Matthias Bartelmann, JGRG 22(2012)111304

"Recent developments in gravitational lensing"

RESCEU SYMPOSIUM ON

GENERAL RELATIVITY AND GRAVITATION

JGRG 22

November 12-16 2012

Koshiba Hall, The University of Tokyo, Hongo, Tokyo, Japan

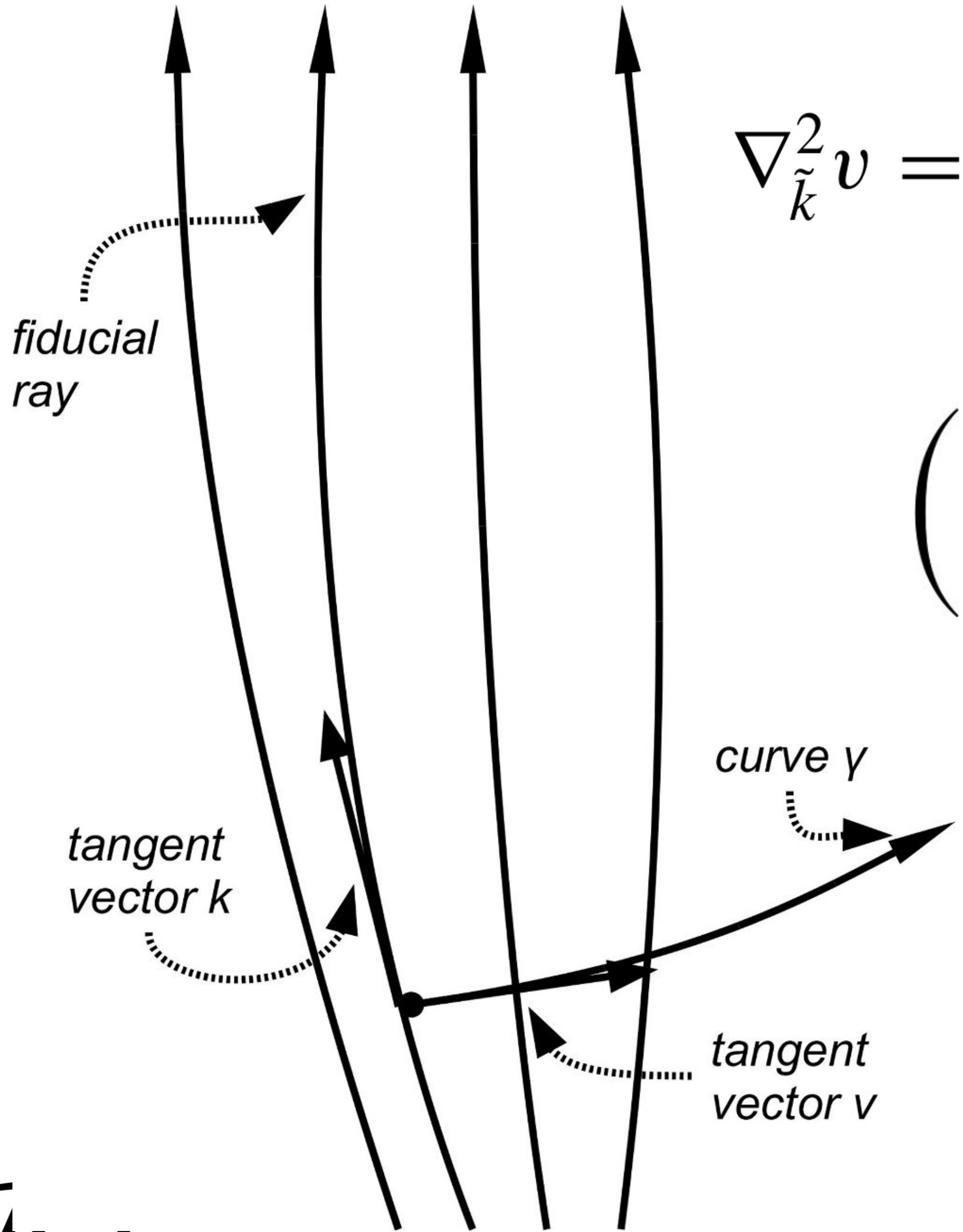
RUPRECHT-KARLS-
UNIVERSITÄT
HEIDELBERG

Some recent developments in gravitational lensing

お誕生日おめでとうございます
to professors
Toshi Futamase, Hideo Kodama and Misao Sasaki

Matthias Bartelmann, Heidelberg University, Institute for Theoretical Astrophysics
JGRG22, Tokyo, Nov. 13, 2012

Lensing From Relativity



$$\nabla^2_{\tilde{k}} v = R(\tilde{k}, v)\tilde{k}$$

$$\left(\frac{\mathrm{d}^2}{\mathrm{d}w^2} + K\right) x^i = -2\partial^i \phi .$$

Ingredients:

1. Equation of geodesic deviation
2. Field equations: relations Between mass and curvature

[cf. MB, CQGr 27 (2010) w3001]

effective lensing potential

$$\psi(\theta^j) = 2\int_0^{w_\mathrm{s}} \mathrm{d}w' \frac{f_K(w_\mathrm{s}-w')}{f_K(w')f_K(w_\mathrm{s})}\phi(f_K(w')\theta^j, w')$$

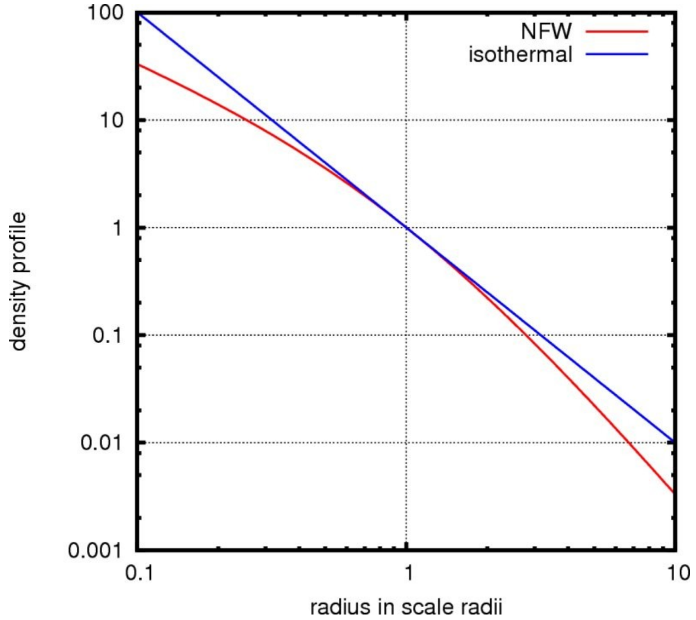
convergence $\kappa = \frac{1}{2}\partial^*\partial\psi$, $\gamma = \frac{1}{2}\partial^2\psi$ shear

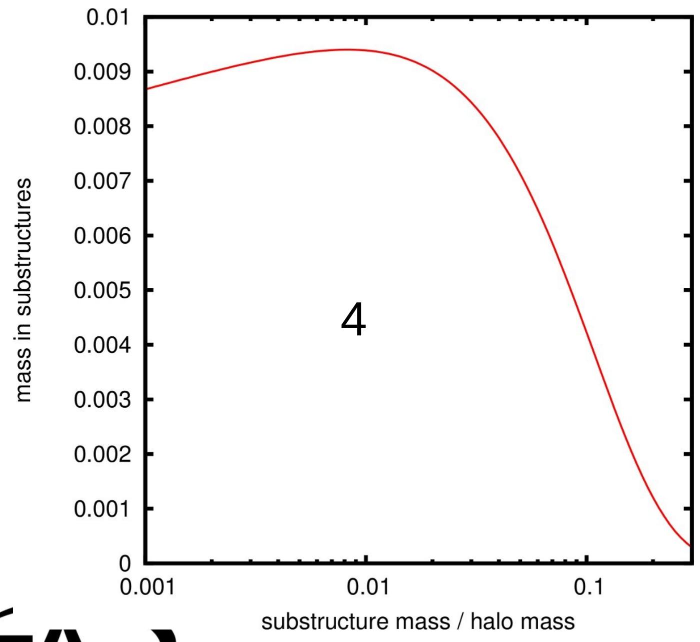
$$\mathcal{F} = \partial\kappa = \frac{1}{2}\partial\partial^*\partial\psi \quad , \quad \mathcal{G} = \partial\gamma = \frac{1}{2}\partial^3\psi$$

spin-1 flexion $\left[\partial = \partial_1 + \mathrm{i}\partial_2\right]$ spin-3 flexion

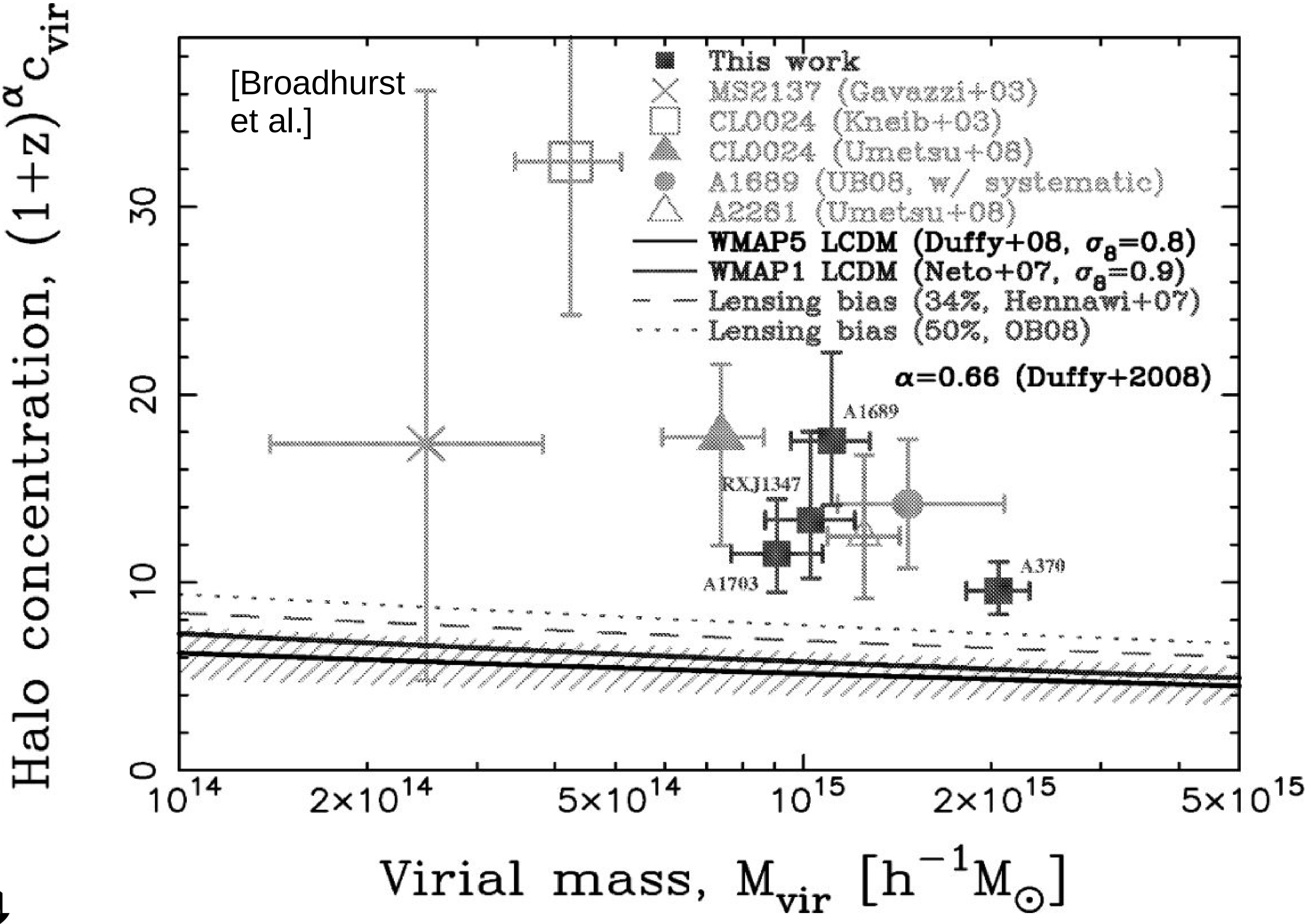
edth operator (in flat space)

Cold Dark Matter Haloes

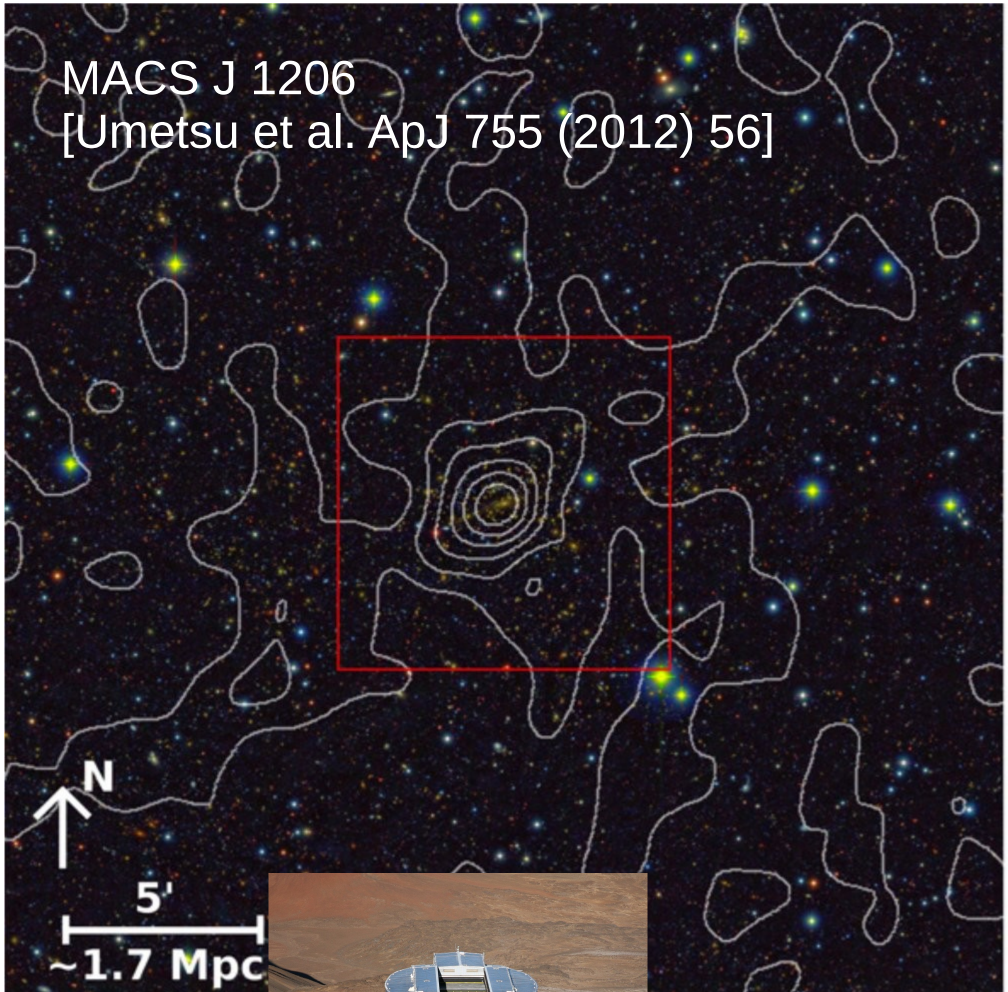


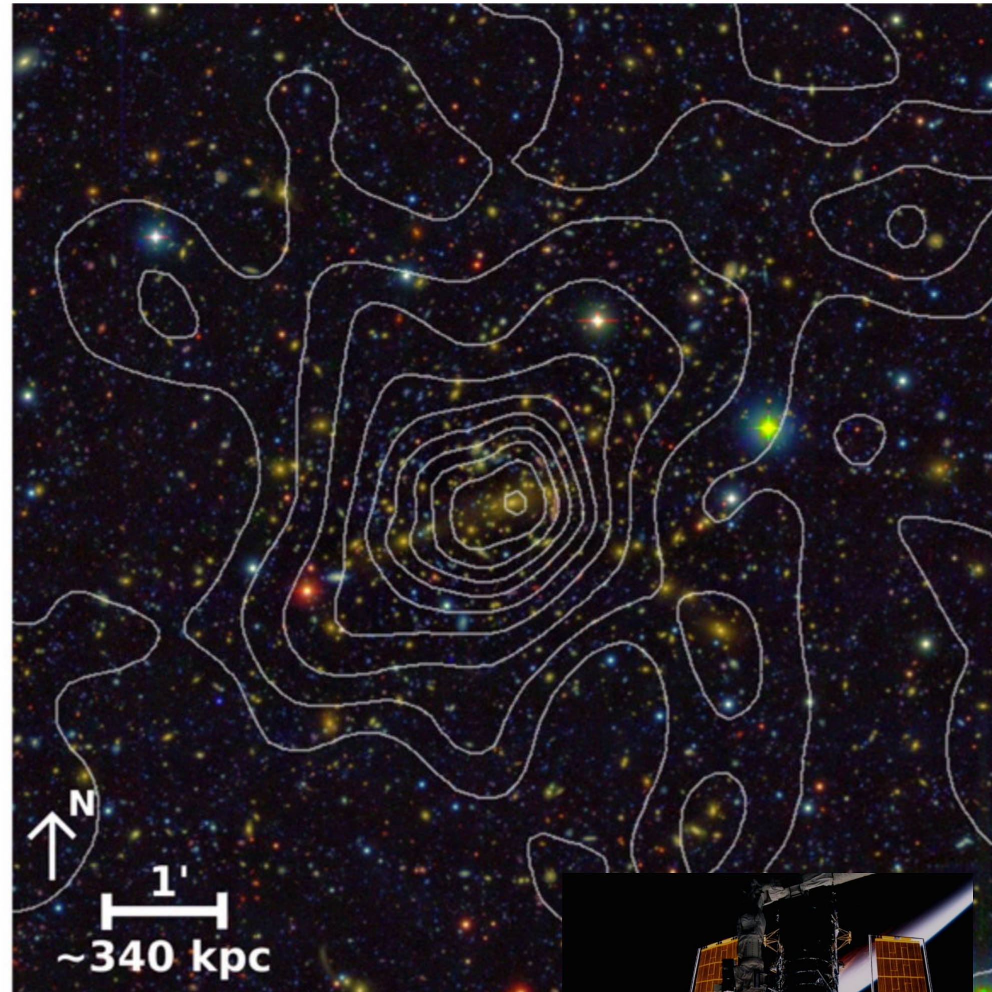


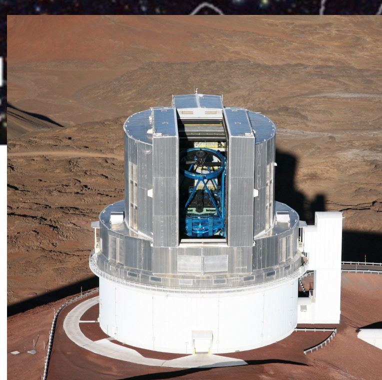
Concentration Parameter



Cluster Lensing

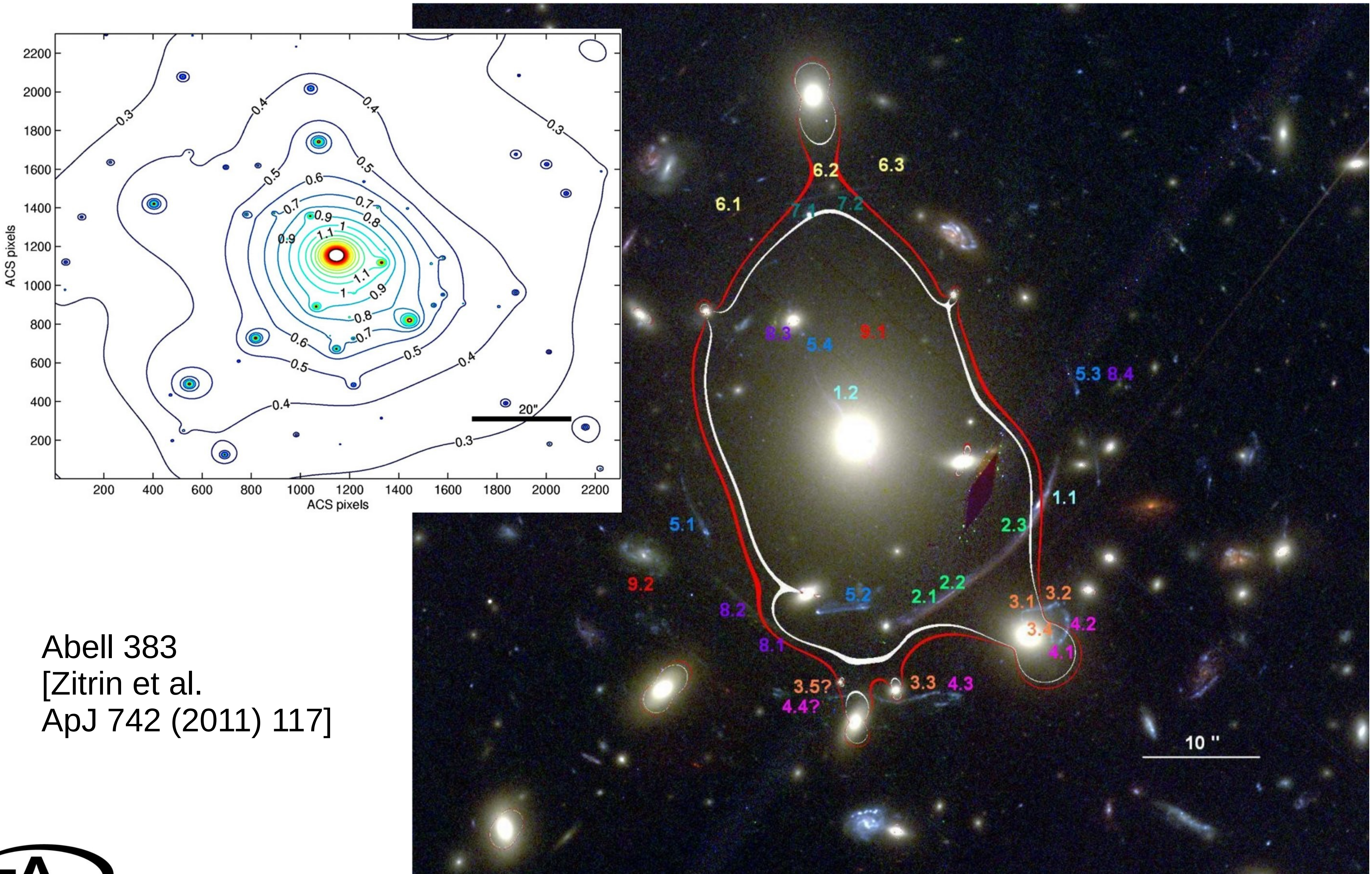






CLASH MCT Programme:
25 clusters in 16 bands
(HST and ground based)

Cluster Lensing: Example

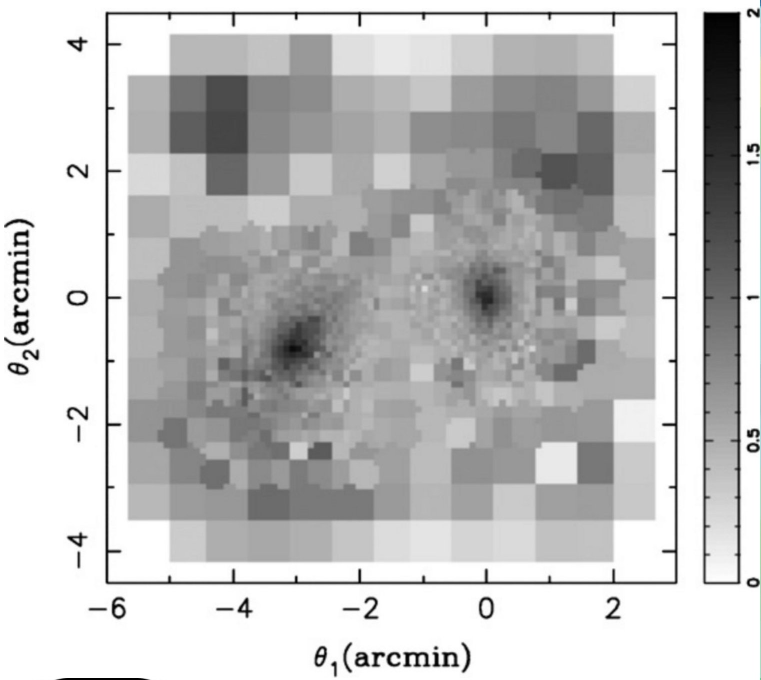


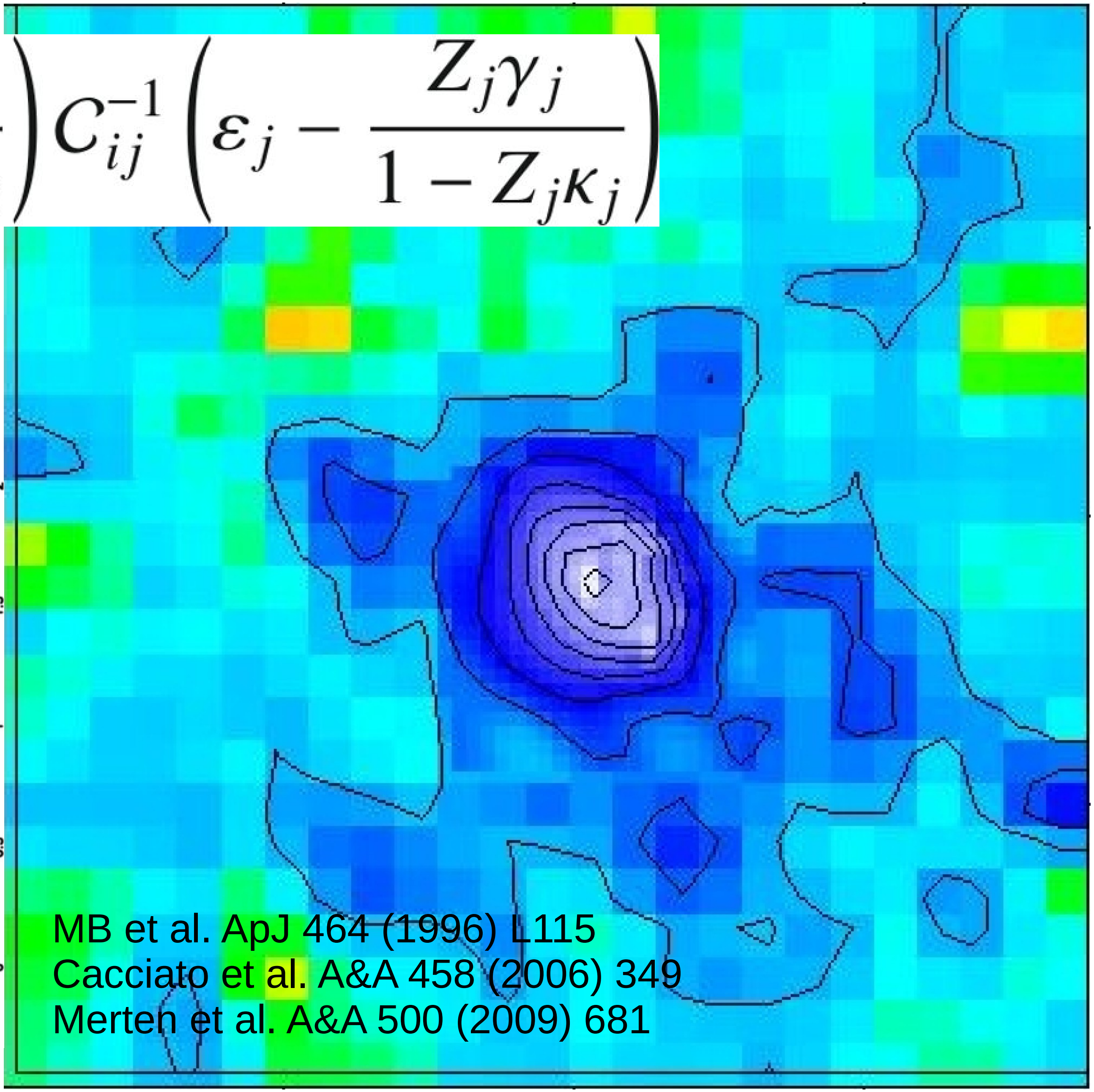
Abell 383
[Zitrin et al.
ApJ 742 (2011) 117]

Strong and Weak Lensing Combined

$$\chi^2 = \left(\varepsilon_i - \frac{Z_i\gamma_i}{1 - Z_i\kappa_i}\right) C_{ij}^{-1} \left(\varepsilon_j - \frac{Z_j\gamma_j}{1 - Z_j\kappa_j}\right)$$

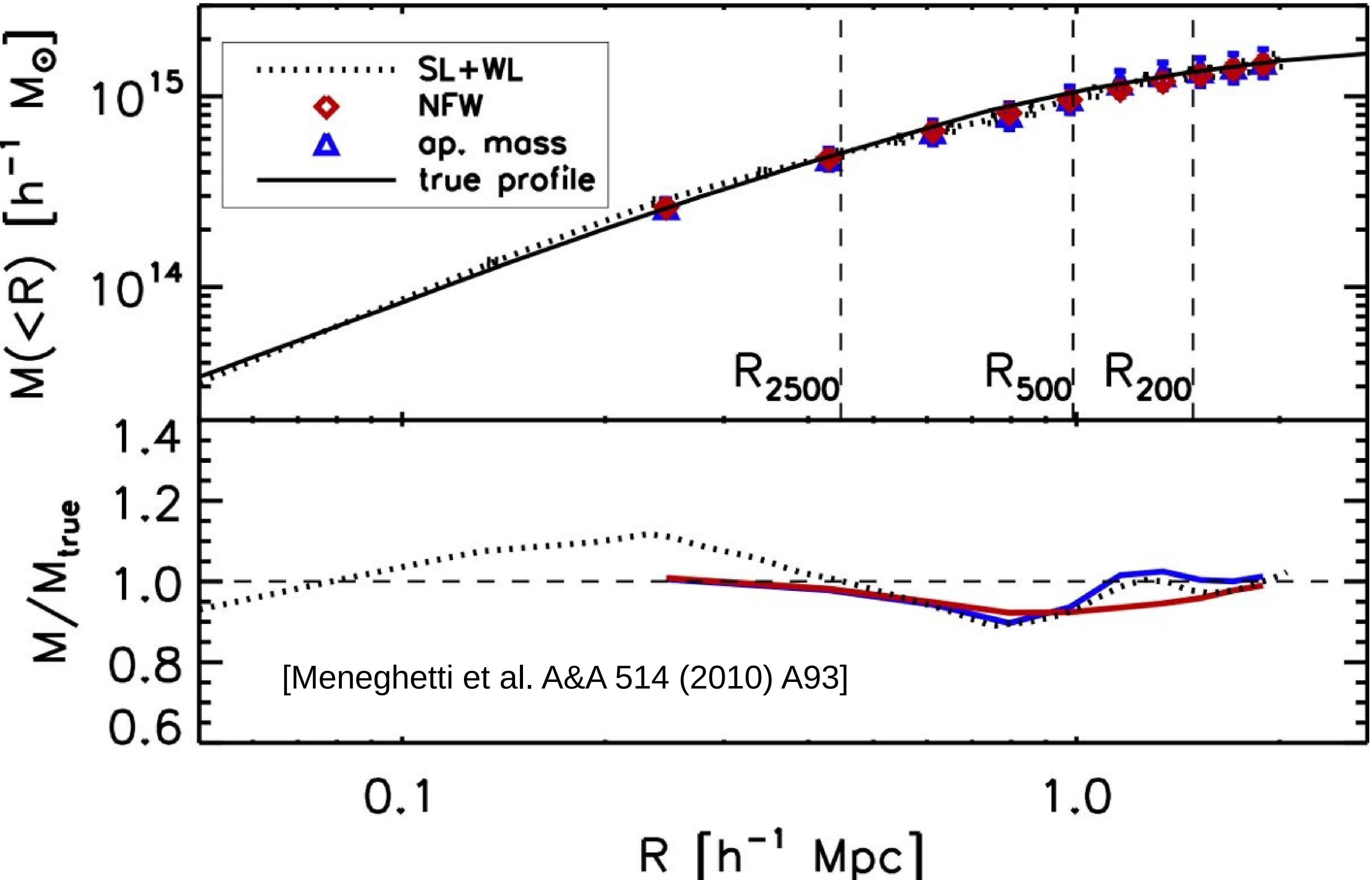
[Bradač et al.
ApJ 706 (2009) 1201]





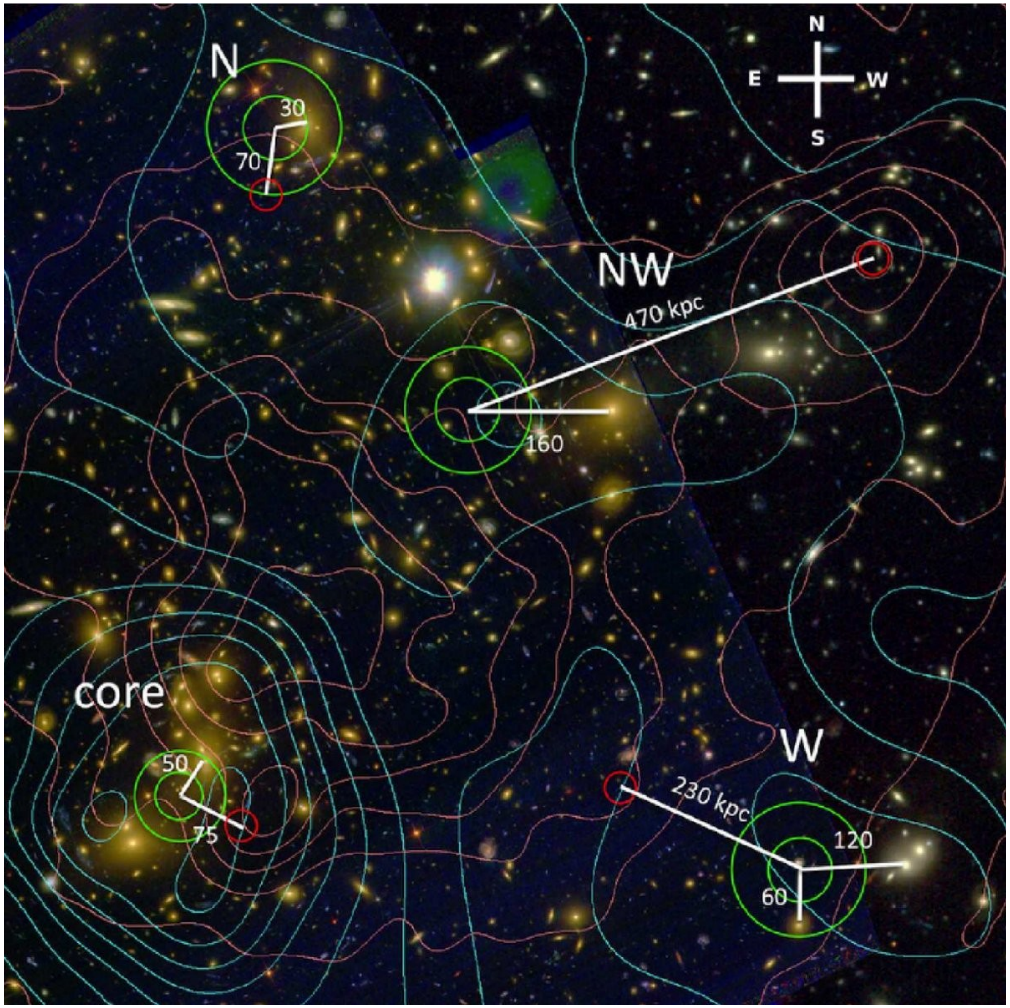
MB et al. ApJ 464 (1996) L115
Cacciato et al. A&A 458 (2006) 349
Merten et al. A&A 500 (2009) 681

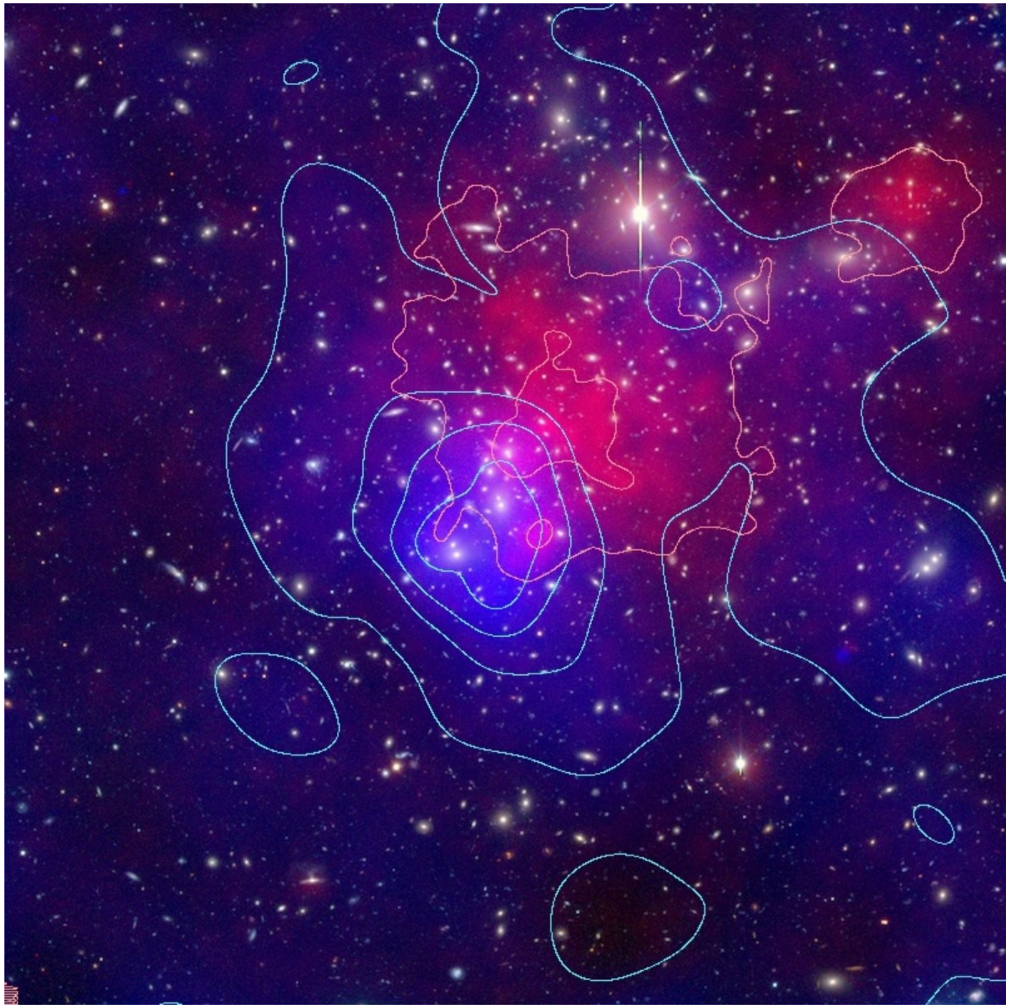
Adaptive Reconstruction: Simulation



[Meneghetti et al. A&A 514 (2010) A93]

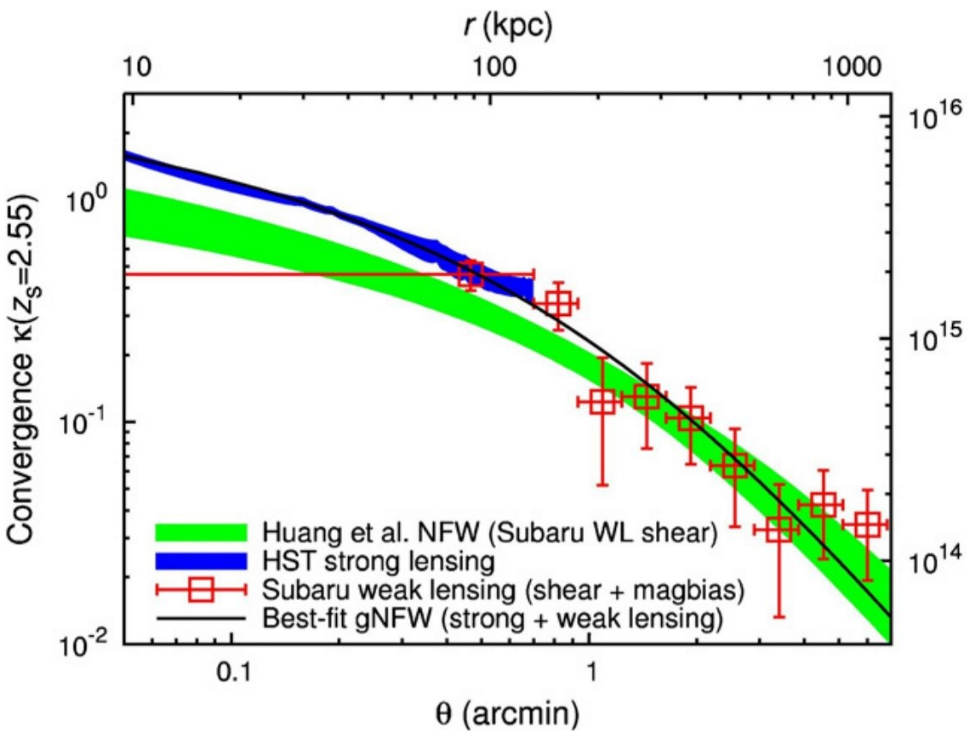
Strong and Weak Lensing Combined: Abell 2744



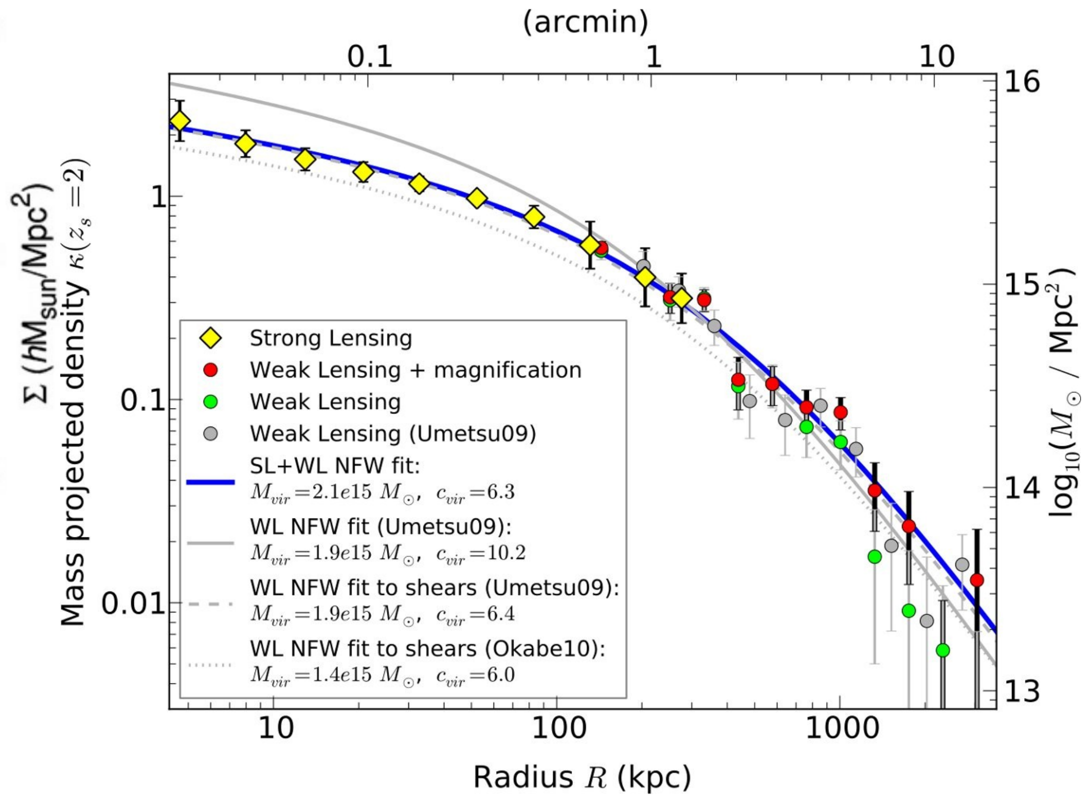


Abell 2744
[Merten et al. MNRAS 417 (2011), 333]

Recovered Density Profiles

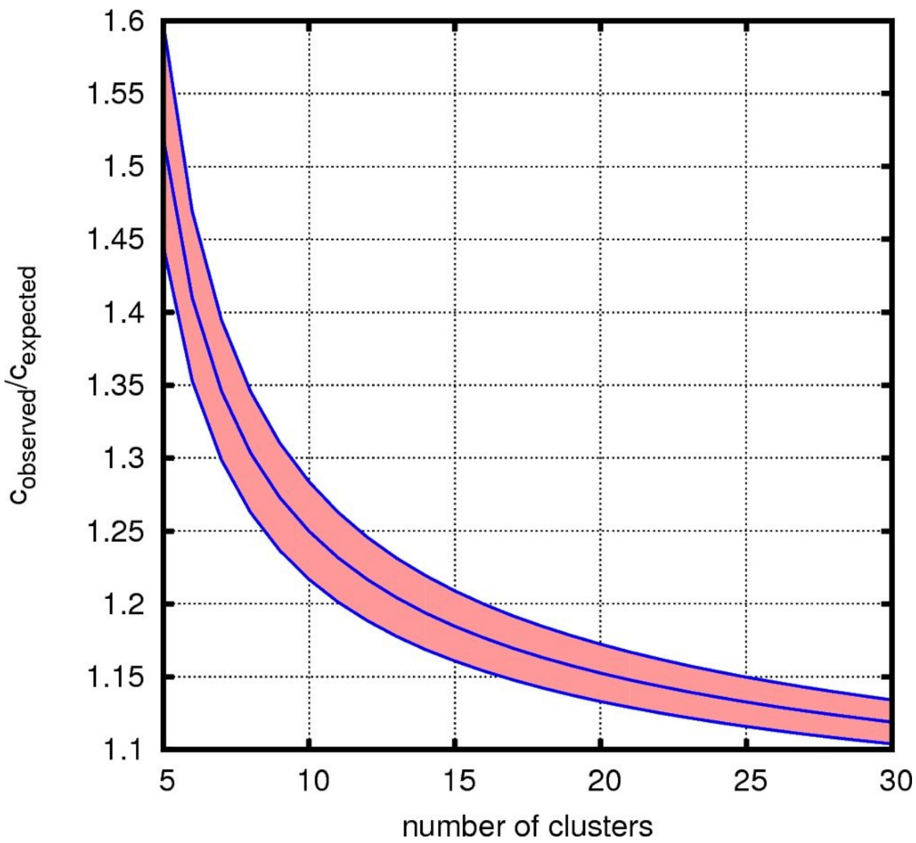


Abell 383
[Zitrin et al. ApJ 742 (2011) 117]

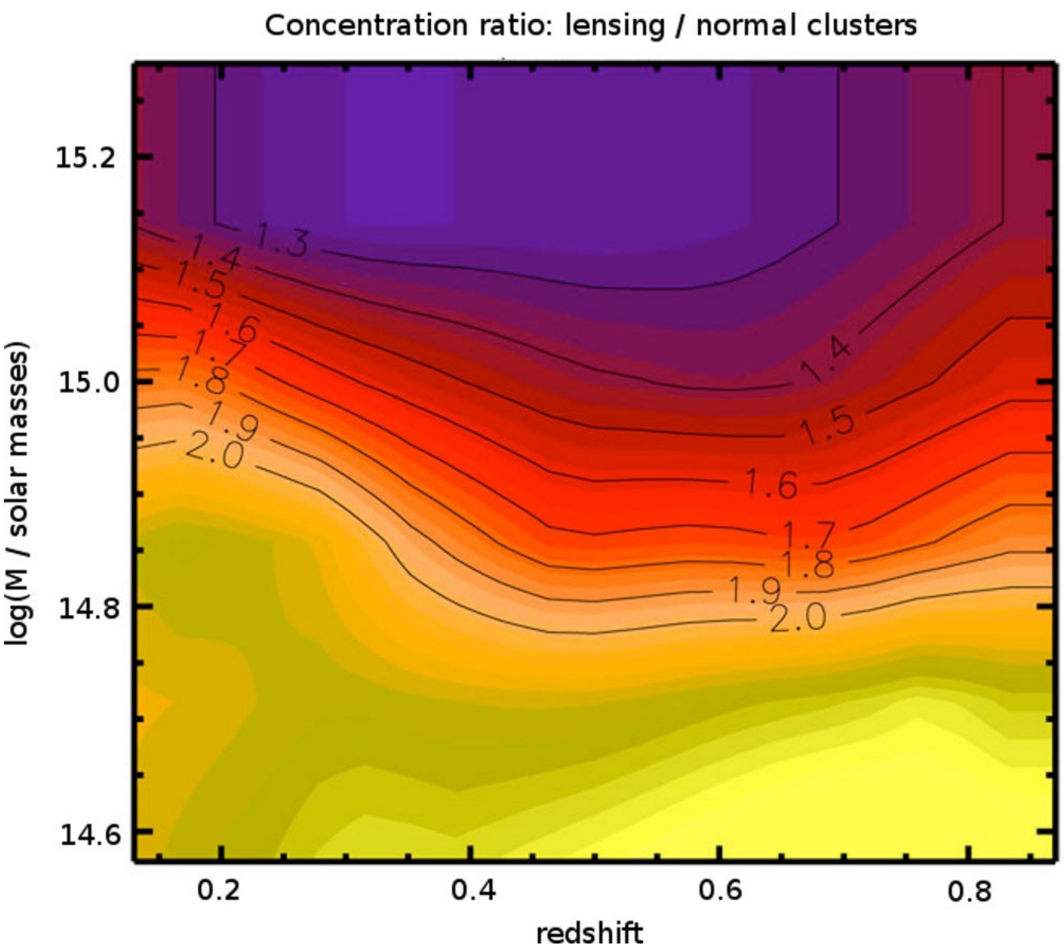


Abell 2261
[Coe et al. ApJ 757 (2012) 22]

Constraints on Concentration Parameter

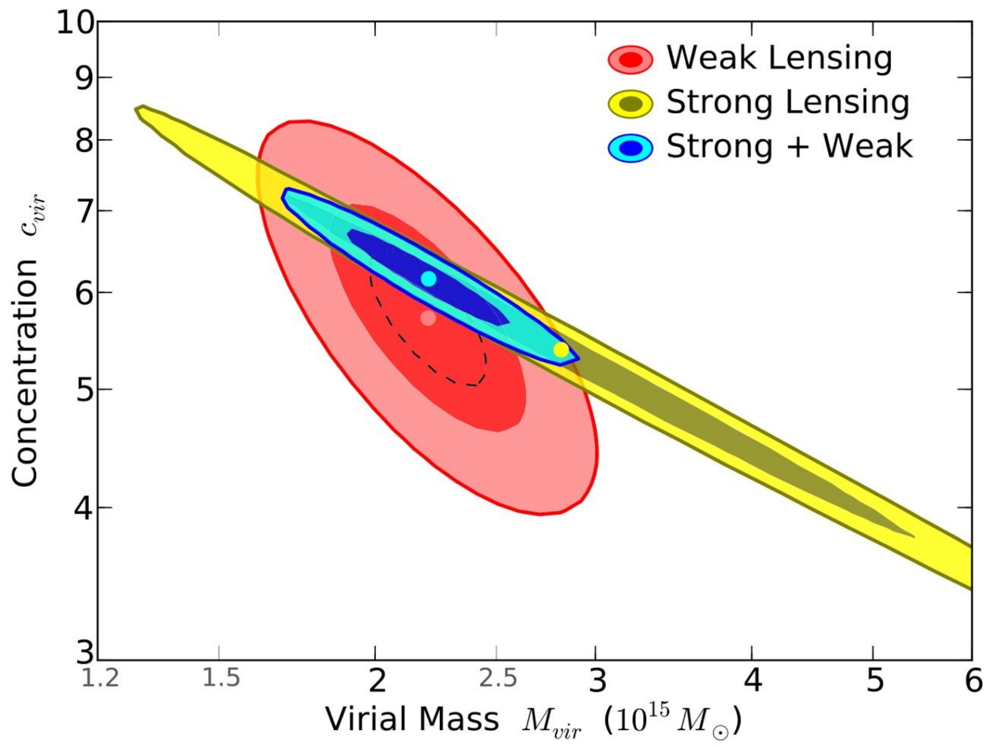


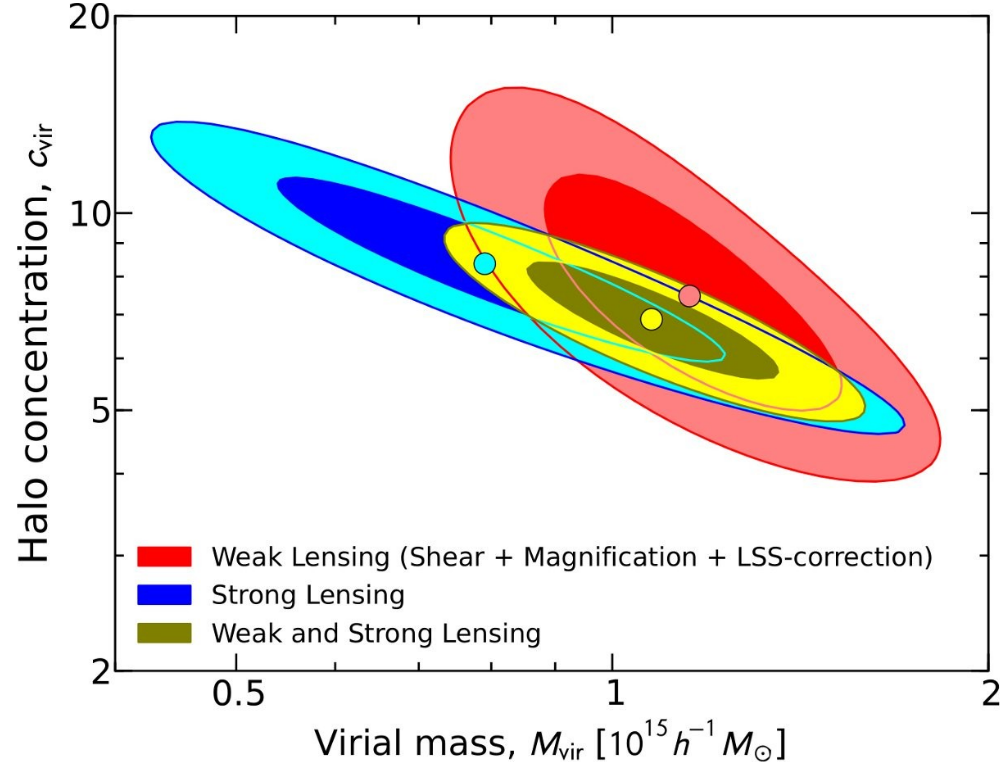
Expected significance with cluster sample
[from CLASH proposal]



Concentration bias: 1.5 – 2 typically
[Meneghetti et al. A&A 519 (2010) 90]

Meaasured Concentration Parameters

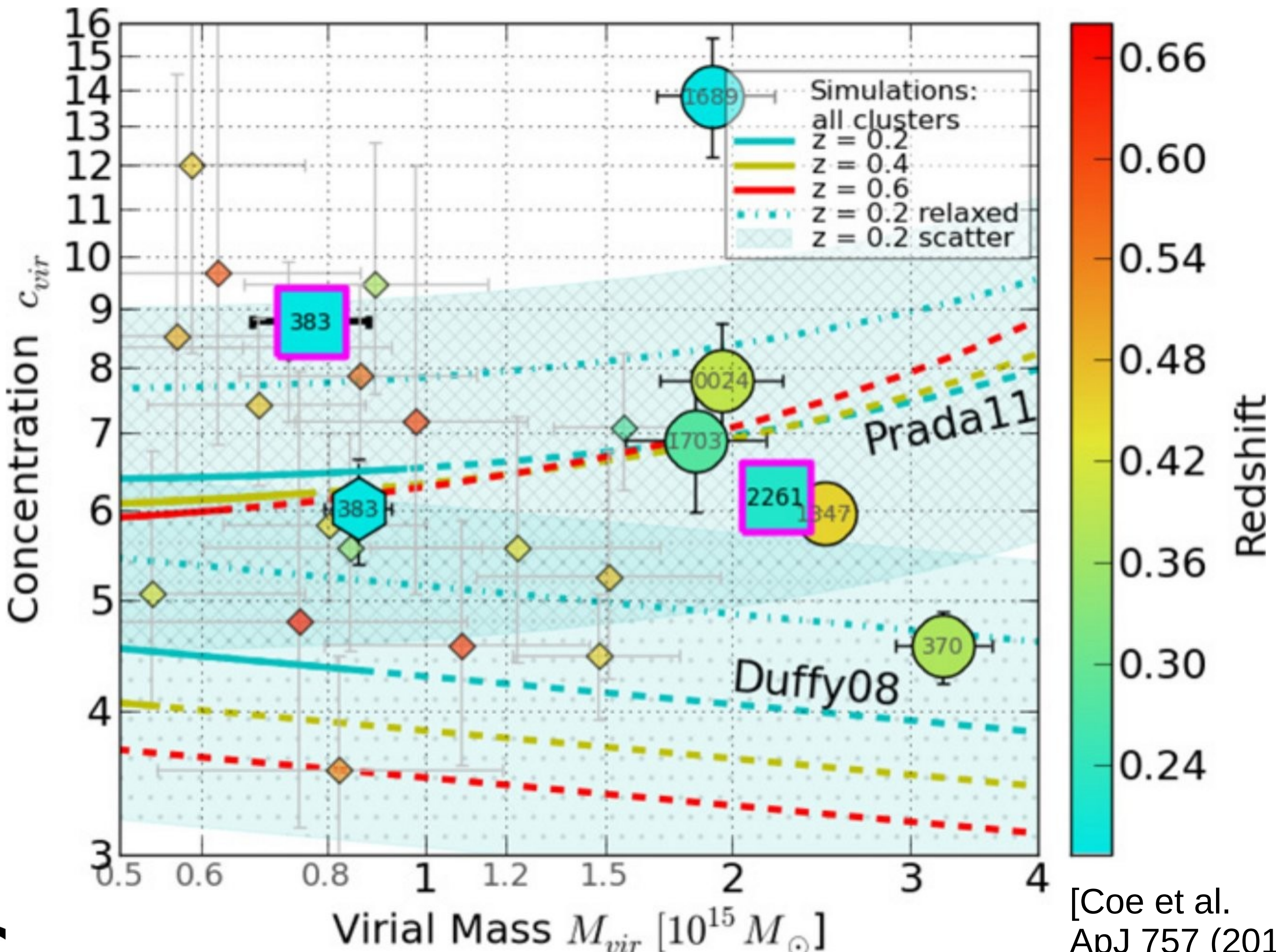




Abell 2261
[Coe et al. ApJ 757 (2012) 22]

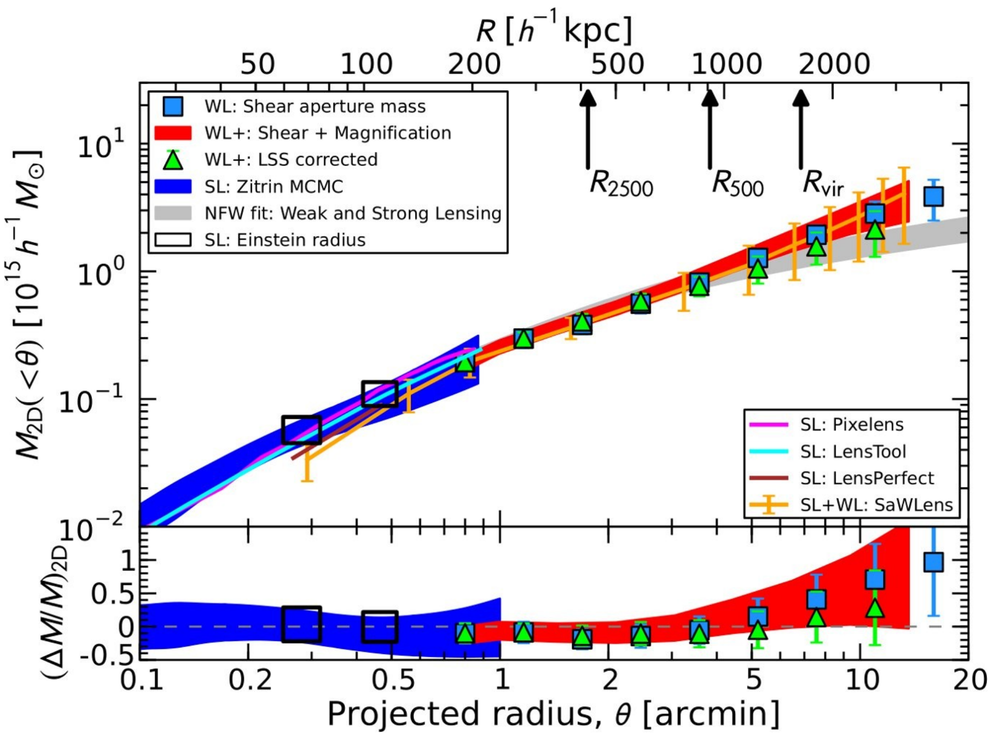
MACS J 1206
[Umetsu et al. ApJ 755 (2012) 56]

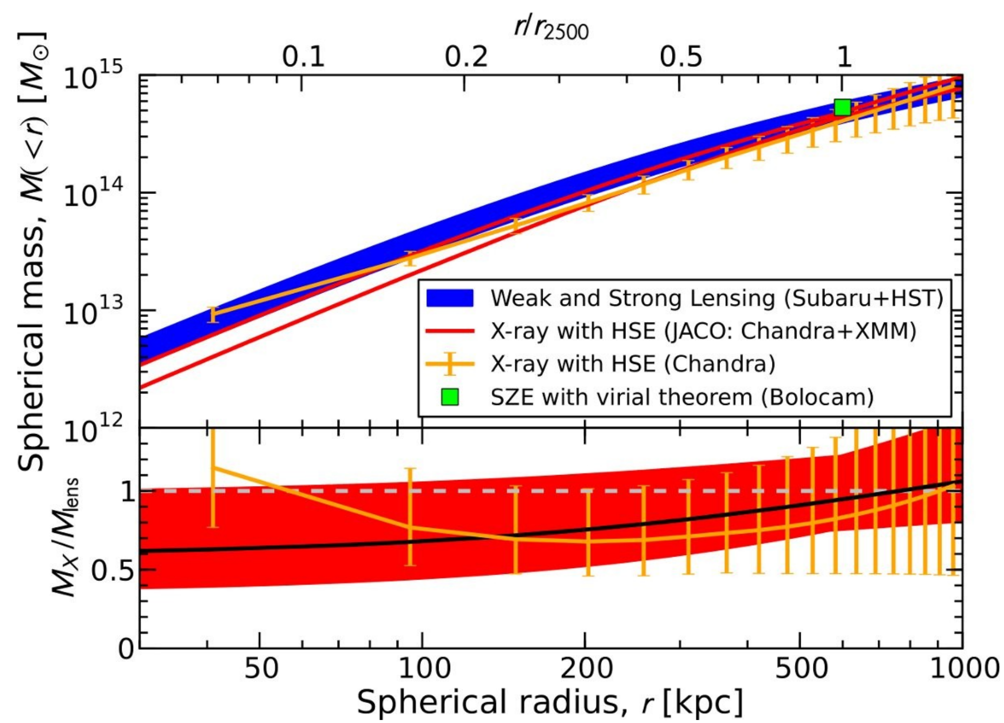
Combined Results so Far



[Coe et al.
ApJ 757 (2012) 22]

Mass Reconstruction

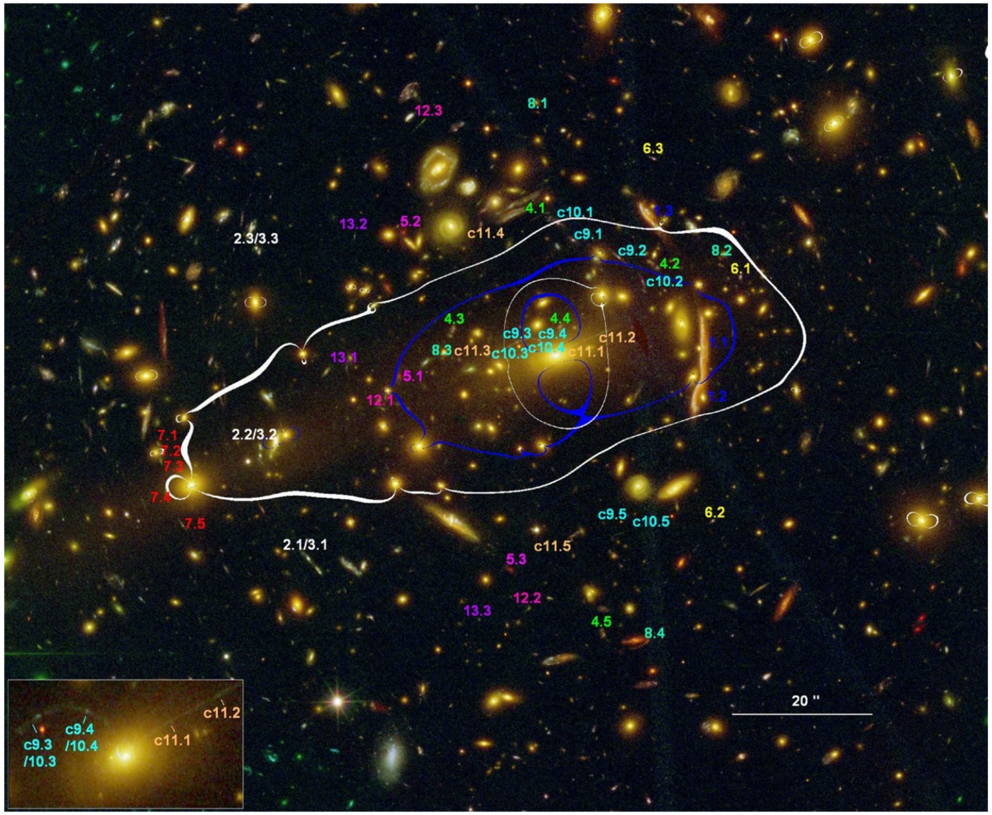




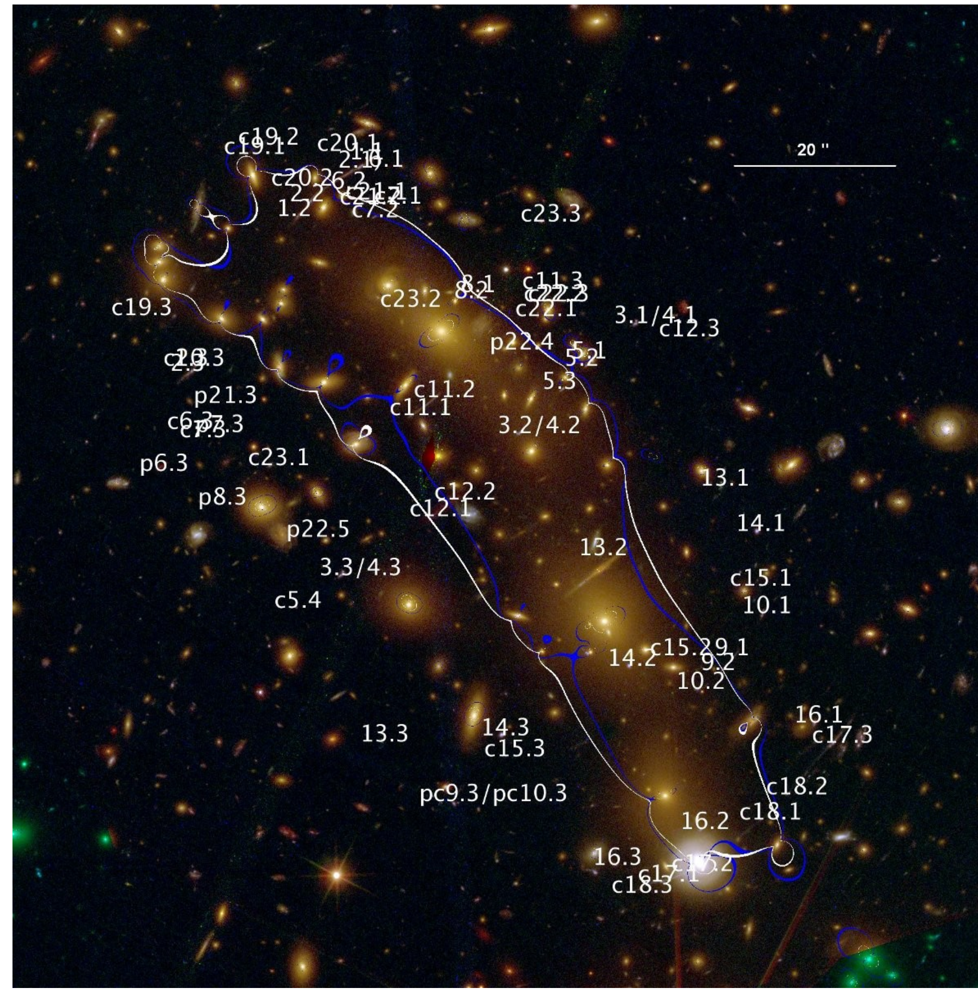
MACS J 1206
[Umetsu et al. ApJ 755 (2012) 56]

Lensing (left),
Lensing and X-ray emission (right)

Extreme Lenses?

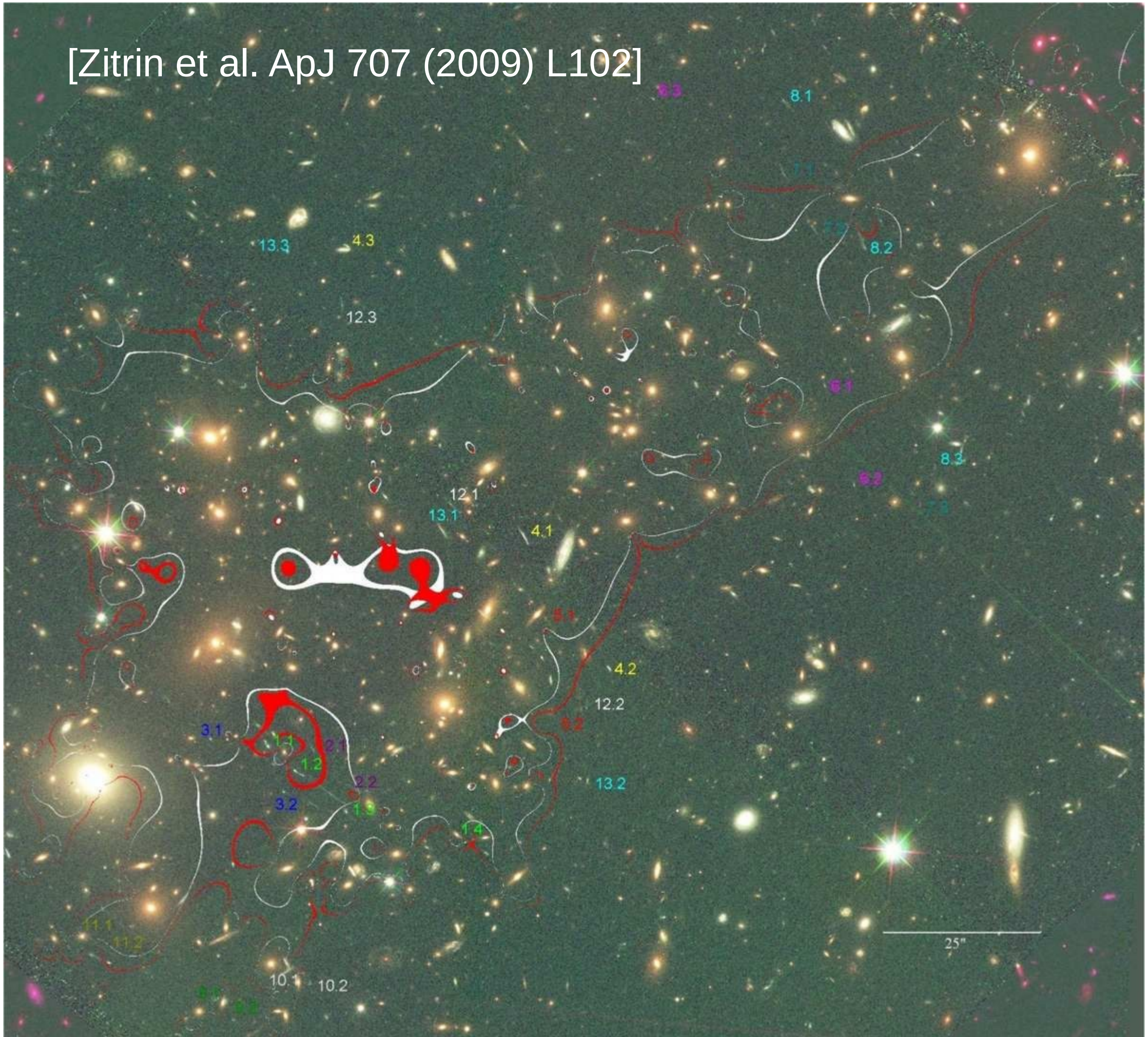


MACS J 1206
[Zitrin et al. ApJ 749 (2012) 97]



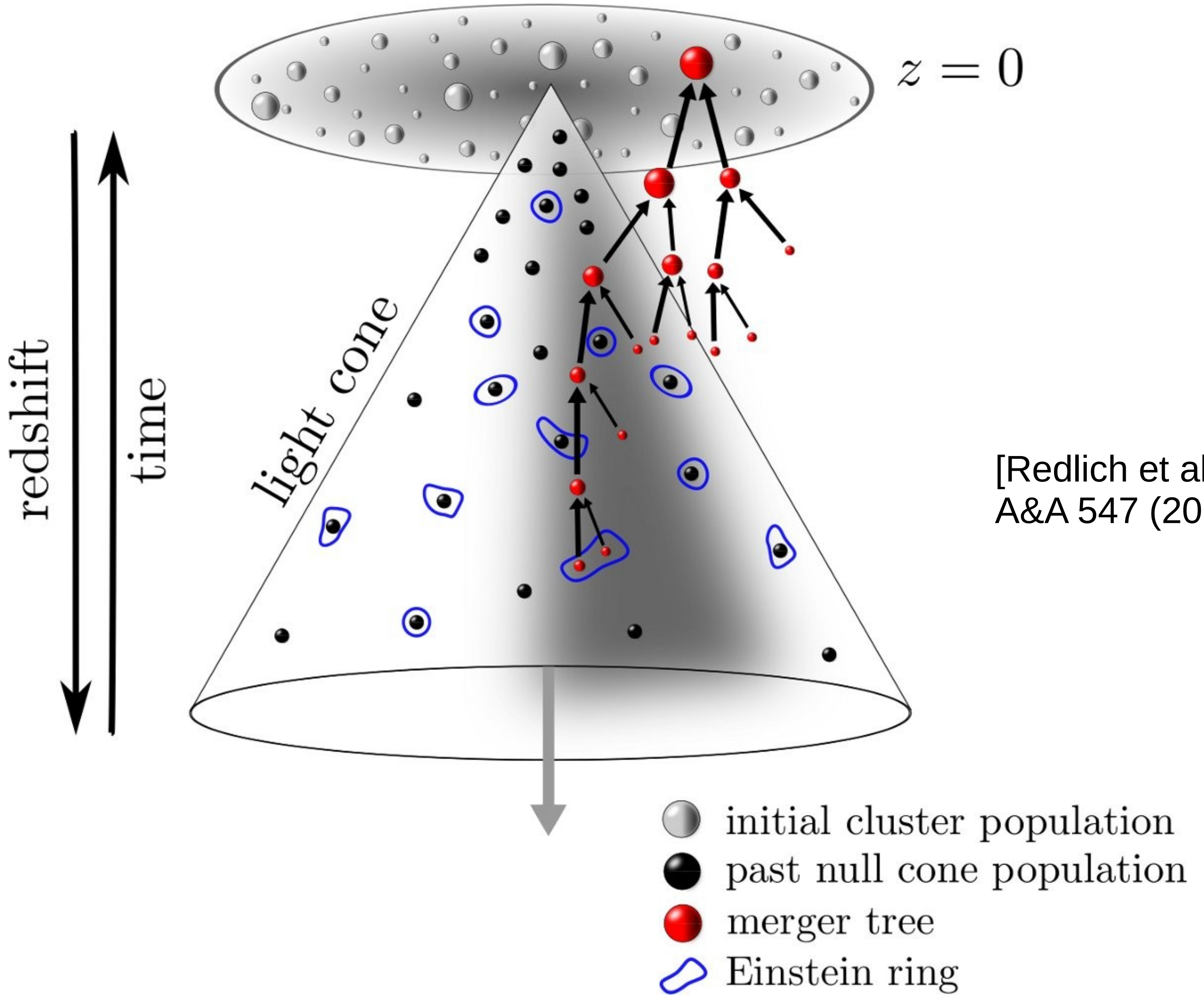
M 0416 [Zitrin et al. in prep.]

Extreme Lenses?



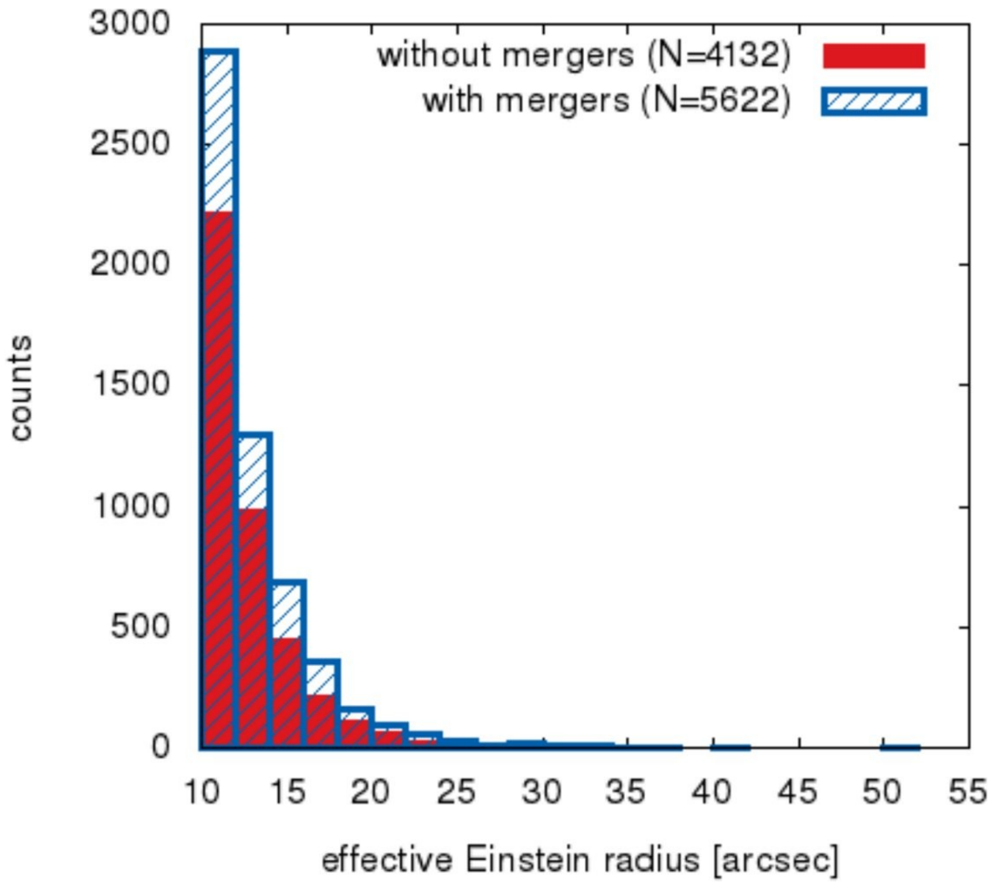
MACS
J 0717

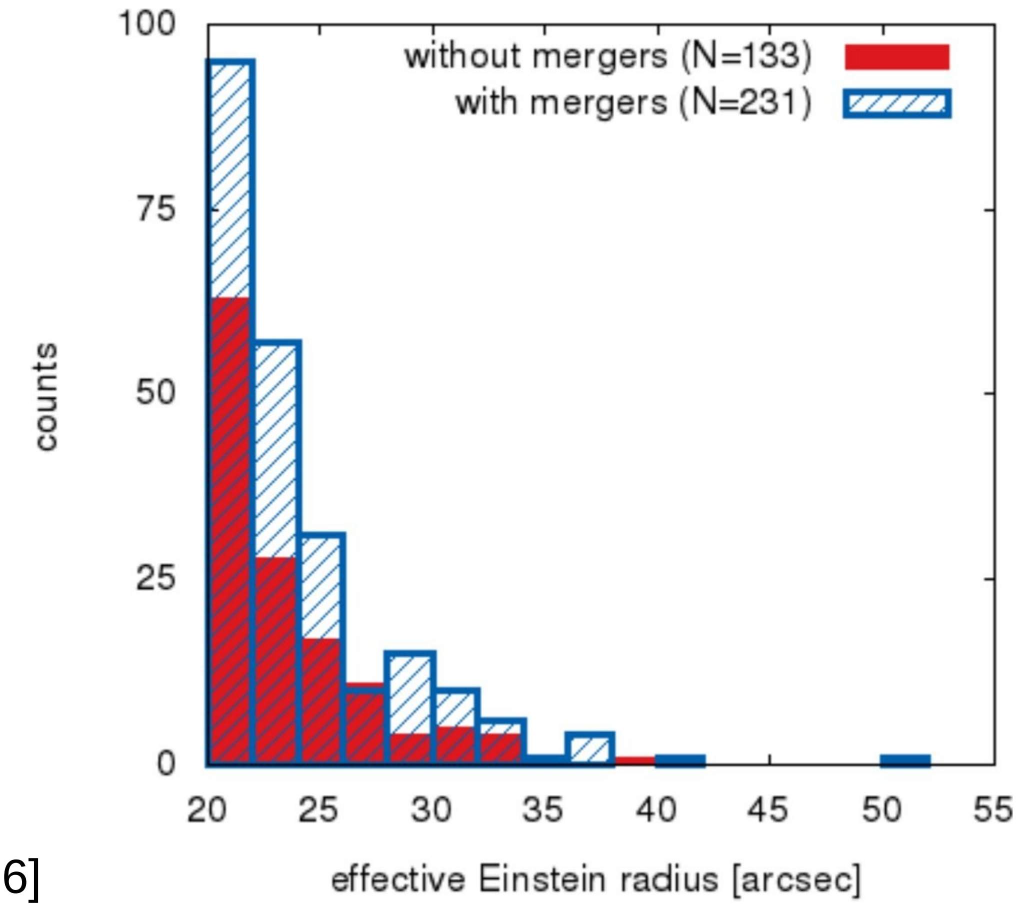
Expectation of Large Critical Curves?



[Redlich et al.
A&A 547 (2012) A66]

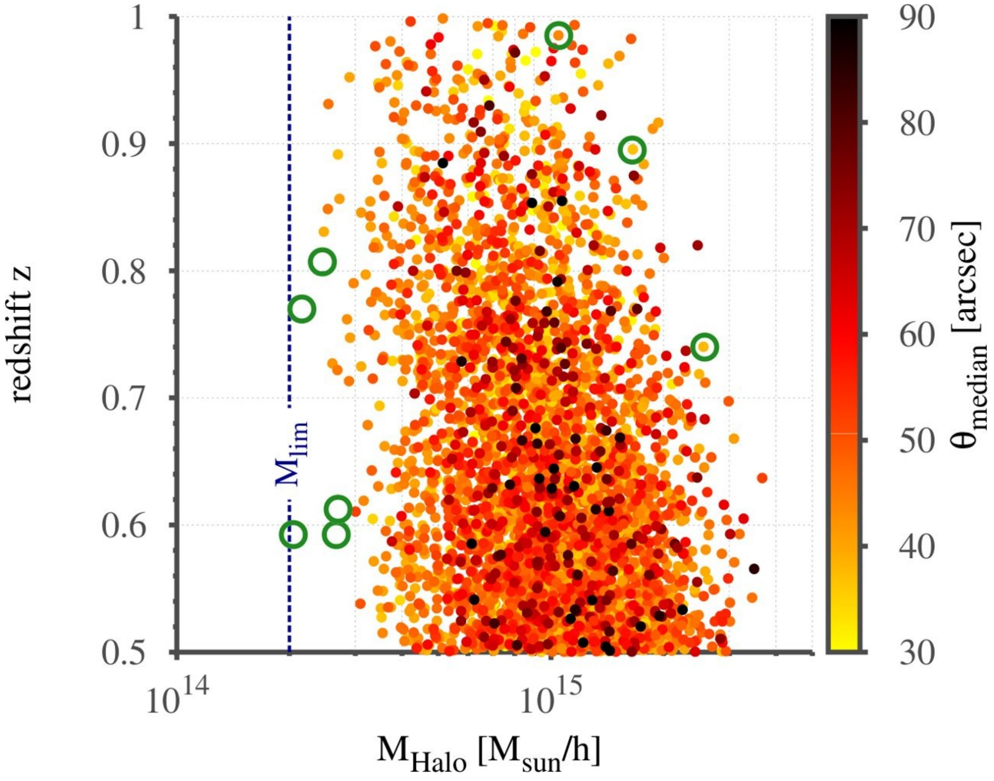
Expectation of Large Critical Curves?



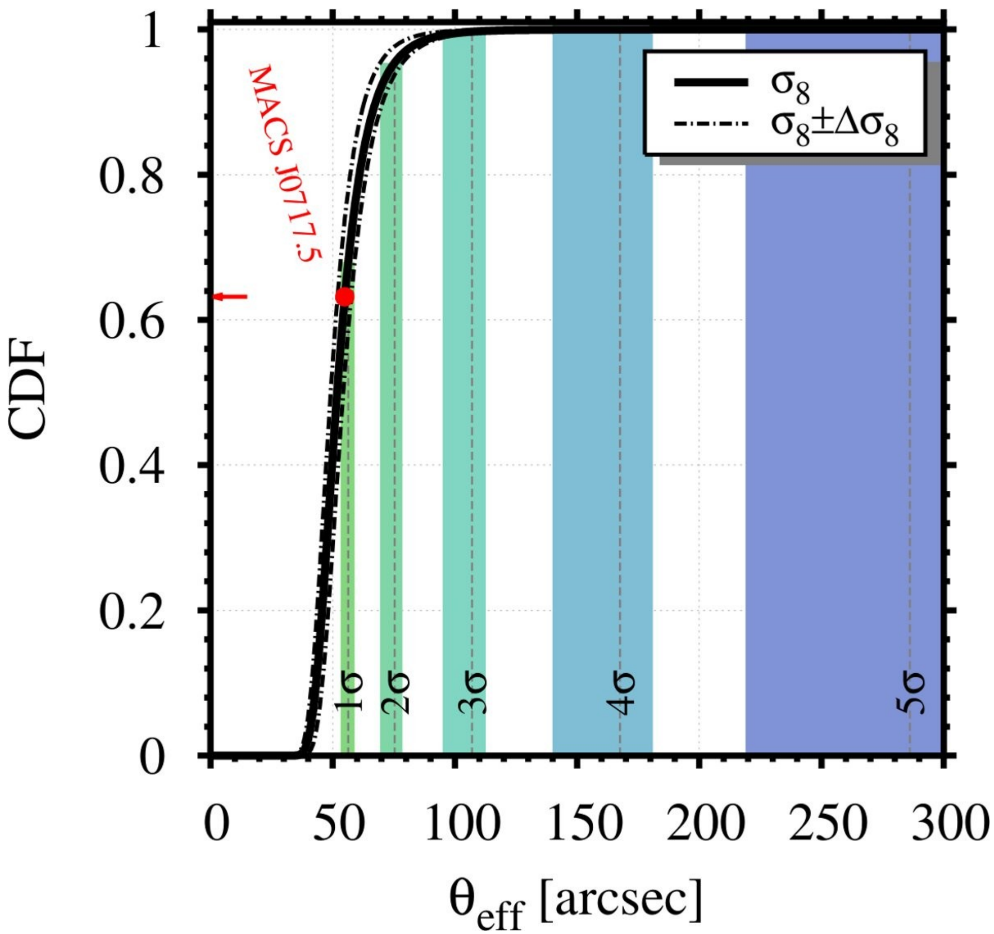


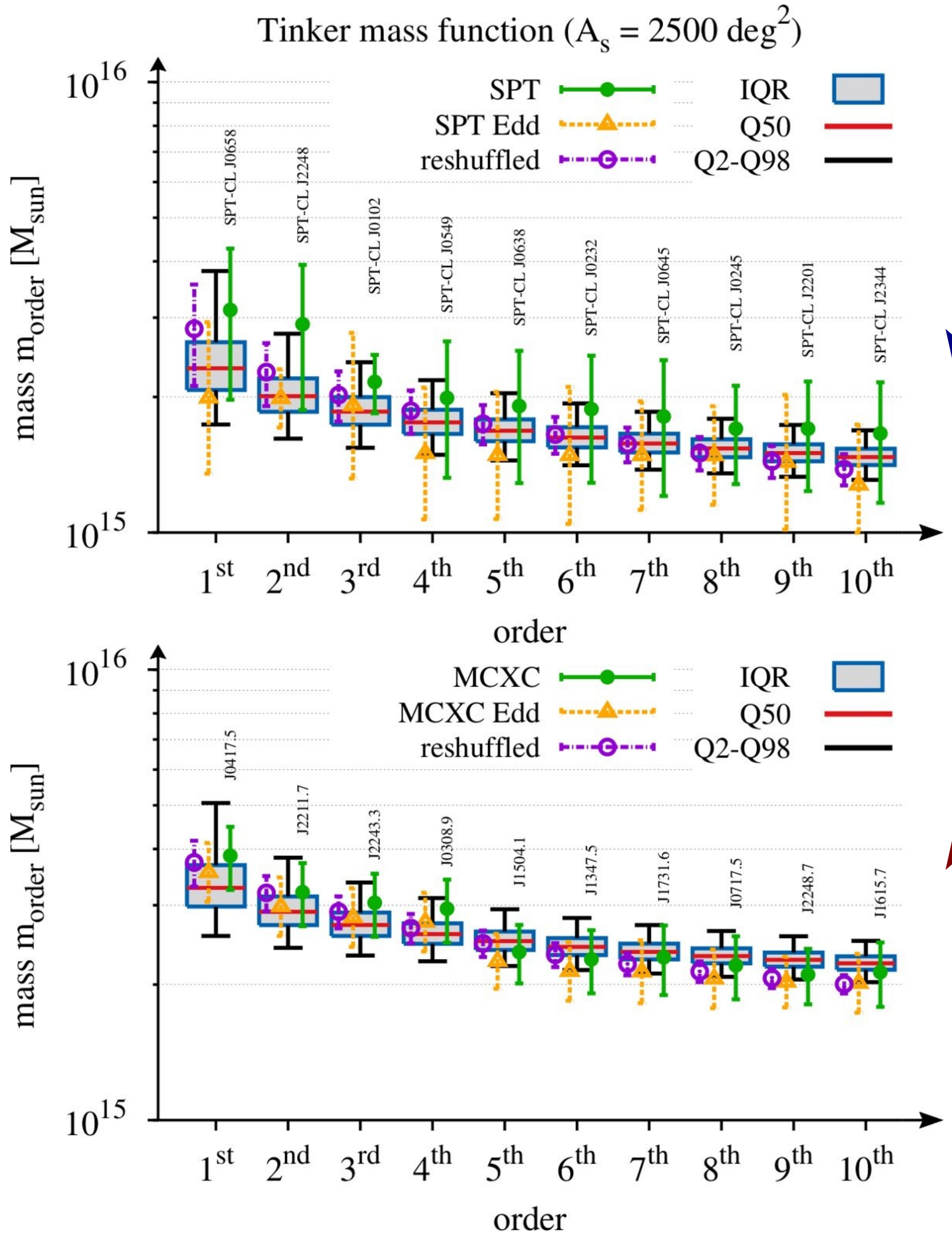
[Redlich et al. A&A 547 (2012) A66]

Extreme-Value Statistics



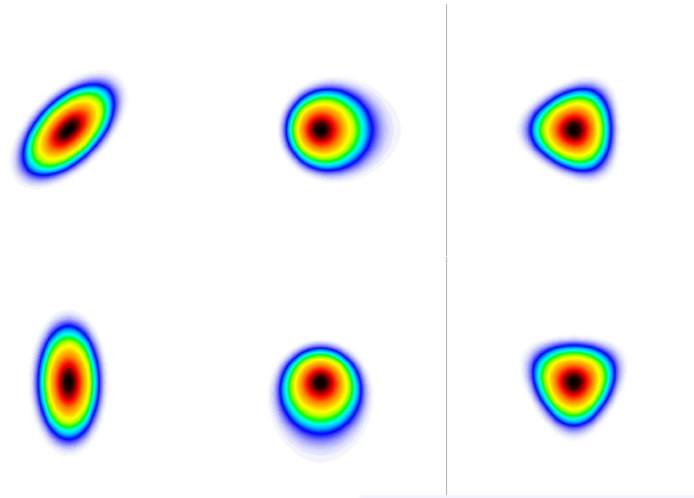
[Waizmann et al. A&A 547 (2012) A67]



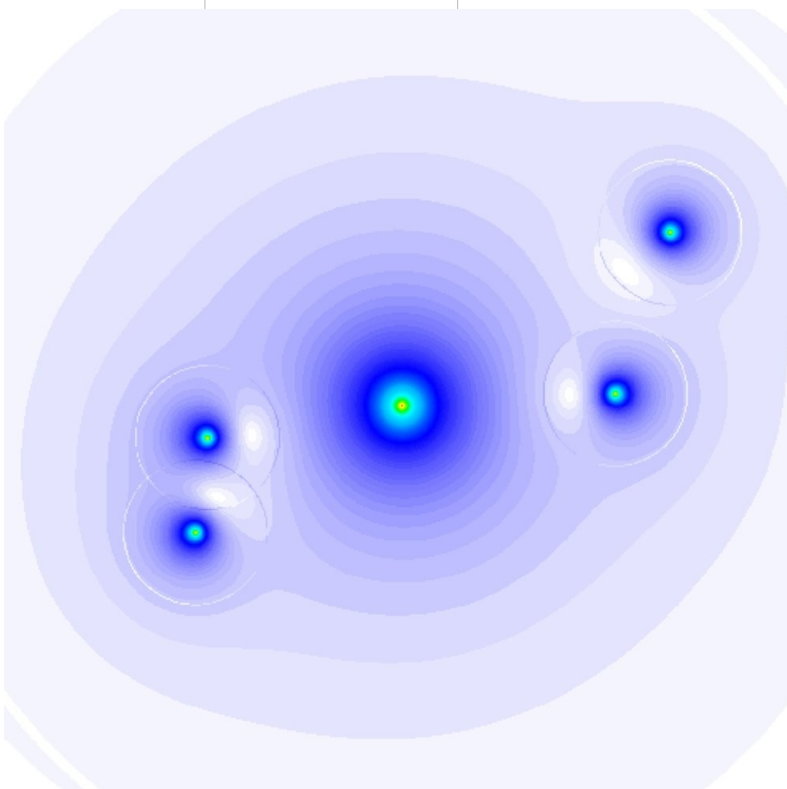


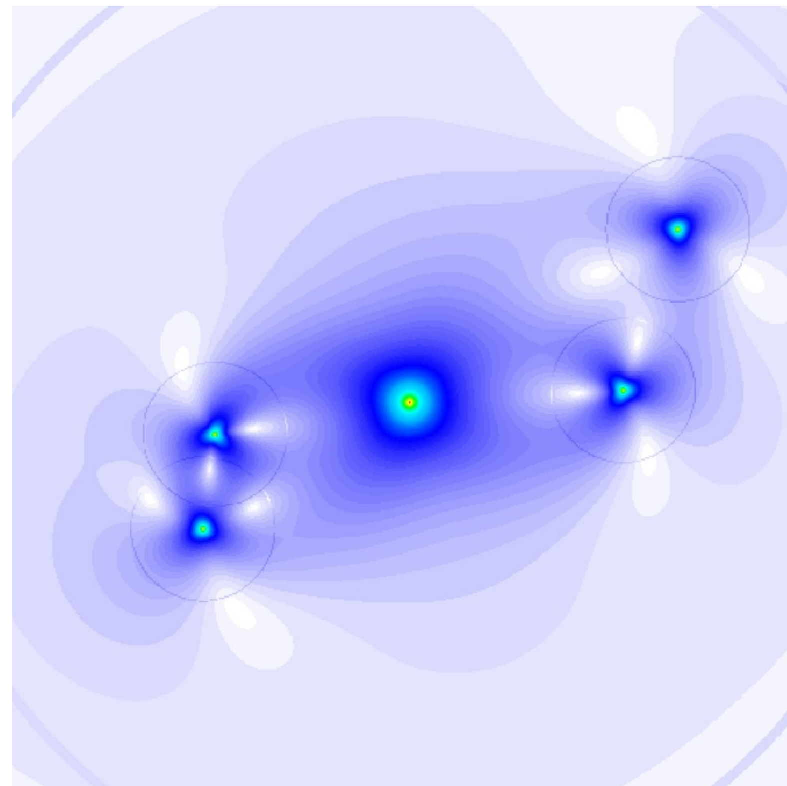
extreme SZ
and
X-ray clusters

[Waizmann et al.
MNRAS (2012)
submitted]



Gravitational flexion
Pioneering work by
T. Futamase, N. Okabe, Y. Okura, K. Umetsu





Flexion Measurement

$$\frac{4}{3}\langle\delta\rangle \simeq G + gF\left(19 - 24\frac{(TrQ)^2}{\xi}\right)$$

$$\langle\zeta\rangle - 2g\langle\zeta^\star\rangle \simeq F\left(\frac{9}{4} - 3\frac{(TrQ)^2}{\xi}\right) + g^\star G\left(\frac{9}{4} - \frac{(TrQ)^2}{\xi}\right) + 2F^\star g\left(3 - 4\frac{(TrQ)^2}{\xi}\right)$$

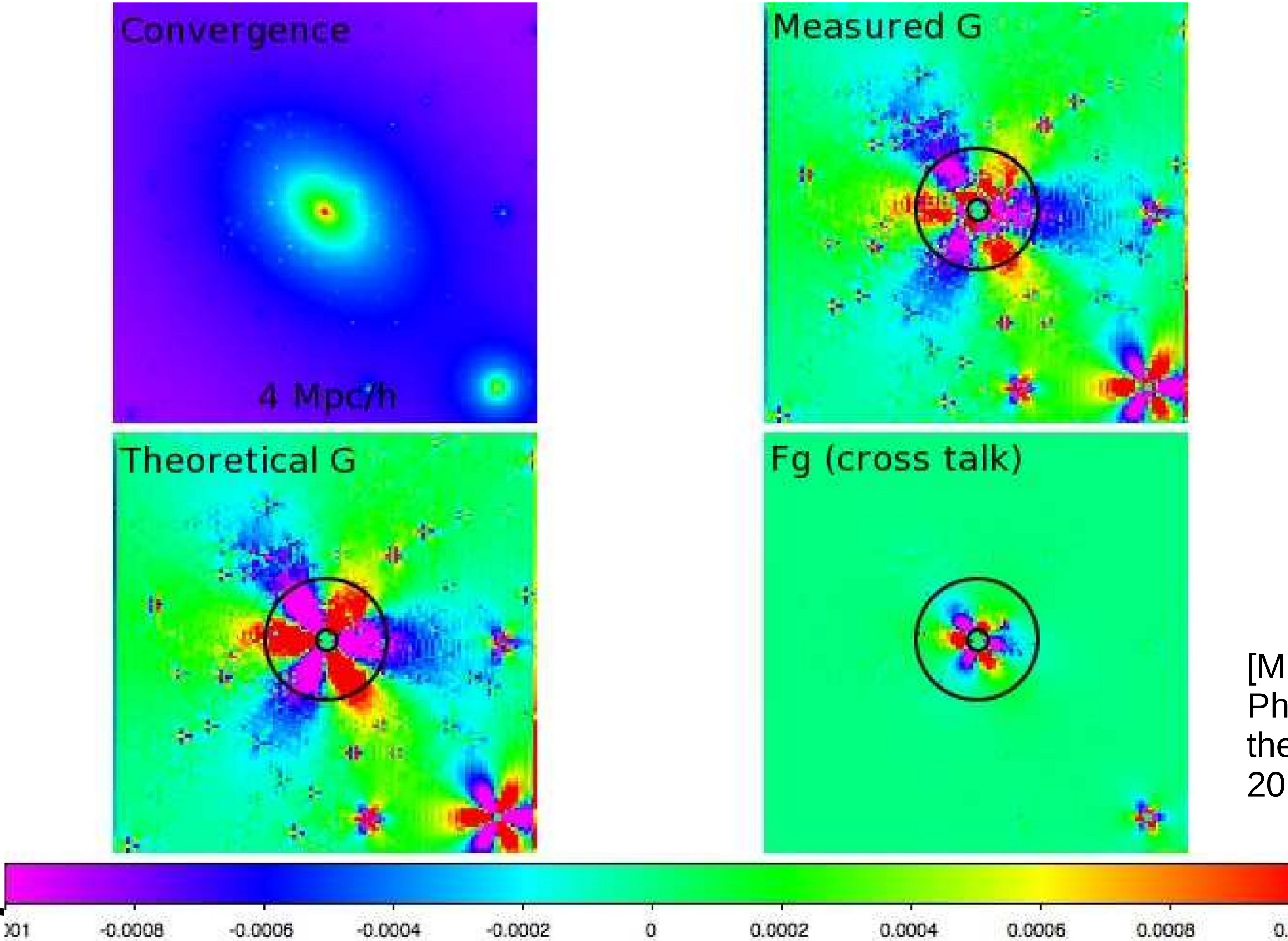
[Viola et al. MNRAS 419 (2012) 2215]

Table 1. Equations for deconvolving all moments up to order $n = 2$. The shown equations are specializations of equation (9).

$$\{G\}_{0,0}\,\{P\}_{0,0} = \{G^\star\}_{0,0}$$
$$\{G\}_{0,1}\,\{P\}_{0,0} = \{G^\star\}_{0,1} - \{G\}_{0,0}\,\{P\}_{0,1}$$
$$\{G\}_{1,0}\,\{P\}_{0,0} = \{G^\star\}_{1,0} - \{G\}_{0,0}\,\{P\}_{1,0}$$
$$\{G\}_{0,2}\,\{P\}_{0,0} = \{G^\star\}_{0,2} - \{G\}_{0,0}\,\{P\}_{0,2} - 2\{G\}_{0,1}\,\{P\}_{0,1}$$
$$\{G\}_{1,1}\,\{P\}_{0,0} = \{G^\star\}_{1,1} - \{G\}_{0,0}\,\{P\}_{1,1} - \{G\}_{0,1}\,\{P\}_{1,0} - \{G\}_{1,0}\,\{P\}_{0,1}$$
$$\{G\}_{2,0}\,\{P\}_{0,0} = \{G^\star\}_{2,0} - \{G\}_{0,0}\,\{P\}_{2,0} - 2\{G\}_{1,0}\,\{P\}_{1,0}$$

DEIMOS
[Melchior et al.
MNRAS 412 (2011) 1552]

Shear-Flexion Cross-Talk



[M. Viola PhD thesis, 2010]

Combining Lensing and X-ray Data

[Konrad et al.
A&A (2012) submitted]