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Sesto 2013

Cluster Mass Distribution from Weak Lensing Shear and Magnification

Keiichi Umetsu,
ASIAA, Taiwan

Acknowledgment

ASIAA, Taiwan

- **Nobuhiro Okabe** (ASIAA → IPMU from Sep) and LocuSS
- **Jean Coupon** (ASIAA →Geneva from Oct)

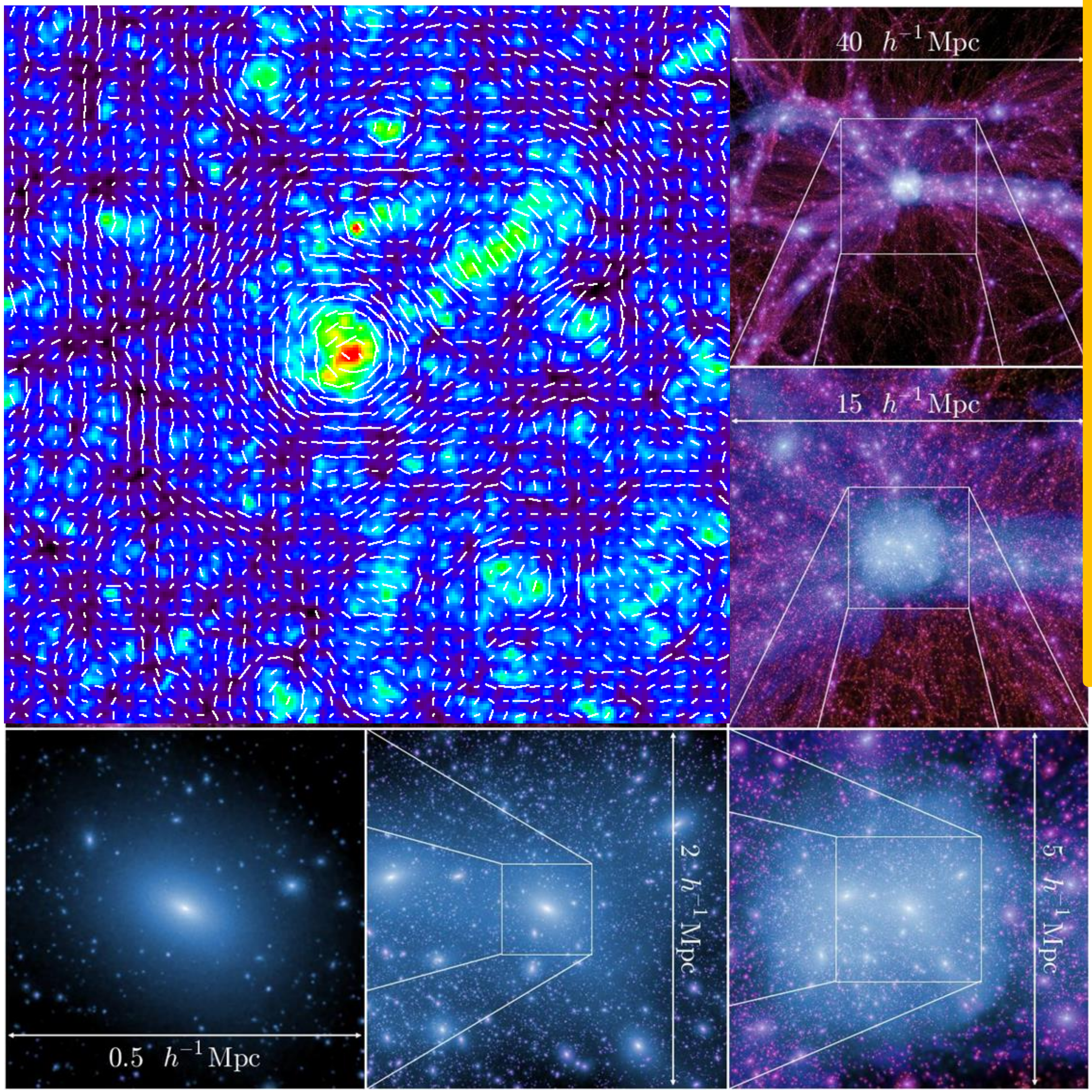
CLASH team, with special thanks to CLASH-WL:

- **Elinor Medezinski**
- **Mario Nonino**
- **Alberto Molino**
- **Stella Seitz**
- **Julian Merten**
- **Peter Melchor**
- **Anton Koekemoer**
- **Marc Postman**
- **Holland Ford**
- **Tom Broadhurst**

Next speakers

Galaxy Clusters as Cosmological Probes

Boylan-Kolchin+09



Surrounding LSS (2h)

- ✓ Halo bias $b(M,z)$
- ✓ Primordial matter $P(k)$

Halo structure (1h)

- ✓ Average & individual $M(r)$: **Cluster cosmology** (**this and Anja's talks**)
- ✓ $c(M,z)$: **Halo assembly history**
- ✓ Central cusp: **DM nature** (**Tommaso's talk**)

Substructure

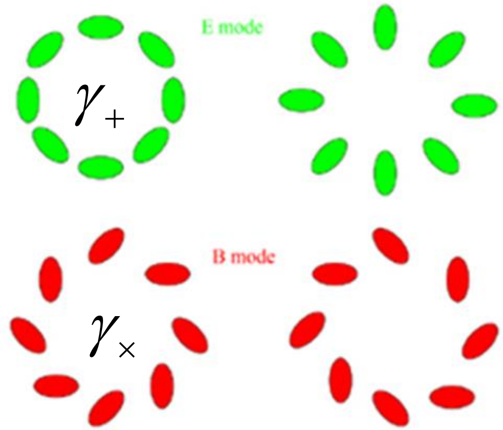
- ✓ Mass accretion history
- ✓ Subhalo mass function

Tangential Shear

Measure of azimuthally-averaged tangential coherence of elliptical distortions around a given point (Kaiser 95):

$$\gamma_+(R) = \Delta\Sigma_+(\mathrm{R}) / \Sigma_{\mathrm{crit}}(z_l, z_s)$$

$$\gamma_\times(R) = 0$$



$\Delta\Sigma_+$(R) is the *modulated* surface mass density of the lens:

$$\Delta\Sigma_+(R) = \Sigma(<R) - \Sigma(R)$$

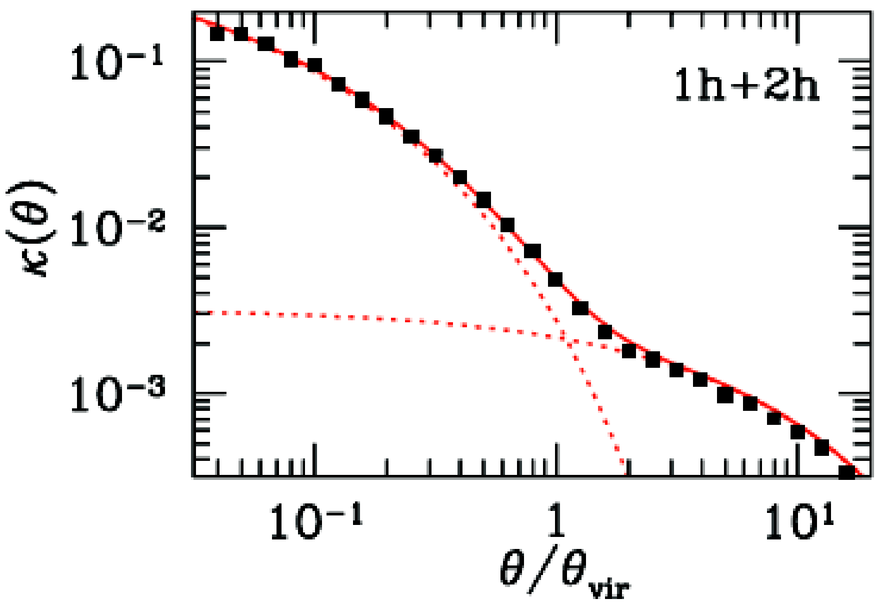
Sensitive to interior mass

$\Sigma_{crit}(z_l,z_s)$ is the *critical surface mass density of lensing*

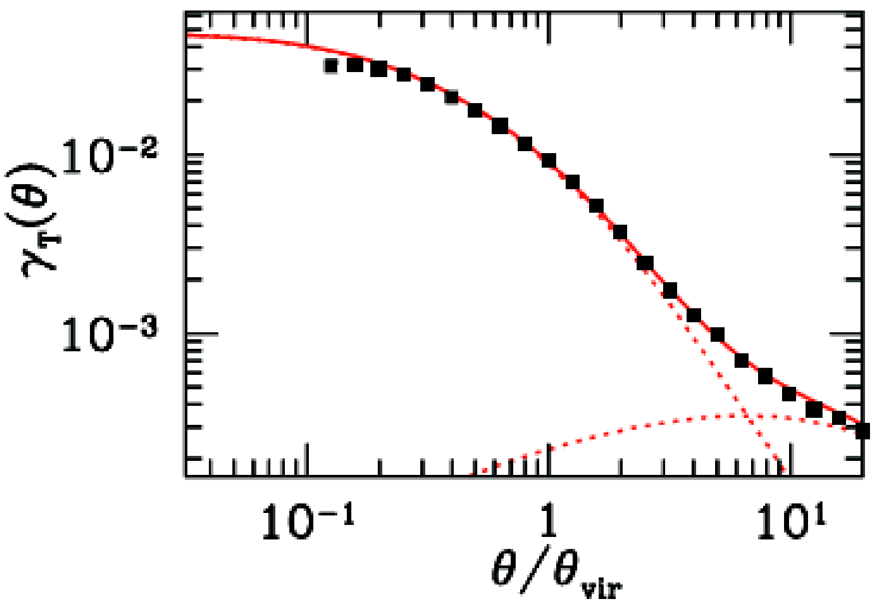
Shear doesn't see mass sheet

Averaged lensing profiles in/around LCDM halos (Oguri+Hamana 11)

$$\kappa = \Sigma(R)/\Sigma_{\rm crit}$$

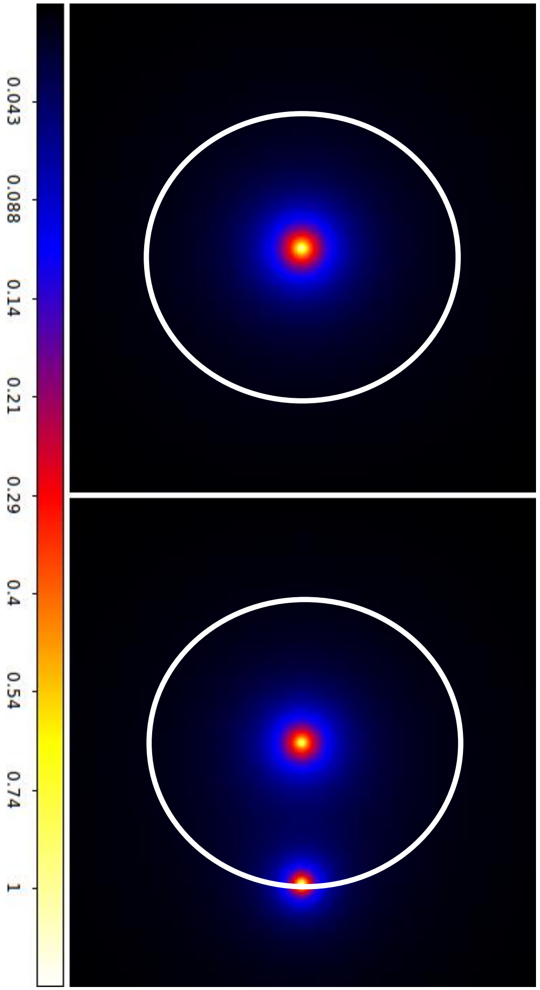


$$\gamma_+ = \Delta\Sigma_+(R)/\Sigma_{\rm crit}$$

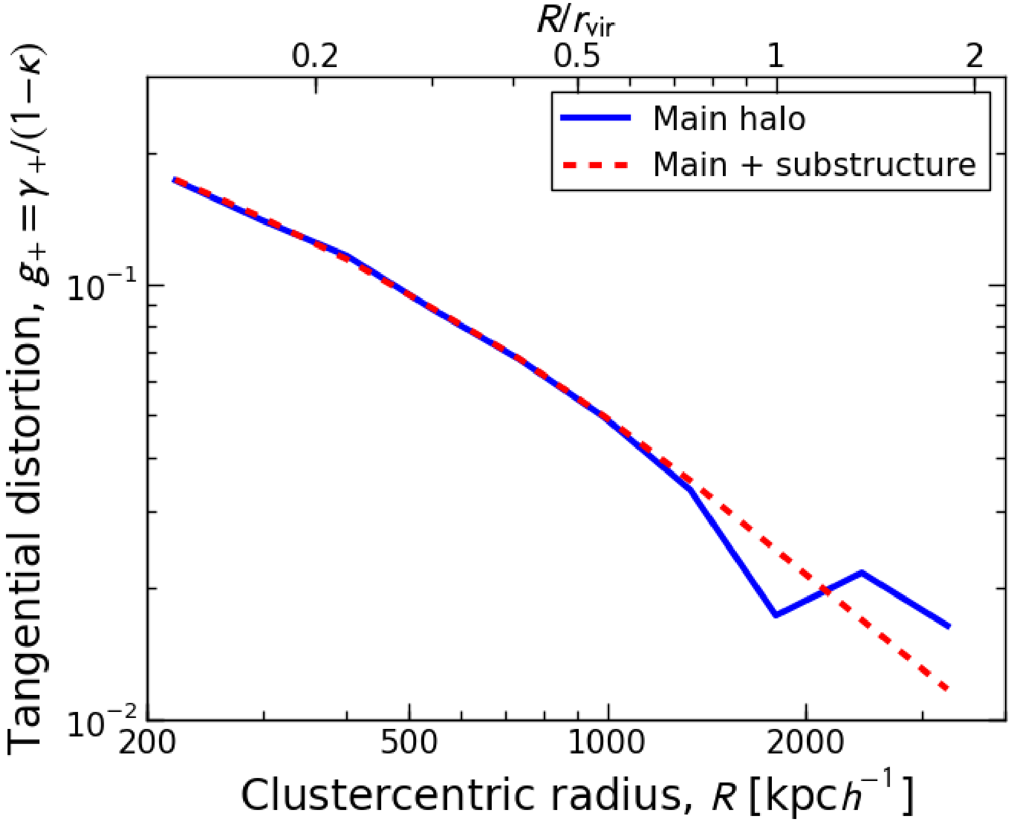


- **Tangential shear is a powerful probe of 1-halo term, or internal halo structure.**
- **Shear alone cannot recover absolute mass, known as *mass-sheet degeneracy***

Non-local substructure effect

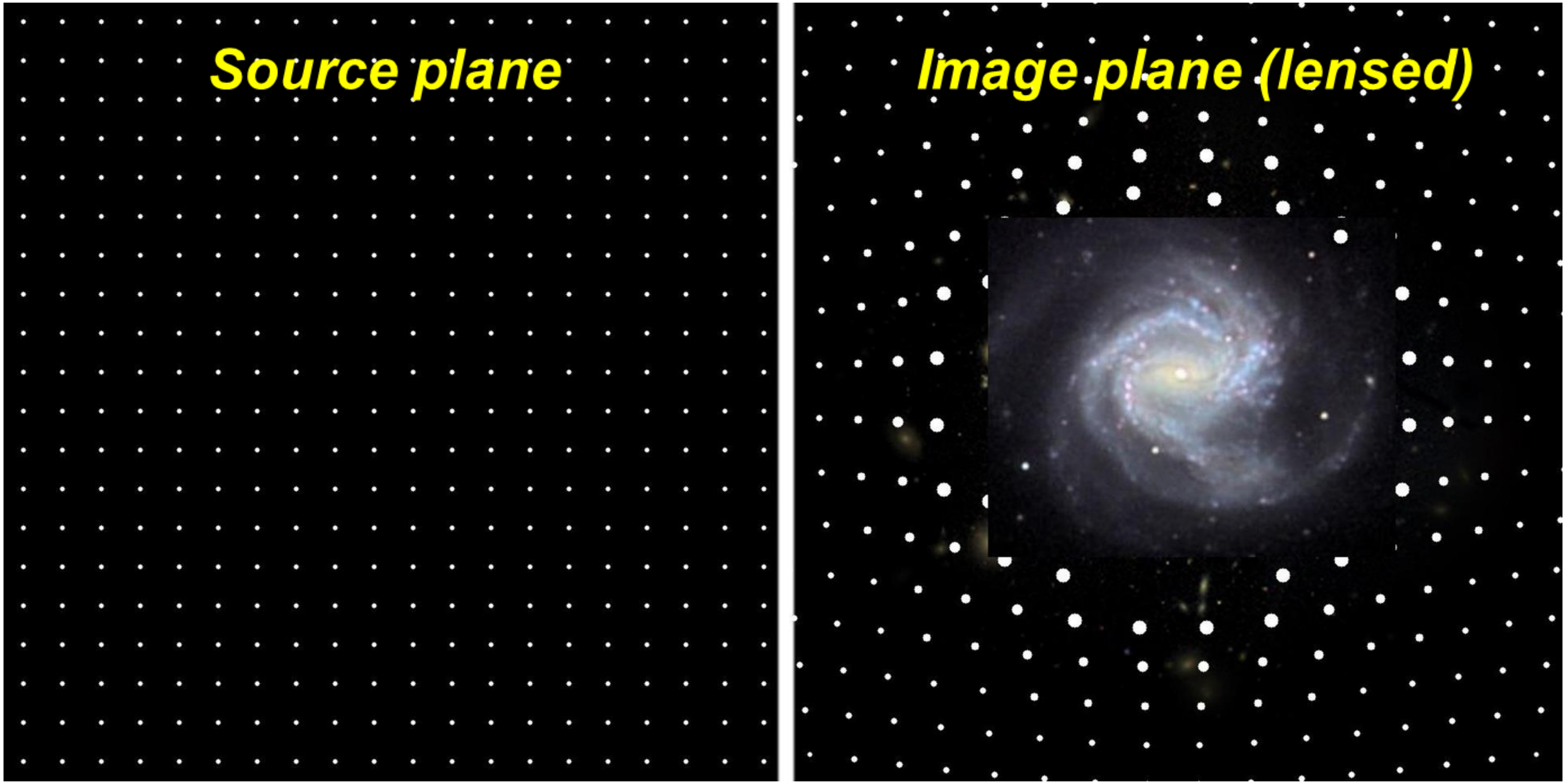


A substructure at R~r_{vir} of the main halo, modulating $\Delta\Sigma_+(R) = \Sigma(<R) - \Sigma(R)$



5-15% negative bias (M_{2500c} - M_{200c}) from tangential shear fitting, inherent to clusters sitting in biased, substructured fields (Rasia+12)

Magnification Effects



- Image flux, *F*: $\mu \sim 1+2\kappa$
- Image size, *r*: $\mu^{1/2} \sim 1+\kappa$
- Sky area, $\Delta\Omega$: $\mu \sim 1+2\kappa$

Sensitive to "local" matter density

$$\kappa = \Sigma / \Sigma_{crit}$$

Magnification bias effects

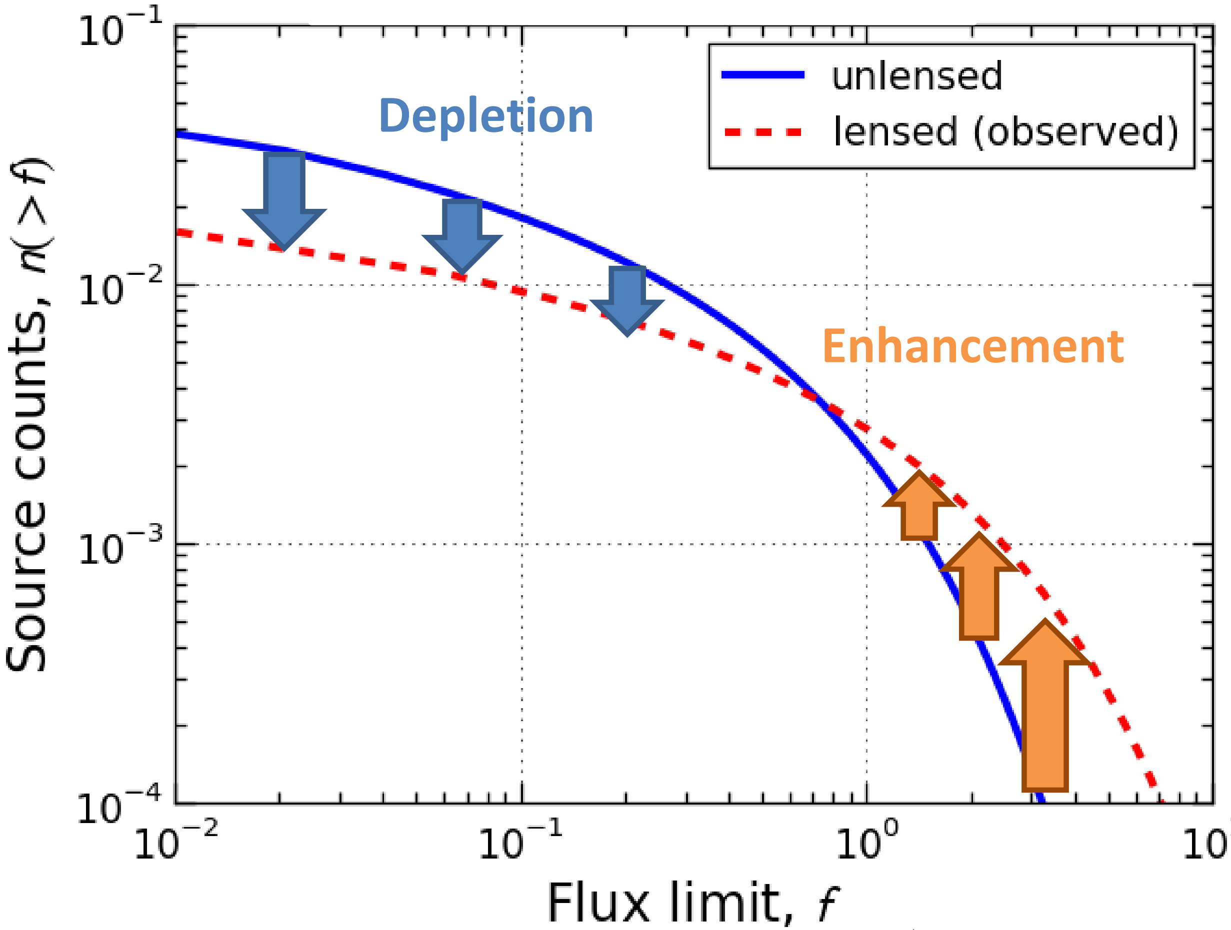
Flux-limited source counts:

$$n_{\rm obs}(>f) = \mu^{-1} n(>\mu^{-1} f)$$

Broadhurst, Taylor & Peacock 95

Geometric area distortion

n/μ

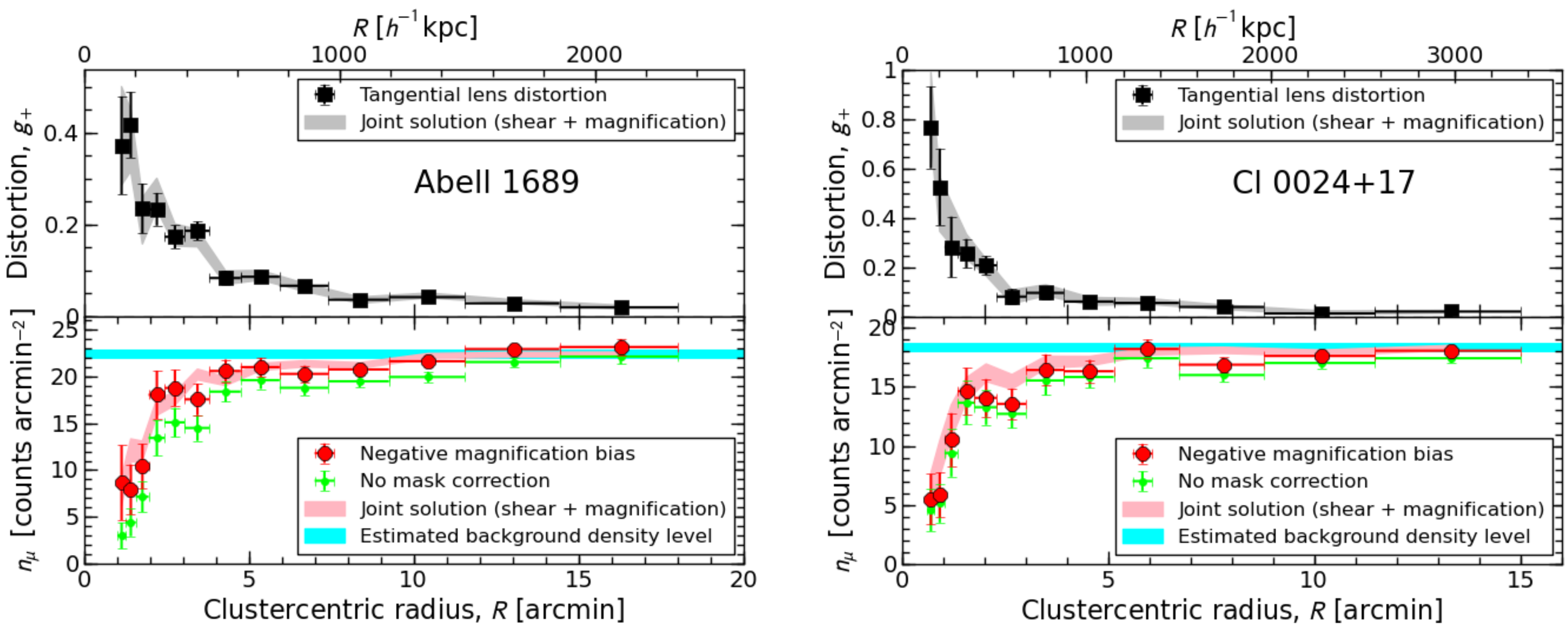


Flux amplification

Count depletion: geometric effect

Geometric shear-magnification consistency

Flux-limited red galaxy samples at <z>~1 highly depleted



Umetsu+11a, ApJ, 729, 127

High-purity background source selection (color-color selection) is the most critical requirement for accurate cluster weak-lensing measurements!!

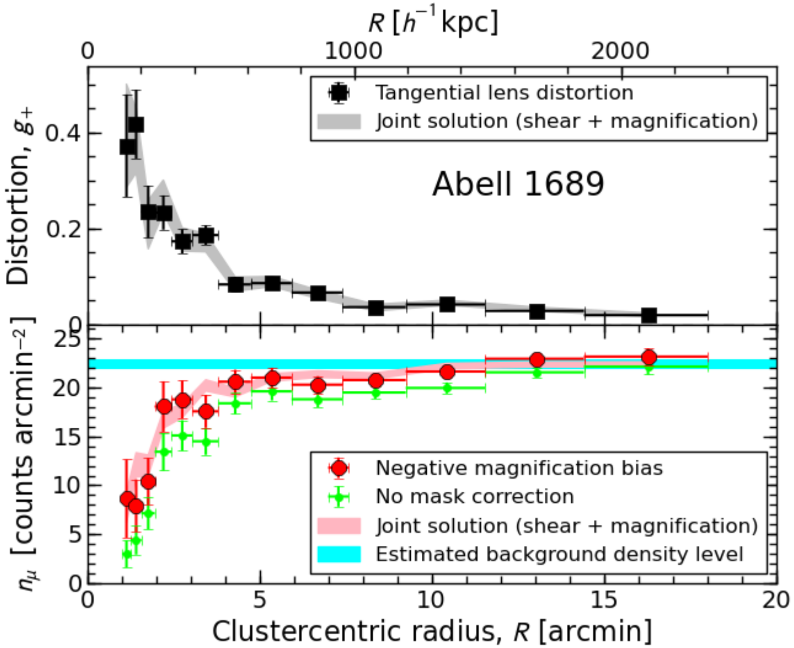
See Elinor's talk.

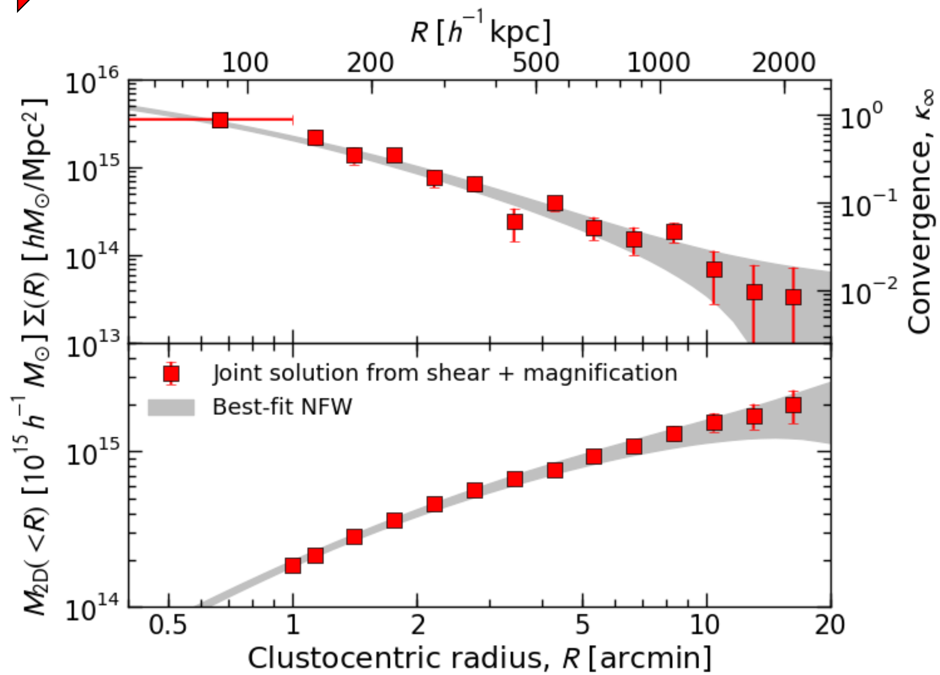
Combining Shear and Magnification

Bayesian joint-likelihood method (Umetsu+11a, ApJ, 729, 127)

Shear + magnification

Non-parametric Σ(R) solution



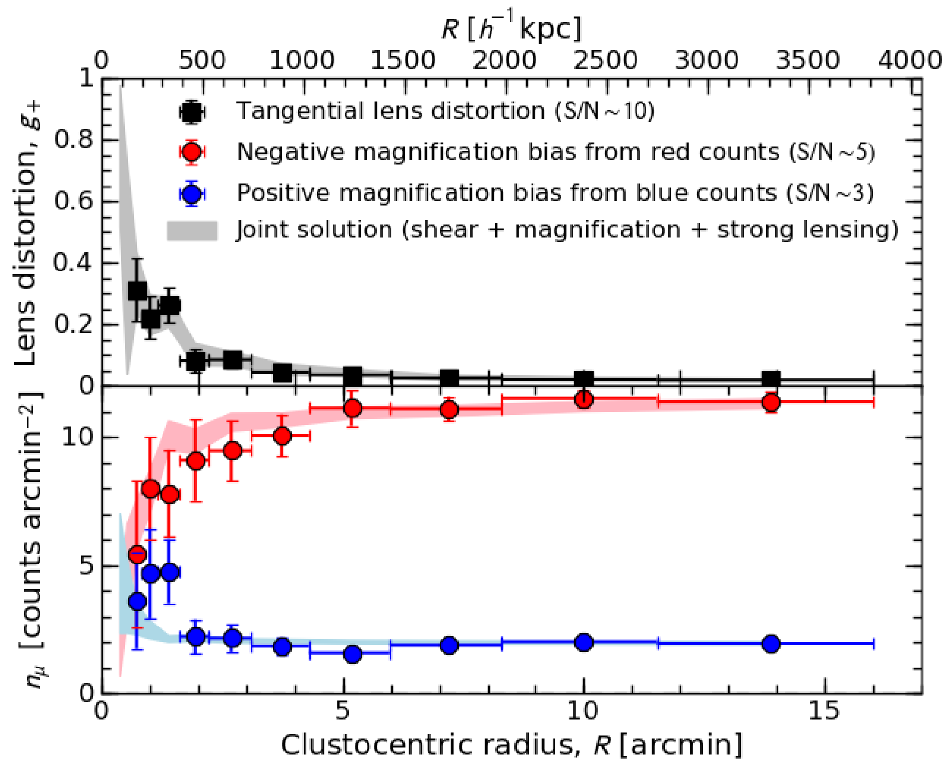


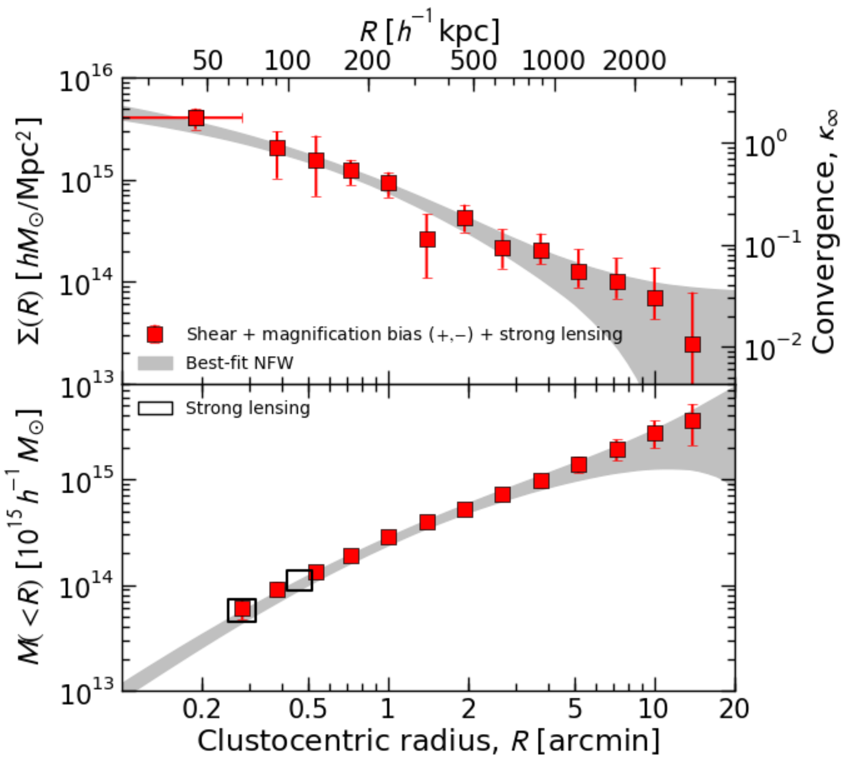
- Mass-sheet degeneracy broken
- Total statistical precision improved by ~20-30%
- Reduced sensitivity to systematics

Multi-probe Lensing Approach:

Shear, magnification bias (+,-), strong lensing

X-ray selected cluster MACS1206 (z=0.44)





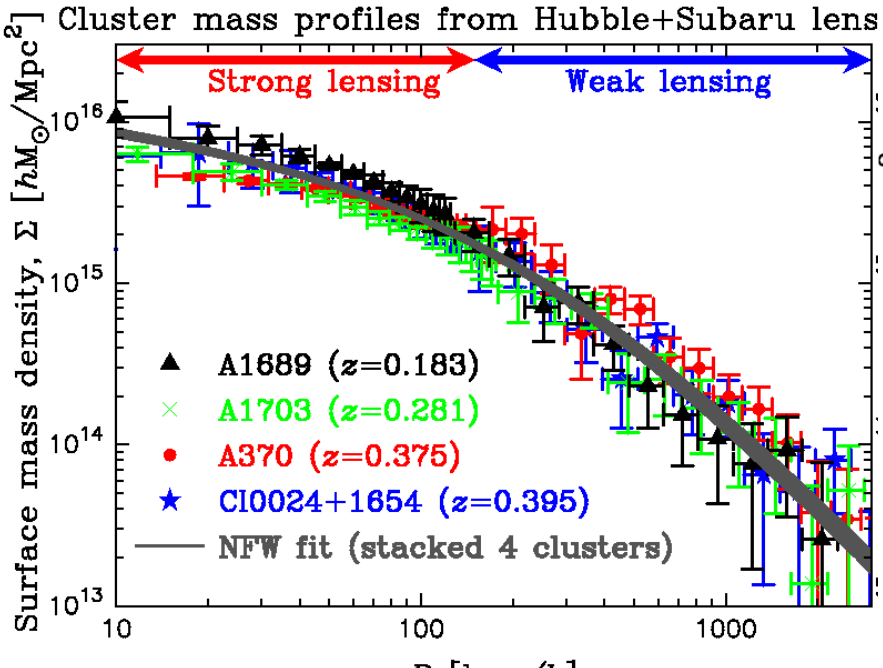
Umetsu, Medezinski, Nonino+CLASH 12, ApJ
Umetsu 13, ApJ, 769, 13 [methodology]

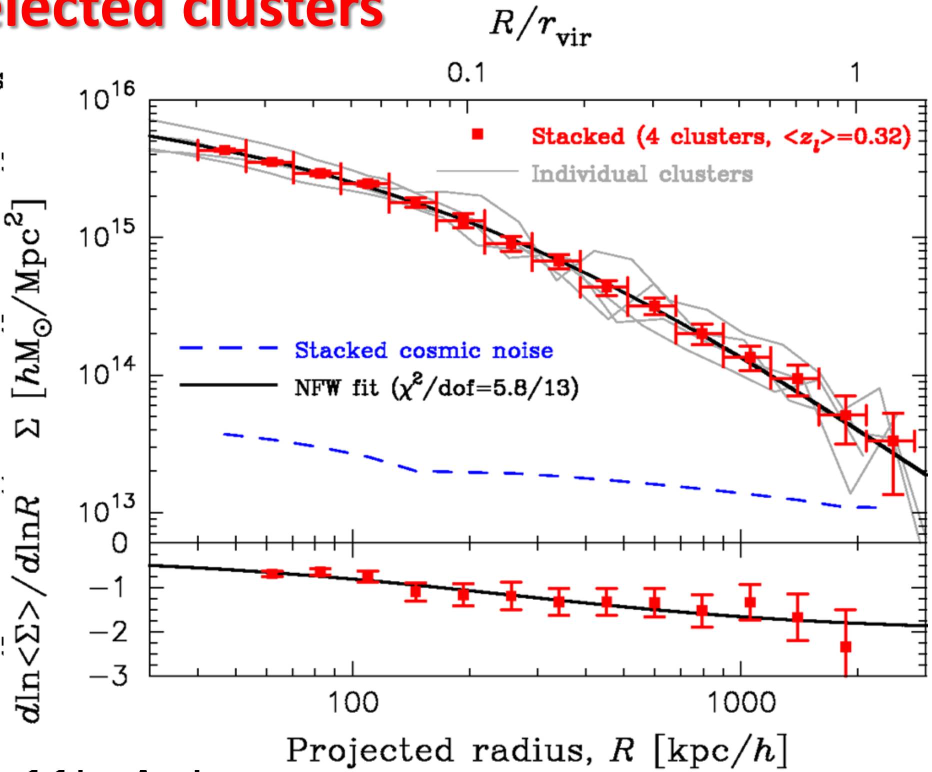
See Elinor's talk for MACS0717

Mass profiles from full lensing analysis

Multi-probe lensing approach (**SL** + **shear** + **magnification**) with ***HST*+Subaru**, probing R= ~10kpc/h to ~3000kpc/h, also providing consistency tests against systematics

“pre”-CLASH work on 4 lensing-selected clusters

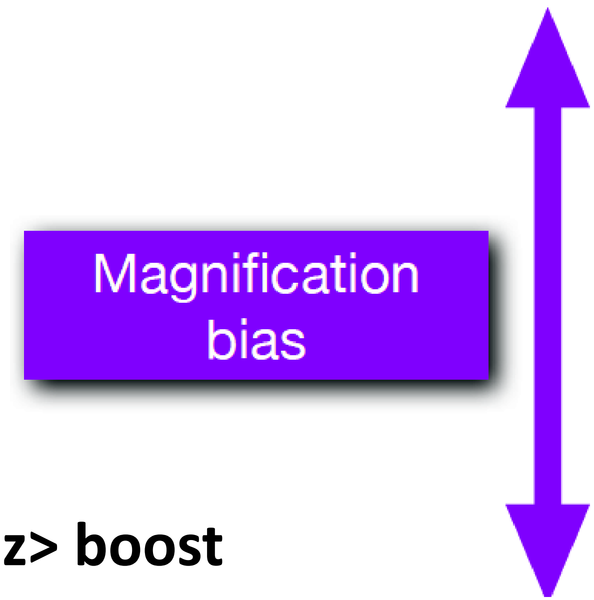


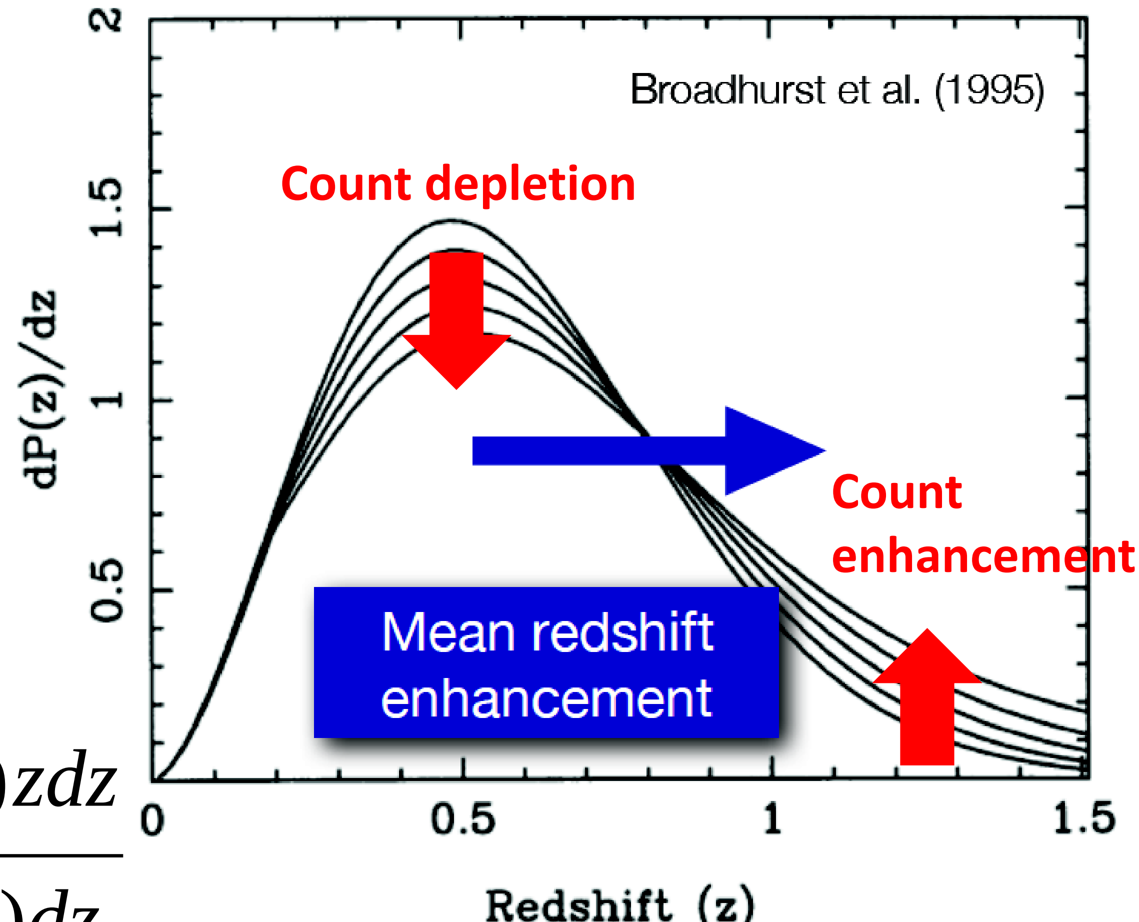


Umetsu+11a. 11b, ApJ

Magnification boosts <z_{source}>

Flux-limited redshift samples of background sources



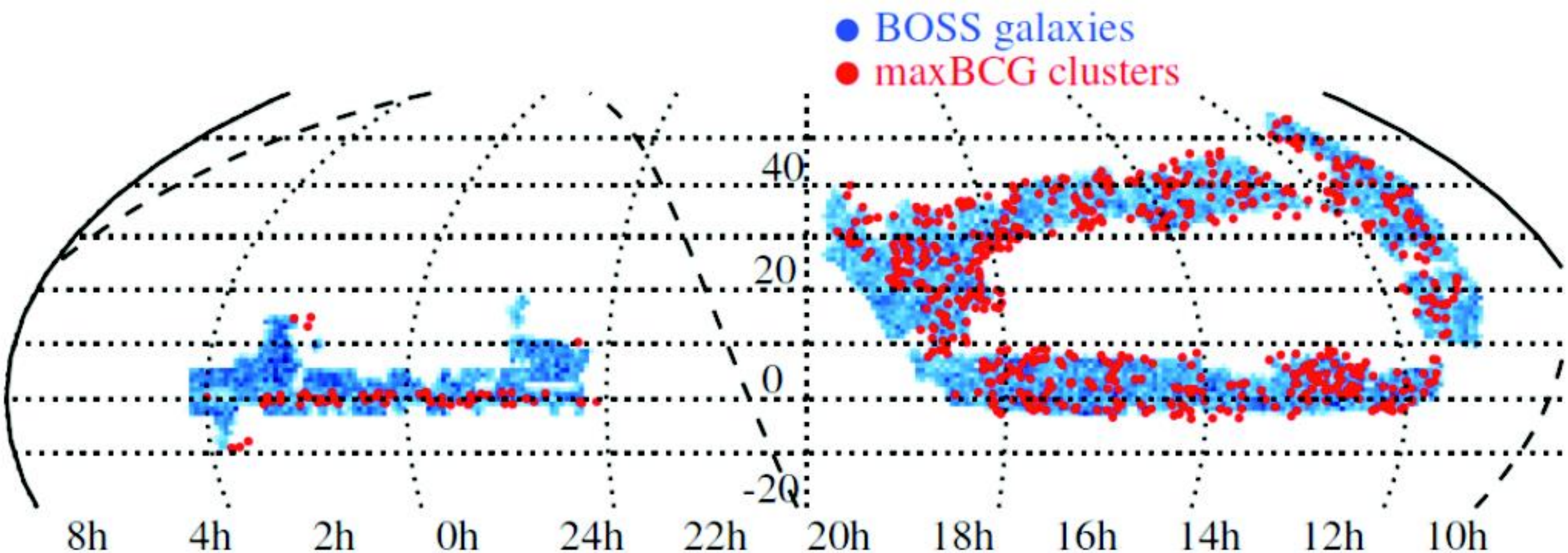


<z> boost

$$\bar{z}_{\mathrm{lensed}} = \frac{\int n_{eff}(z;\mu[z]) z dz}{\int n_{eff}(z,\mu[z]) dz}$$

Applications to SDSS/BOSS

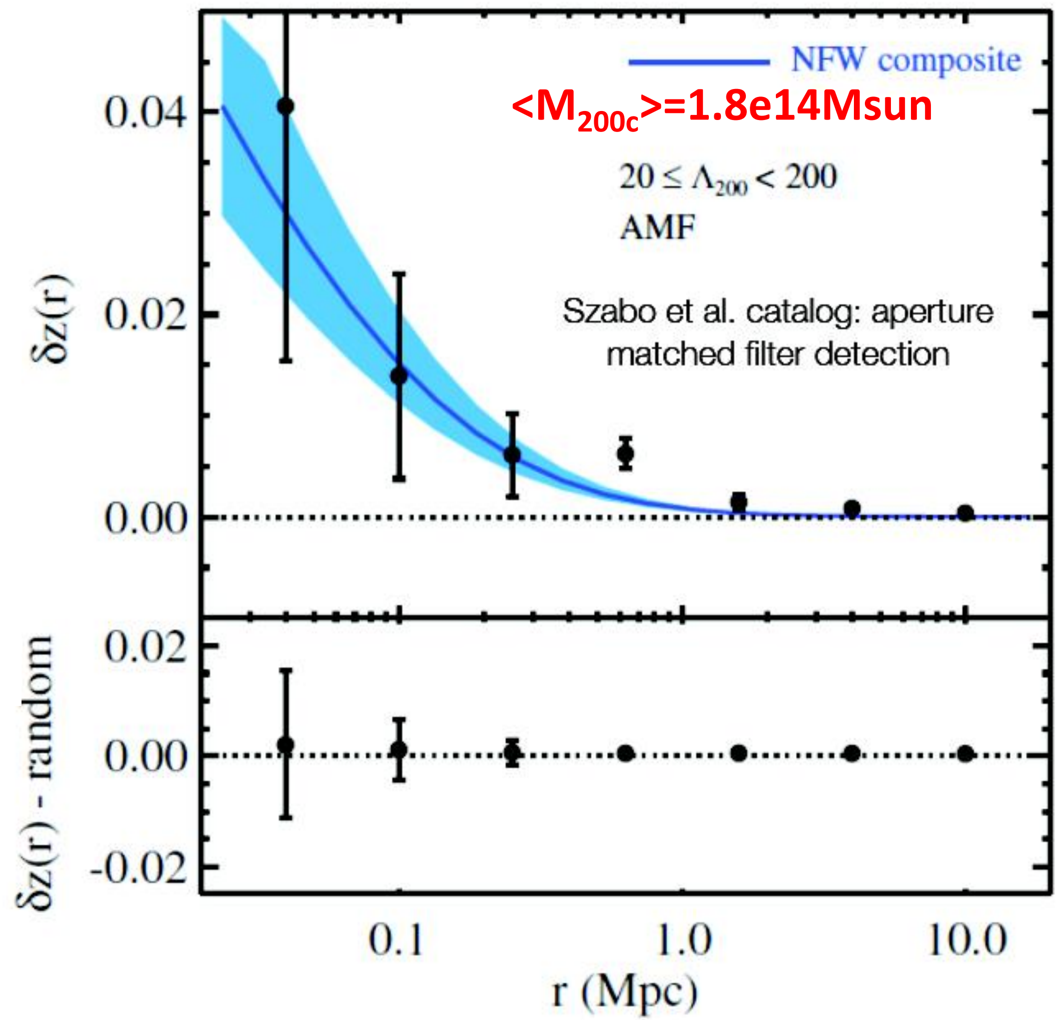
- **SDSS: ~10,000 foreground (lens) clusters (z<0.3)**
- **BOSS: ~300,000 background galaxies (z>0.45)**



Coupon, Broadhurst, & Umetsu 13, ApJ in press (arXiv:1303.6588)

5σ detection behind SDSS clusters

5,646 clusters



<u>Model uncertainty</u>

- LF cosmic variance
- BOSS color selection

<u>Measurement uncertainty</u>

- Variance in BOSS n(z), estimated from randomizing cluster positions

Coupon, Broadhurst, & Umetsu 13, ApJ in press (arXiv:1303.6588)

Prospects of the <z>-boost effect

- First detection at 5σ in SDSS/BOSS
- Very low systematic error budget
- More sensitive to clustering 2h-term than shear

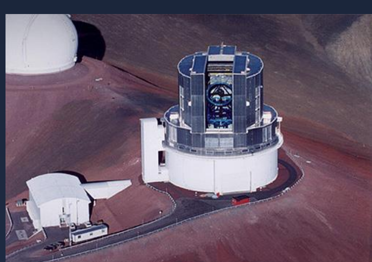
Upcoming redshift surveys

- Completed BOSS (10,000deg^2) → S/N~15
- BigBOSS (14,000deg^2, 18M gals) → S/N~60
- Euclid (15,000deg^2, 50M gals) → S/N~100
- Subaru PFS (1,400deg^2, 4M gals), up to zs=2 (high res), with high-z clusters from HSC [unique]

CLASH:

Cluster Lensing And Supernova survey with Hubble

An HST Multi-Cycle Treasury Program designed to place new constraints on the fundamental components of the cosmos: dark matter, dark energy, and baryons.

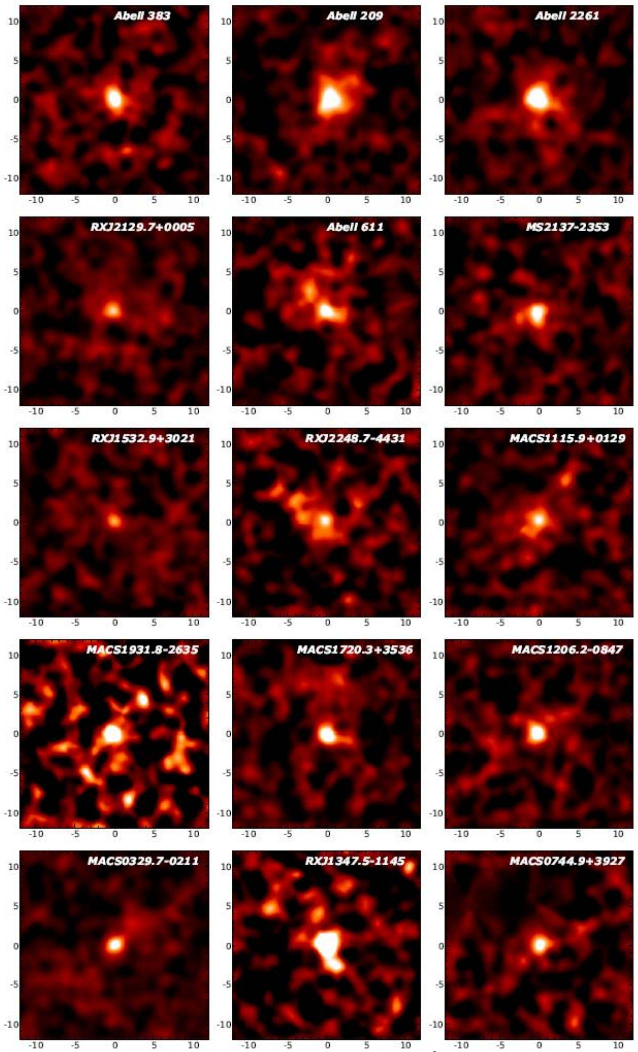


Wide-field Subaru imaging (0.4 - 0.9 μm) plays a unique role in complementing deep HST imaging of cluster cores.

My talk will focus on CLASH-WL based primarily on Subaru data. See Marc, Elinor, and other CLASH talks.

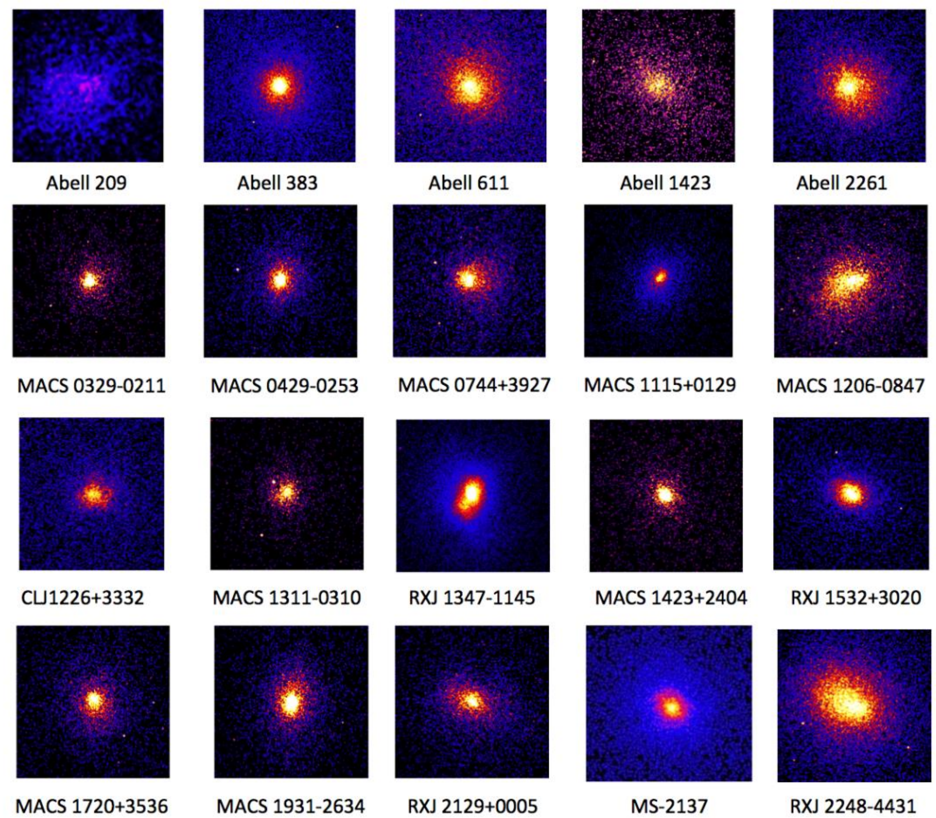
X-ray selected CLASH clusters

WL mass maps: 15 clusters completed



24’x24’ (Subaru+WFI/MPG)

X-ray maps: 20 CLASH clusters are purely X-ray selected, mostly “relaxed” (Allen+04,08, Mantz+10)



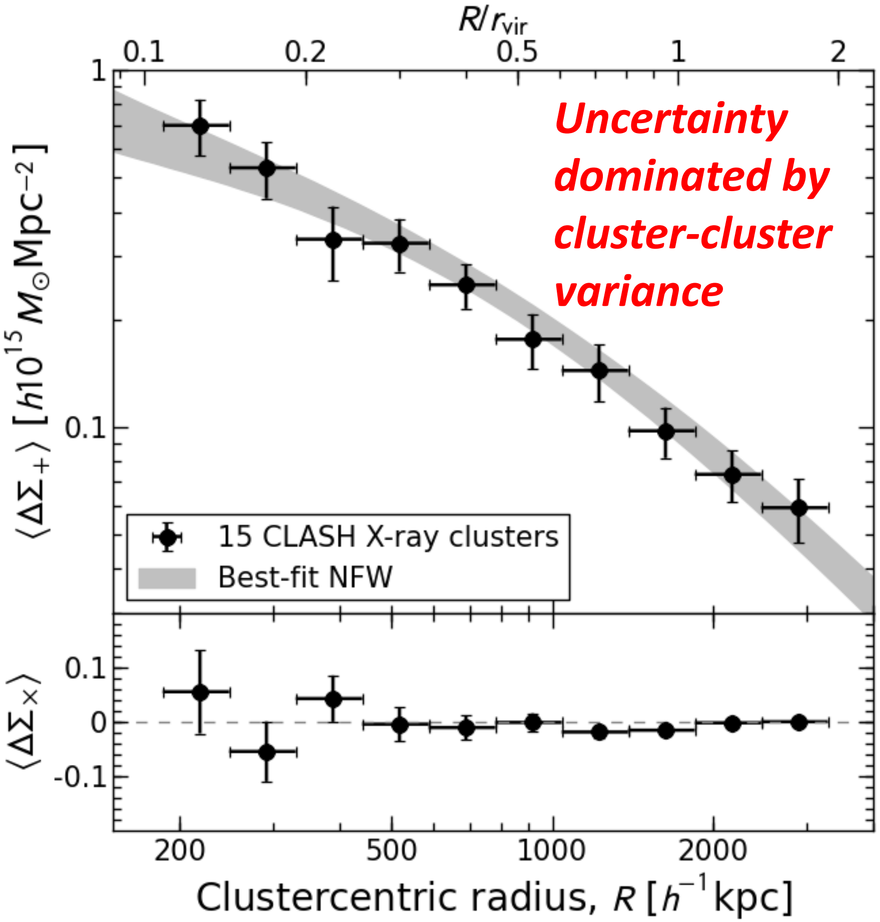
Postman+CLASH 12, ApJS

Toward unbiased mass measurements

1. **Stack WL signals around many clusters** to average out projection effects due to halo asphericity, substructure, and cosmic shear, providing the net 1-halo constraint (**this talk**)
2. **Multi-probe lensing approaches** (individual clusters):
   - Combine shear + magnification to get κ (**this talk**)
   - Combine shear + SL to get κ (**SaWLenS** by Julian Merten: **Marc's talk**)
   - Combine shear + magnification + SL to get κ (**CLASH in progress**)

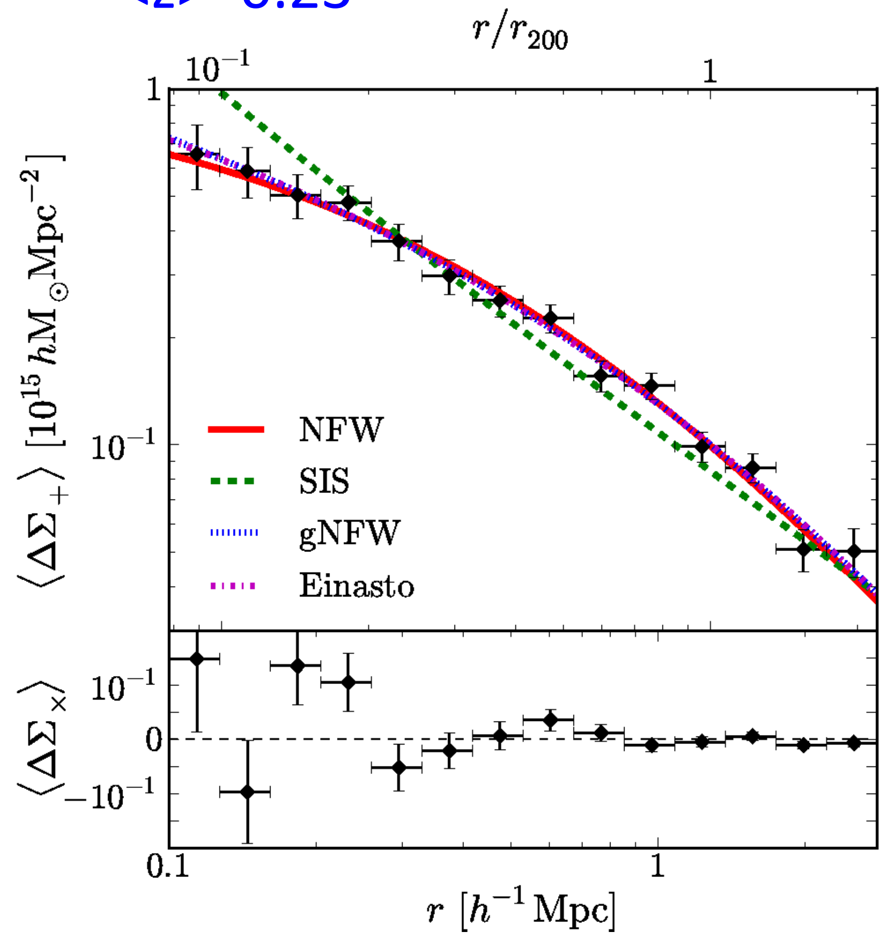
Stacked WL-shear analysis

CLASH: 15 X-ray relaxed clusters at <z>=0.36



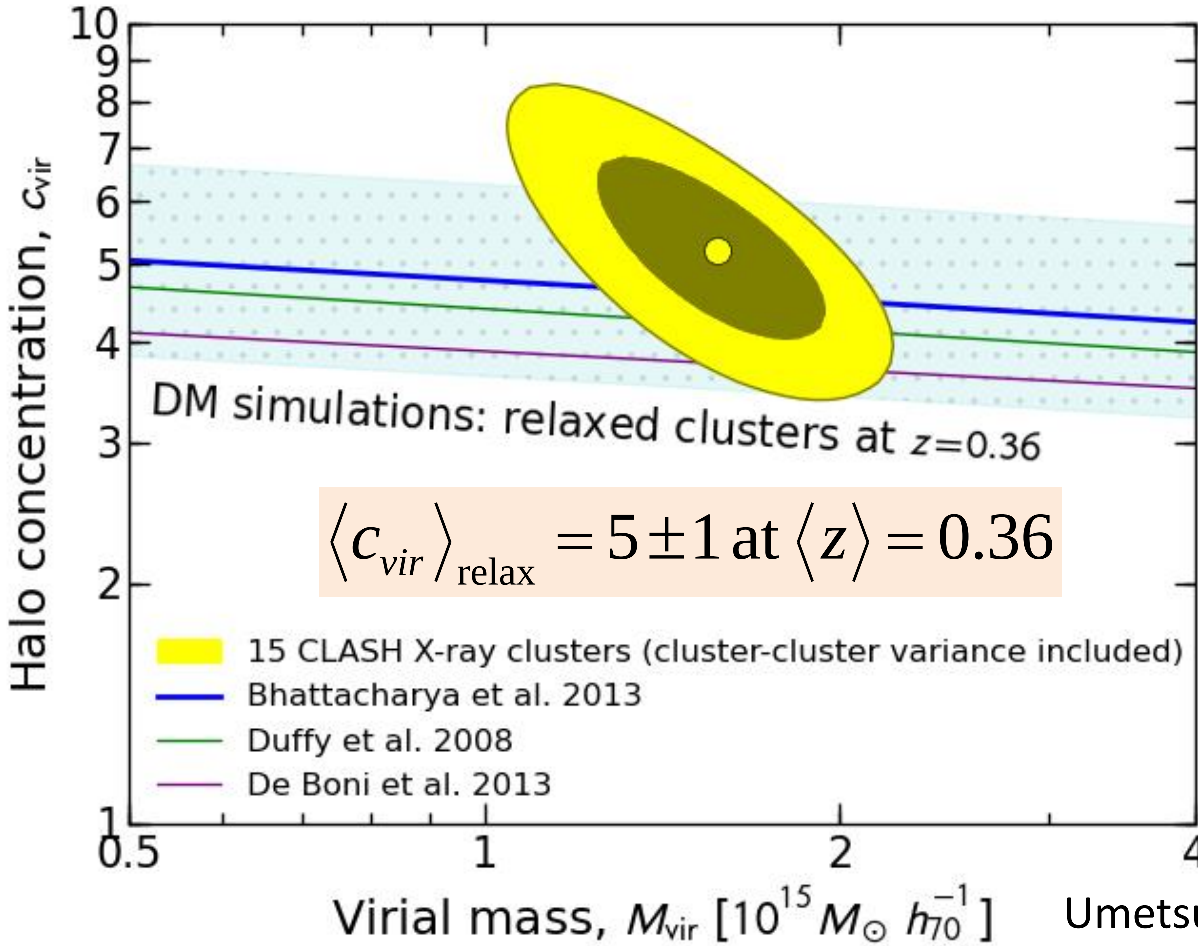
Umetsu+CLASH13, in prep

LoCuSS: 50 X-ray clusters at <z>=0.23



Okabe, Smith, Umetsu+13, ApJL

CLASH-WL vs. DM simulations



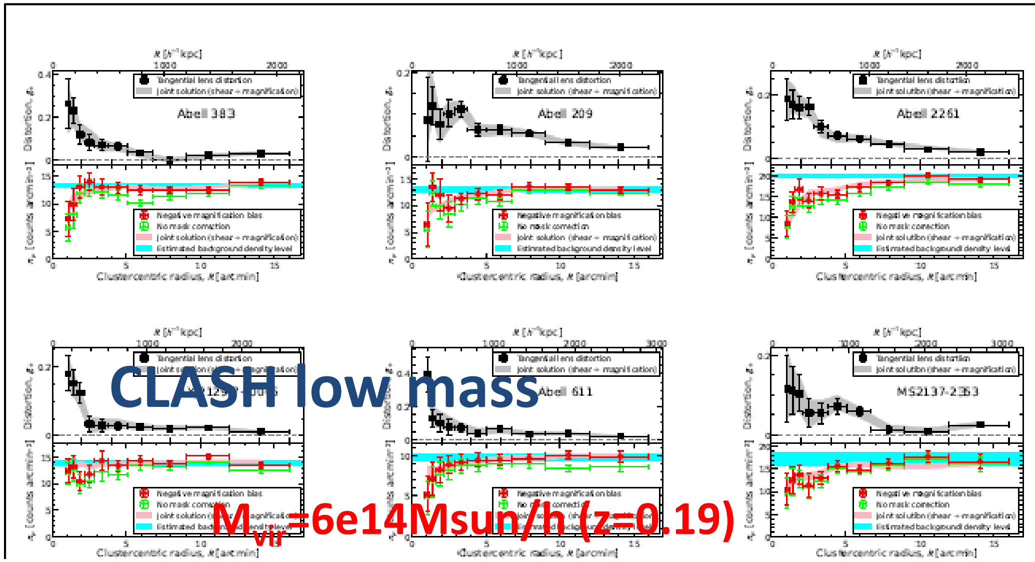
Δ_{vir}=130c

Umetsu+CLASH13 in prep

Data: Total mass vs. matter concentration
Theory: DM mass vs. DM concentration

Nontrivial baryonic feedback
(Duffy+10; De Boni+13)

d magnification
X-ray clusters

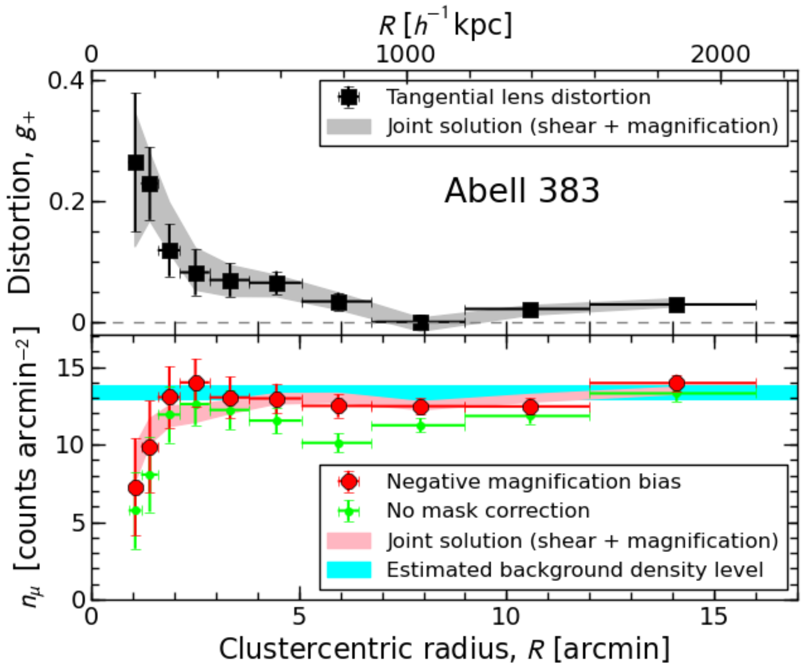


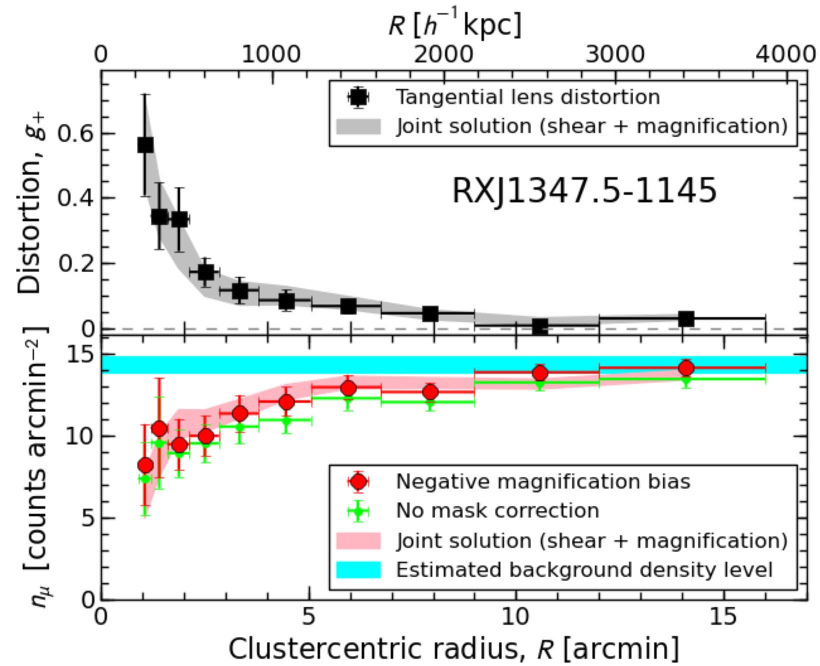
CLASH low mass

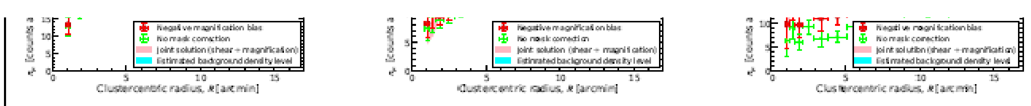
CLASH high mass

M_{vir}=6e14Msun/h (z=0.19)

M_{vir}=23e14Msun/h (z=0.45)



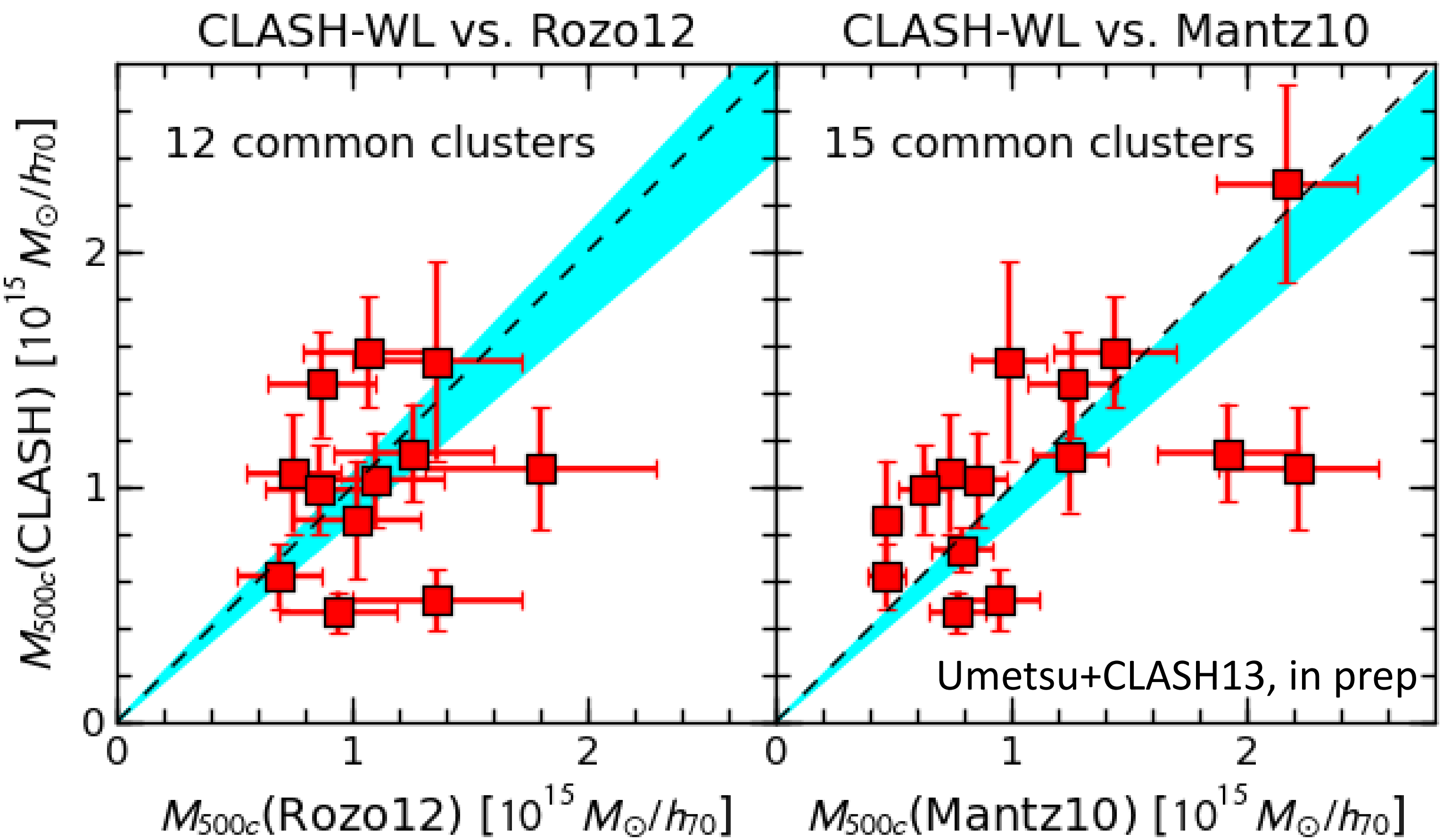




Spherical mass comparison

(without aperture correction)

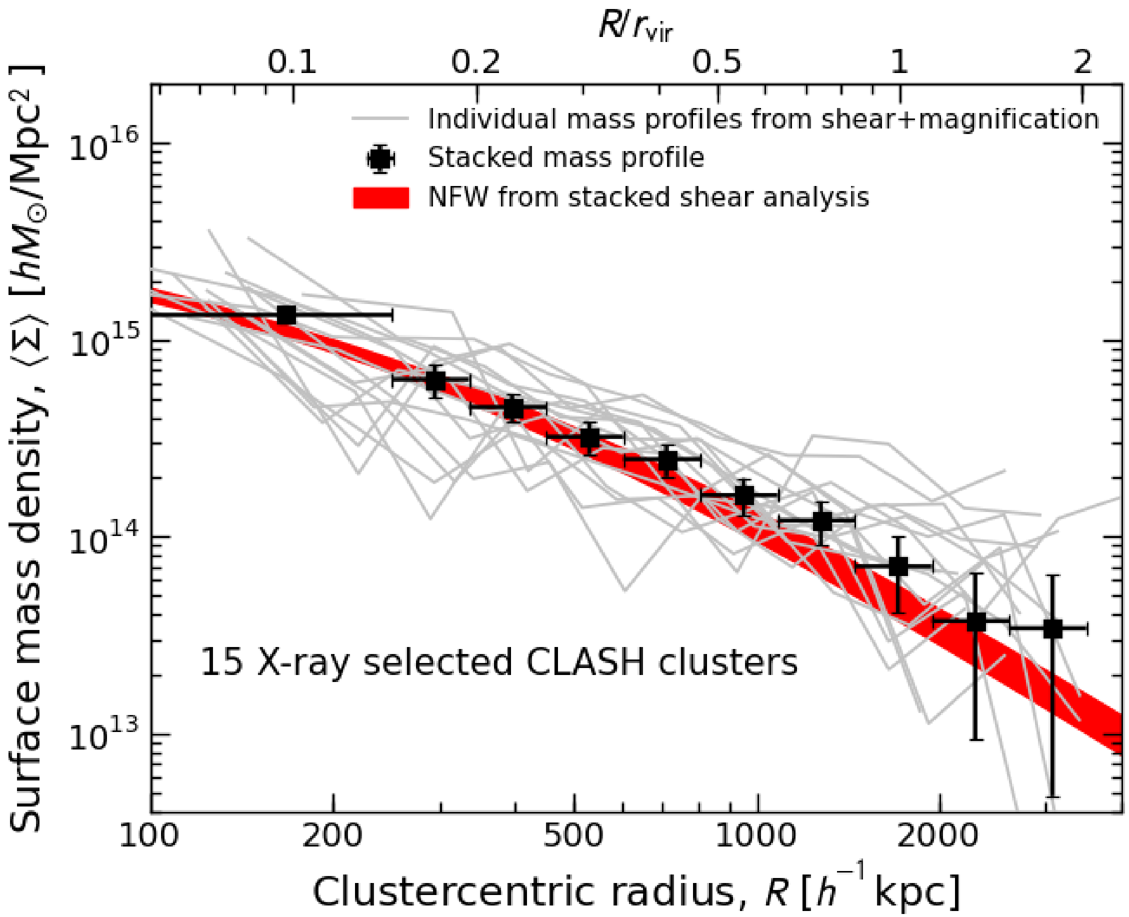
CLASH-WL: Shear + Magnification



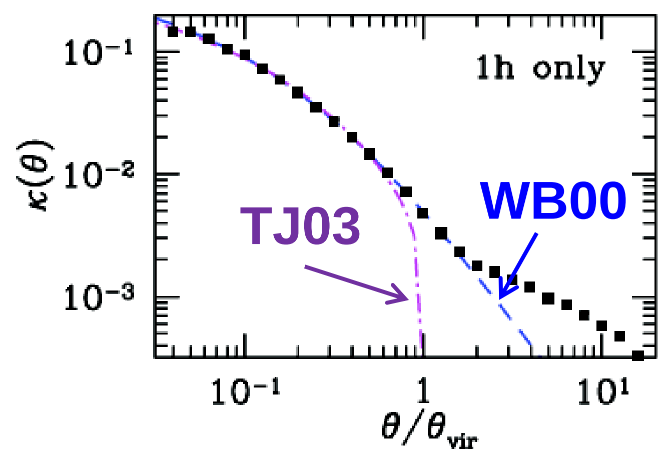
Lx [HSE-bias corrected] — **M_{gas} [constant f_{gas}]**

CLASH-WL: Stacked mass profile from combined shear + magnification

- Measuring 1h + 2h term out to $R=2r_{vir}$ around 15 X-ray clusters with $\langle M_{vir} \rangle$=1.1e15Msun/h at $\langle z \rangle$=0.36 → $b_h(M,z)$ = 9 (Tinker+10)
- Testing shear vs. magnification consistency



Model: NFW density projected out to $r_{||} = \infty$ (Wright & Brainerd 00), approximating 1h+2h term out to $R=2r_{vir}$



Umetsu+CLASH13 in prep

CLASH-WL: Stacked mass profile from combined shear + magnification

- Measuring 1h + 2h term out to $R=2r_{vir}$ around 15 X-ray clusters with $<M_{vir}>$=1.1e15Msun/h at <z>=0.36 → $b_h(M,z)$ = 9 (Tinker+10)
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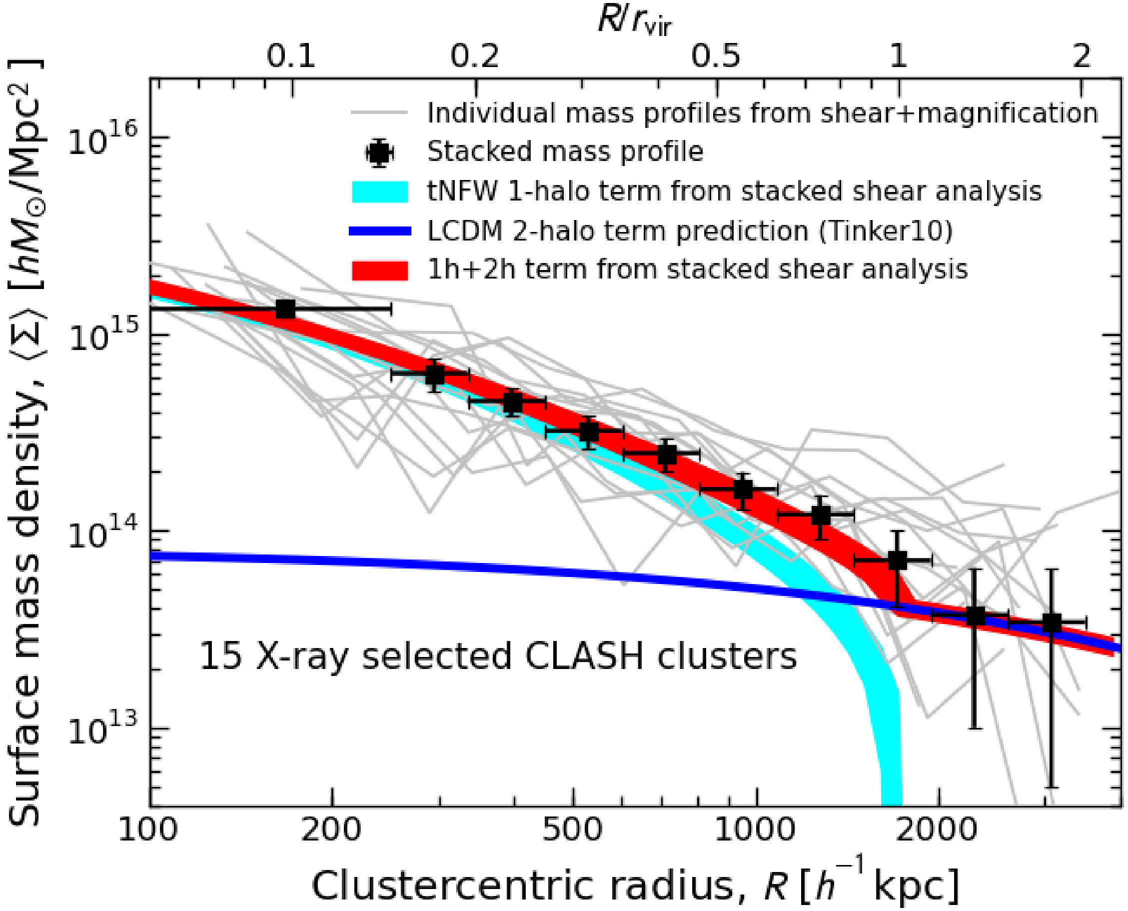
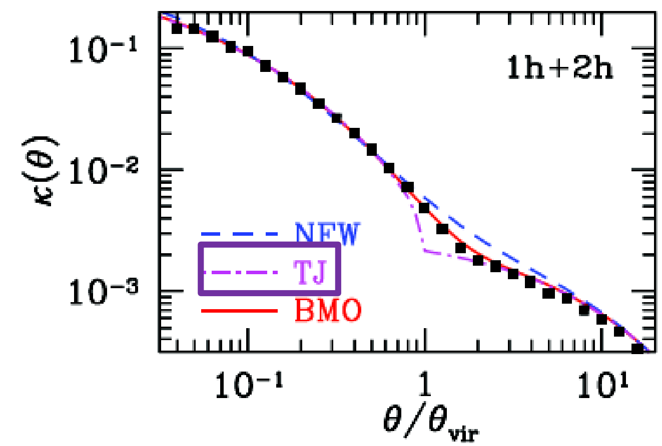


2D halo model: truncated NFW (Takada+Jain 03) + LCDM 2h-term



Umetsu+CLASH13 in prep

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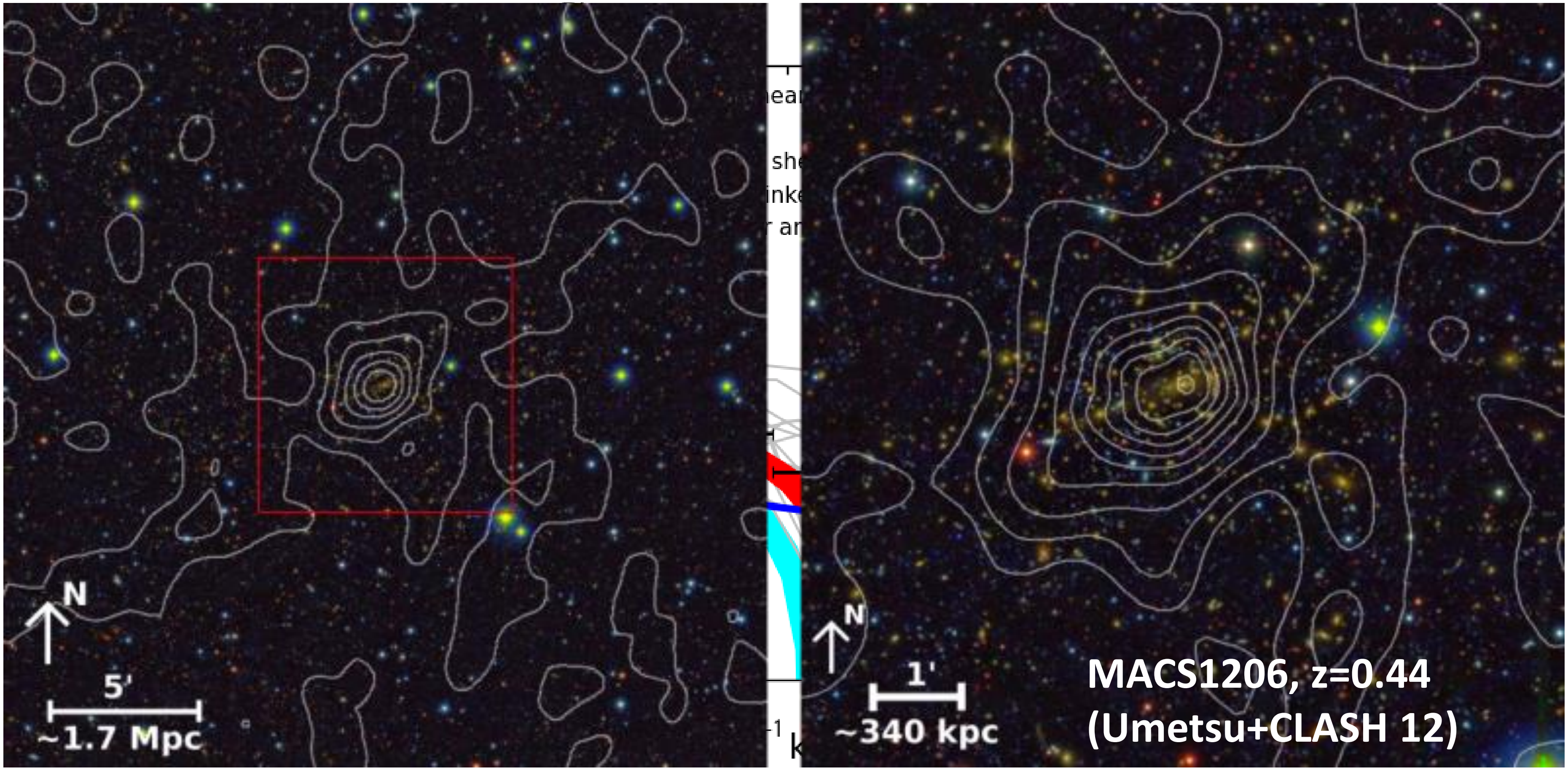

CLASH-WL Summary (1)

- **Stacked shear constraint from 15 X-ray clusters in good agreement with recent LCDM predictions** (Bhattacharya+13)
  - 2-paramter NFW form (3-para Einasto, ok)
  - $\langle c_{vir} \rangle \sim 5$ ($\langle c_{200c} \rangle \sim 4$) for “relaxed” $\langle M_{vir} \rangle \sim 1.6e15$Msun clusters at z=0.36
  - $c(\text{CLASH-WL})/c(\text{Bhat13})|_{relax} = 1.1 +/- 0.2$ (Umetsu+CLASH)
  - $c(\text{LoCuSS-WL})/c(\text{Bhat13})|_{full} = 1.1 +/- 0.1$ (Okabe+13)
  - CLASH-WL in agreement with CLASH-SaWLenS (Merten+CLASH 13, in prep). See **Marc’s talk**.
- **An apple-to-apple comparison with theory requires**:
  - Apply CLASH sample selection to theory (**Massimo’s talk**)
  - Include baryons in sim (AGN feedback, gas cooling, SF)
  - Or subtract baryonic components from data (**Claudio’s talk**)

CLASH-WL Summary (2)

- **A model-independent, averaged mass profile $<\Sigma(R)>$ is derived from WL shear+magnif data, for a sample of 15 X-ray clusters out to $R=2r_{vir}$**
  - The $<\Sigma(R)>$ profile is consistent with LCDM (1h+2h) predicted from stacked shear analysis of the same sample.
- **CLASH in progress to combine full lensing constraints: i.e., SL, shear and magnification.**