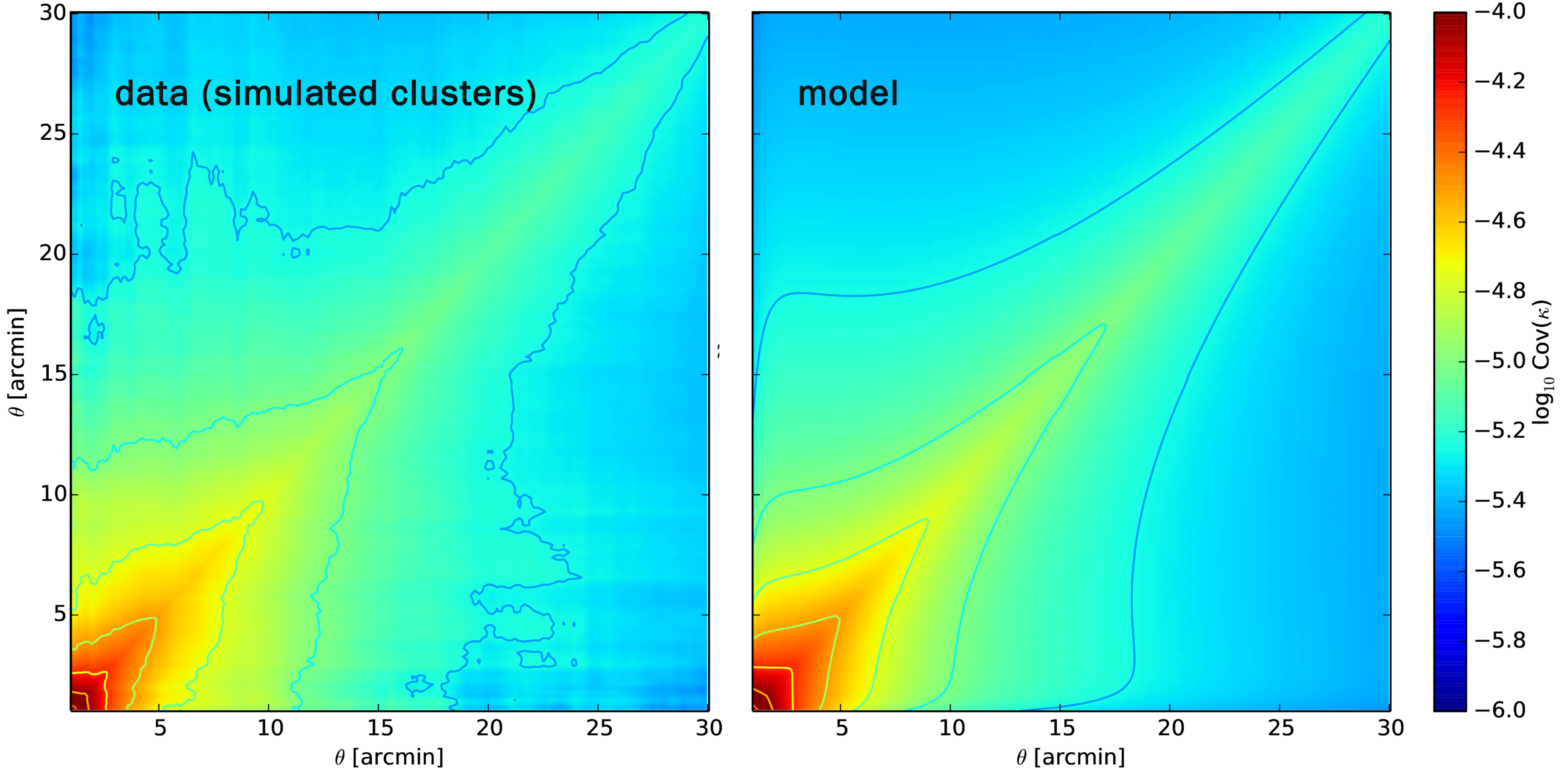
- observational uncertainty $\mathbf{C}^{\mathbf{obs}}$
- uncorrelated structure $\mathbf{C}^{\mathbf{LSS}}$ common
  (e.g. Hoekstra 2001, 2003; Dodelson 2004; Schirmer+2007)
- Intrinsic variations of cluster profiles
  - Concentration scatter $\mathbf{C}^{\mathbf{conc}}$
  - Halo ellipticity and orientation $\mathbf{C}^{\mathbf{ell}}$ new
  - Projected correlated structure $\mathbf{C}^{\mathbf{corr}}$

Covariance model for κ(r)

$$C(M) \quad = \quad C^{\rm obs} + C^{\rm LSS} + C^{\rm conc}(M) + \quad c^{\rm corr}(\nu)C^{\rm corr}(M) + c^{\rm ell}(\nu)C^{\rm ell}(M)$$

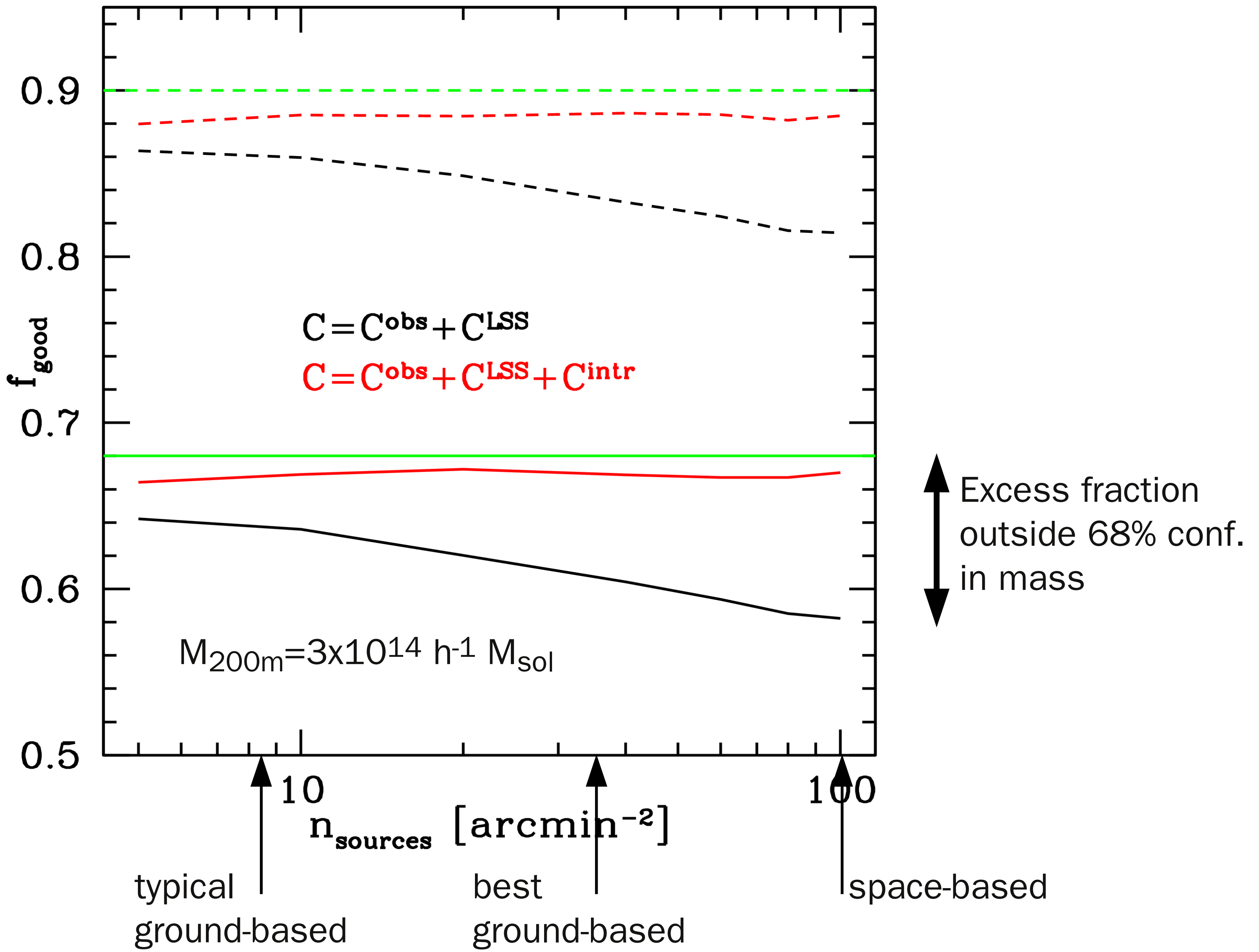


Covariance model for κ(r)



z_l=0.25, z_s=1, M_{200m}=2x10^{14} h^{-1} M_{sol}

Mass confidence intervals



Summary

- Lensing analysis of Planck clusters with indication of discrepancies
  - self-similar slope? hydrostatic bias? size/noise bias?
- Environment-based selection in Planck clusters
  - at low S/N: point source confusion? blending?
- Intrinsic variation of cluster density profiles influences lensing analysis / MOR calibration
  - simple model captures most of this