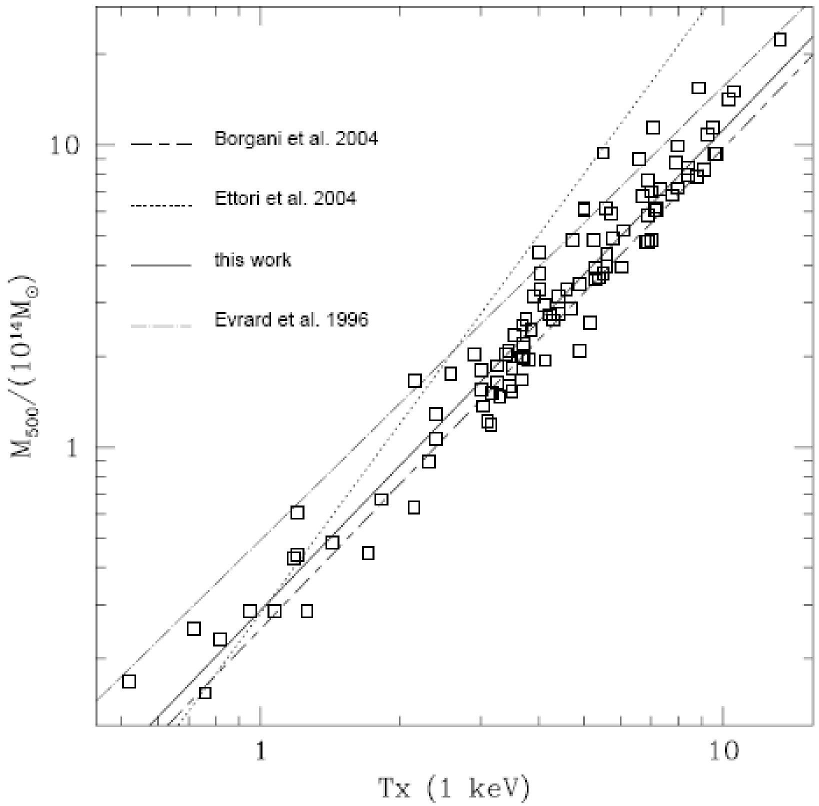
Scaling relations in clusters of galaxies: What gravitational lensing can tell us?

Scaling relations in clusters of galaxies

- Self-similarity of the scaled properties of clusters is a natural consequence of hierarchical processes of structure formation
- However observed scaling laws seem to depart from expected ones (cooling/heating, complex baryonic physics)
- Example of the slope of the M-T relation in clusters (Popesso et al.)
  - Predicted 1.5
  - Simulated ~2.1
  - Observed 1.6



What gravitational lensing can tell us?

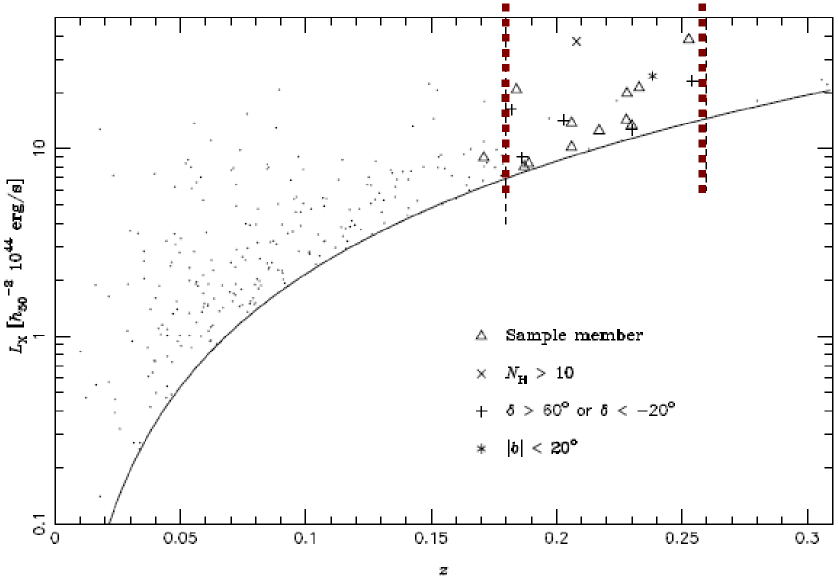
- Potentially a powerful tool to measure total masses in clusters
- But is sensitive to projection effects (from 2D to 3D masses, projection of large scale structures on the line of sight)

- Importance of joint analyses to compare weak lensing masses with other mass estimators and then with other cluster properties

- Illustration by two samples of lensing clusters:
  - Sample of z=0.2 X-ray luminous clusters
  - Weak lensing detected structures in the CFHTLS

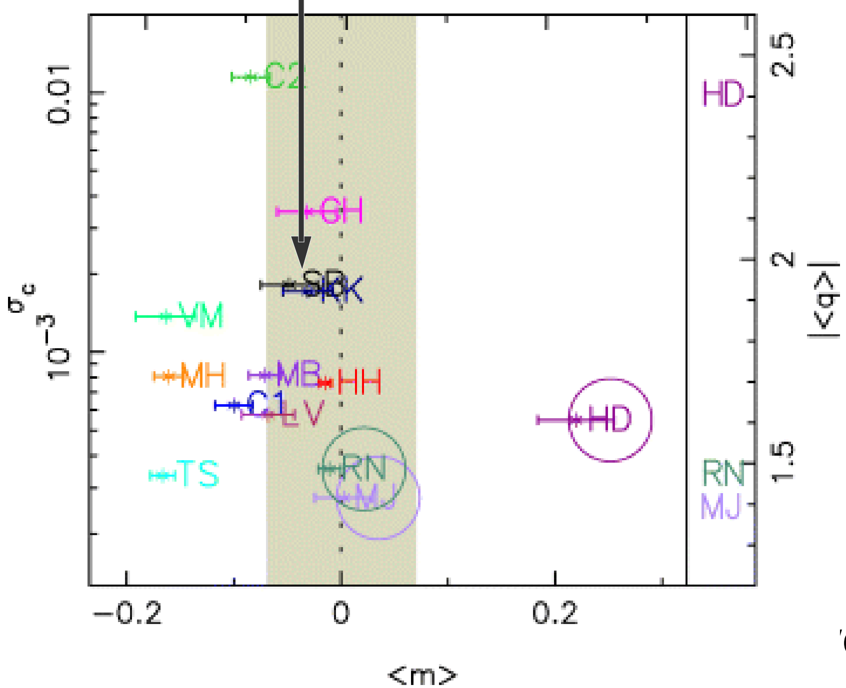
X-ray luminous clusters at z~0.2

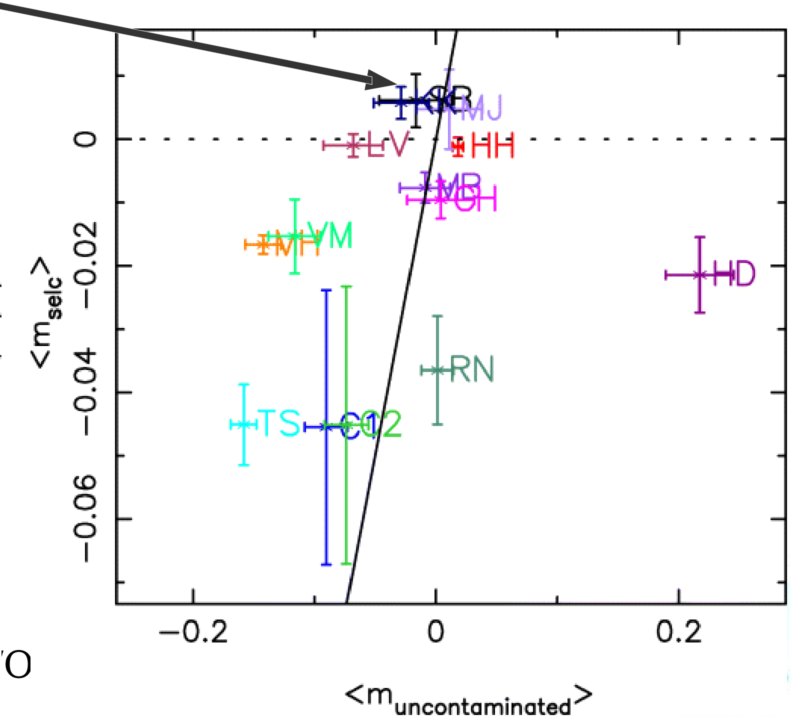
- From Bardeau, Soucail, Kneib, Czoske, Ebeling, Hudelot, Smail, Smith
- The sample
  - A sample of X-ray selected clusters from XBACS
  - Redshift range 0.17<z<0.26
  - Observational constraints: 11 clusters
- CFHT Optical observations
  - CFH12k images in BRI
  - Homogeneous dataset
  - Weak lensing analysis in R (Rlim ~ 26)



Cluster sample analysis

- Measurement of galaxy shape parameters
  - PSF correction using **IM2SHAPE** software (Bridle et al. 2001)
  - Validated by STEP1

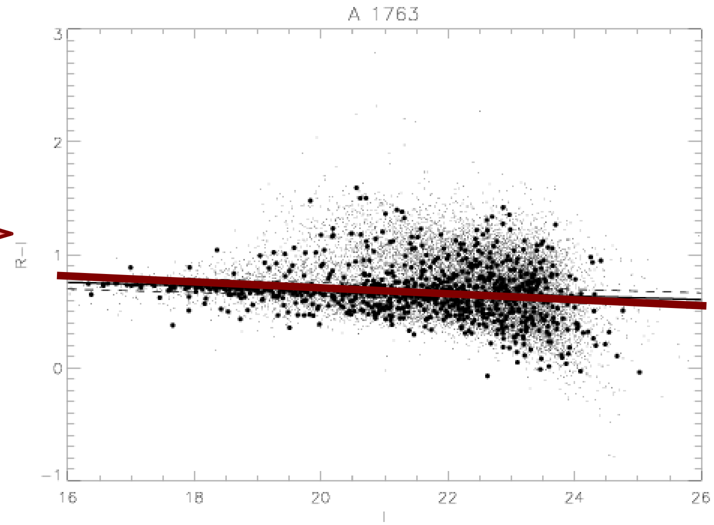


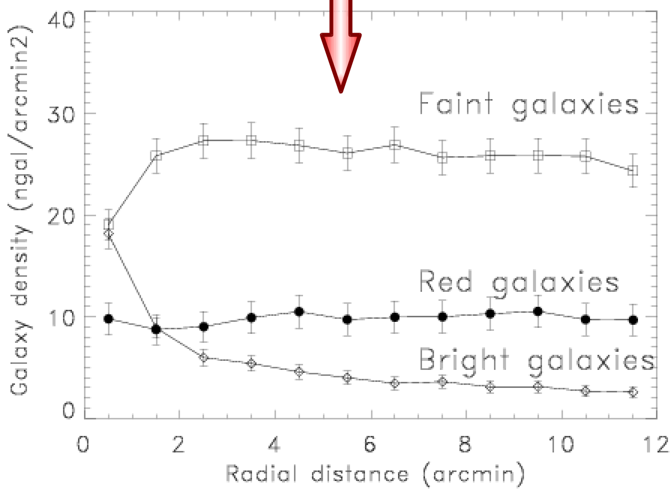


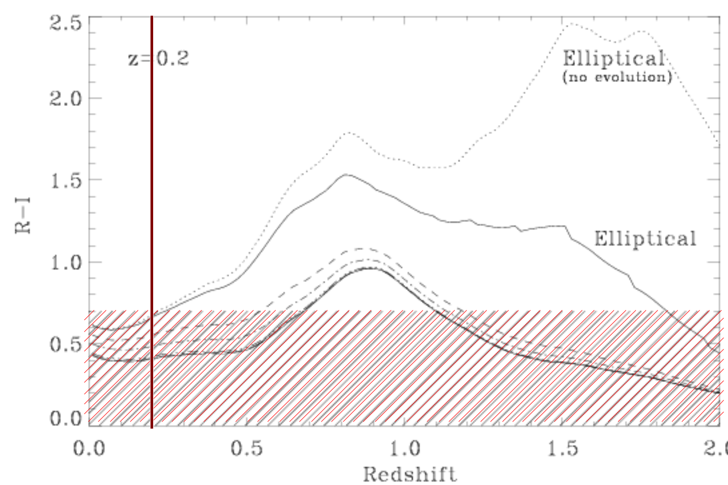
Cluster sample analysis

- Photometric analysis
  - « red » galaxies, selected above the color sequence, considered as background galaxies
  - Mean redshift z ~ 0.8
  - Reduced cluster contamination

(but with a lower source density ~8-10 gal/arcmin2)

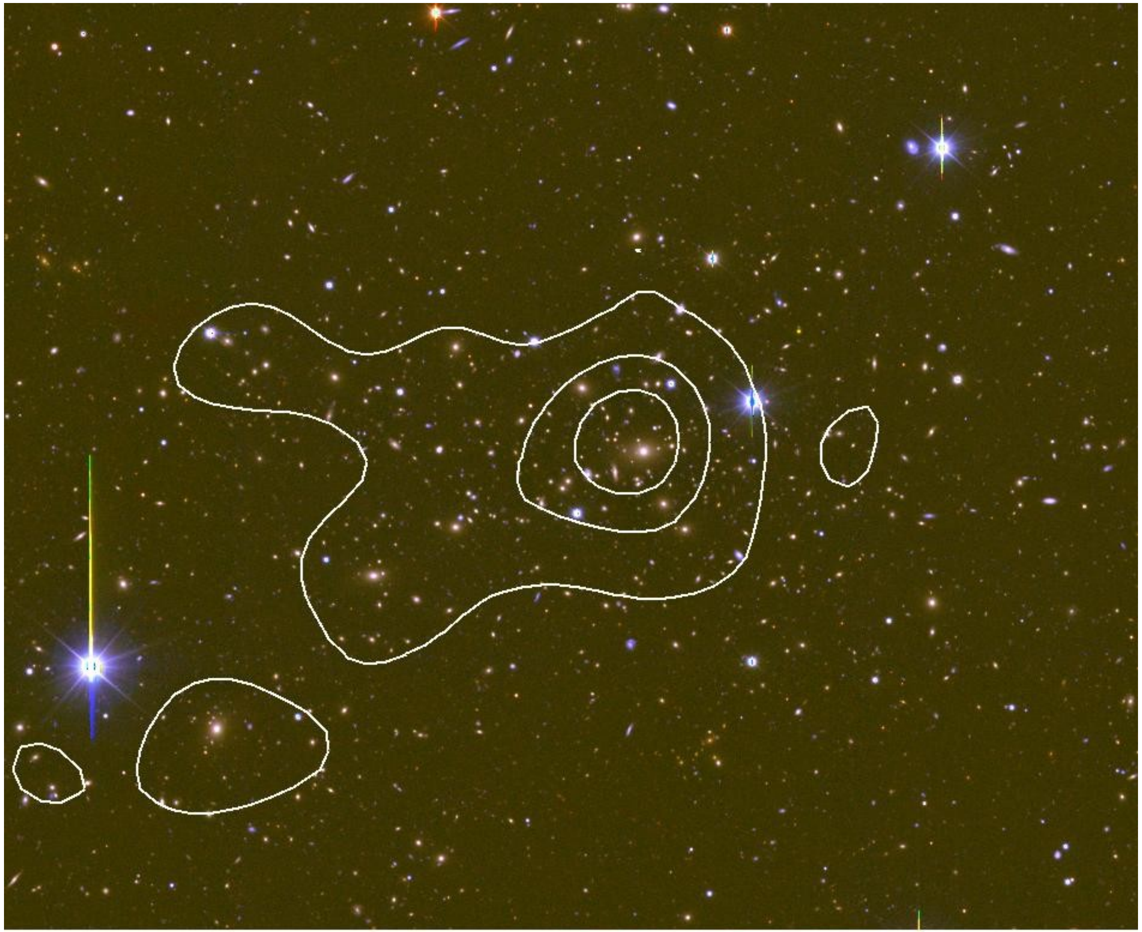






Cluster sample analysis

- Photometric analysis
  - « elliptical galaxies », selected from the C-M diagram

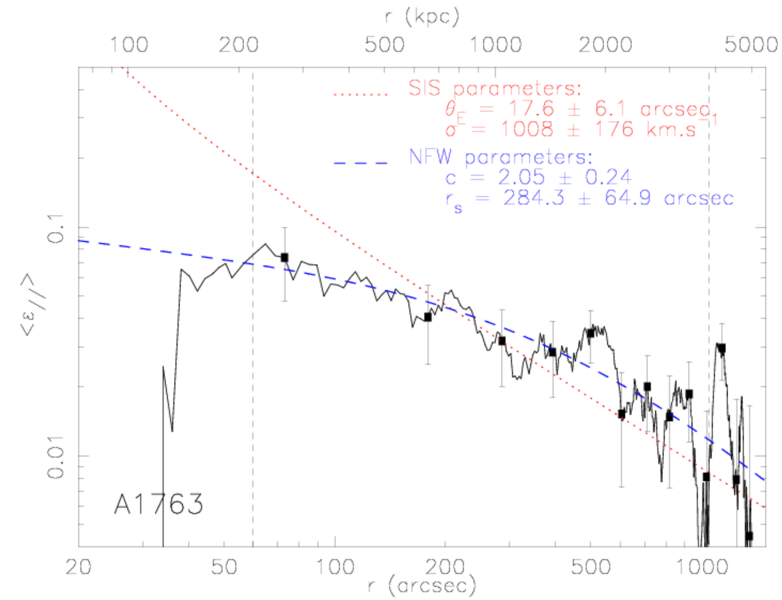


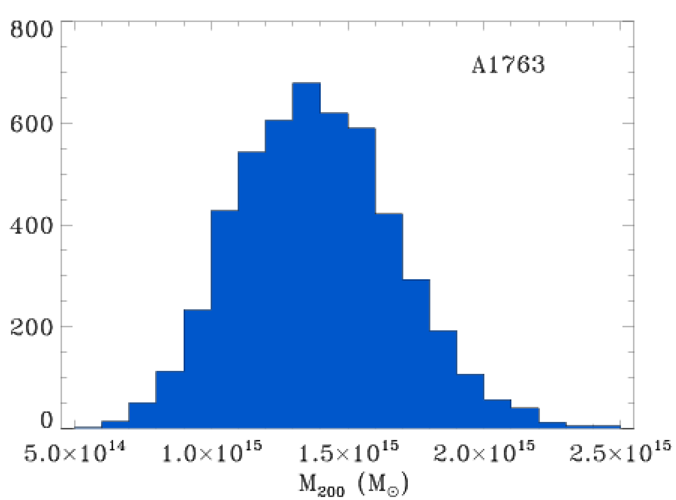
Abell 1763: luminosity contours

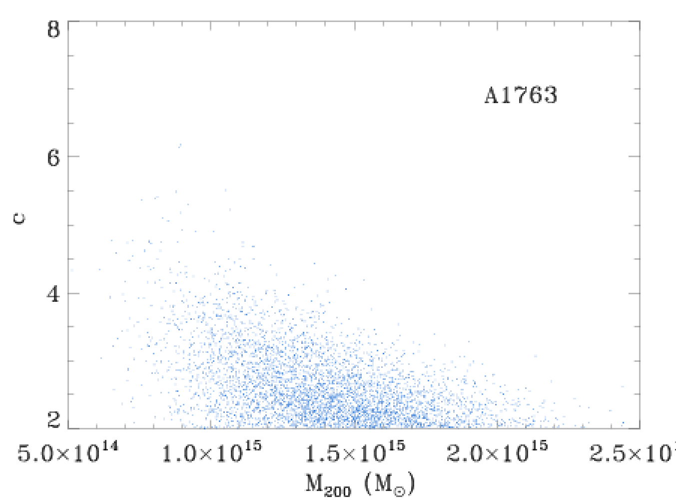
Observatoire Midi-Pyrénées OMP

Fit of the shear profile: example of A1763

- 2 mass profiles (NFW and SIS)
- Direct radial fit
  - SIS: θ_E=17.6''±6.1 - σ=1008 ± 176 km/s
  - M_{200} ~ 13.7 10^{14} M_{sol} & c=2,05 ± 0,24
- Global approach with **McADAM**
  - SIS: θ_E=15.0''±1.9 - σ=932 ± 60 km/s
  - Prior 2<c<10, 1 clump centered on cD
  - M_{200} = 13.8 ± 2.6 10^{14} M_{sol} & c=2.63 ± 0.63







Observatoire Midi-Pyrénées OMP

Results for the 11 clusters at z=0.2

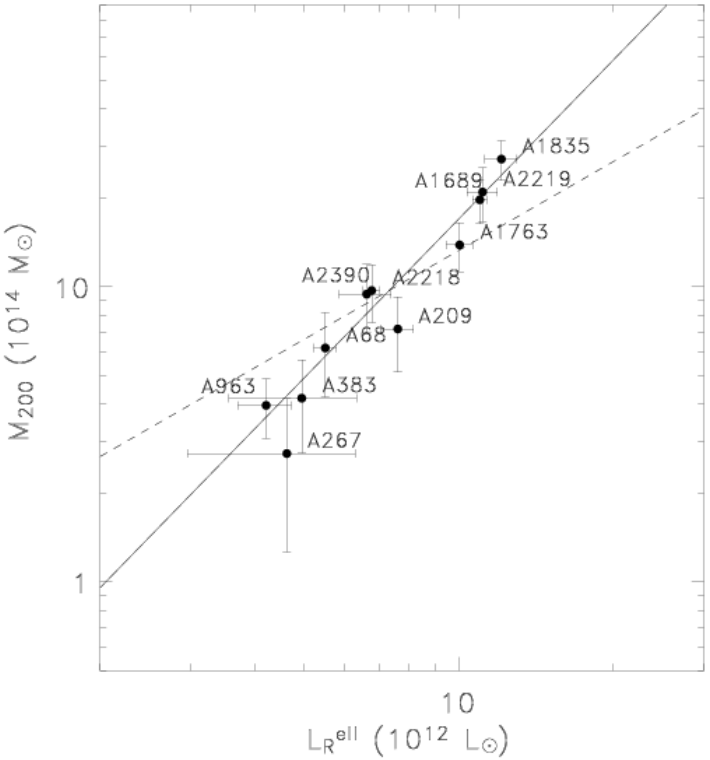
Cluster	c	r_{200} (h_{70}^{-1} Mpc)	M_{200} ($10^{12}\,h_{70}^{-1}\,M_\odot$)	$\sigma_{\rm shear}$ (km/s)	θ_E ($''$)
A 68	3.84 ± 1.13	1.49 ± 0.18	620 ± 197	880 ± 65	12.9 ± 1.9
A 209	3.00 ± 0.92	1.57 ± 0.17	719 ± 204	813 ± 70	12.4 ± 2.1
A 267	4.54 ± 2.01	1.15 ± 0.23	272 ± 146	634 ± 116	6.7 ± 2.4
A 383	2.62 ± 0.69	1.32 ± 0.17	419 ± 146	619 ± 72	7.4 ± 1.7
A 963	8.35 ± 1.25	1.33 ± 0.10	396 ± 90	812 ± 67	12.3 ± 2.0
A 1689	4.28 ± 0.82	2.25 ± 0.14	1971 ± 336	1277 ± 37	31.8 ± 1.8
A 1763	2.63 ± 0.63	1.93 ± 0.14	1386 ± 263	932 ± 60	15.0 ± 1.9
A 1835	2.58 ± 0.48	2.39 ± 0.14	2707 ± 414	1240 ± 47	26.6 ± 2.0
A 2218	6.86 ± 1.30	1.81 ± 0.14	971 ± 215	1040 ± 50	21.2 ± 2.0
A 2219	3.84 ± 0.99	2.25 ± 0.18	2094 ± 435	1175 ± 53	23.4 ± 2.1
A 2390	5.26 ± 1.43	1.74 ± 0.17	943 ± 246	1015 ± 54	18.1 ± 1.9

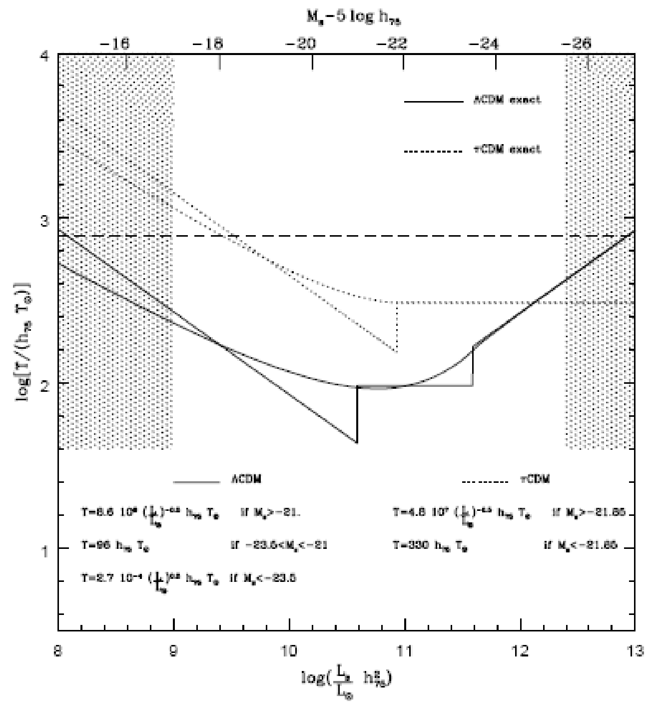
- Two mass estimates, from NFW and SIS profiles
- M200 is well determined but *c* is poorly constrained (needs strong+weak lensing)

Mass versus light

- M200 – Lopt: $\langle M/L_R^{\rm tot}\rangle = (100 \pm 38)\, h_{70}\, (M/L)_\odot$ or $M/L \propto L^{0.80\pm0.24}$

compatible with predictions from simulated clusters (Marinoni & Hudson 2002). M/L increases with mass (decrease in SF efficiency in dense environments ?)





Observatoire Midi-Pyrénées

Mass versus temperature

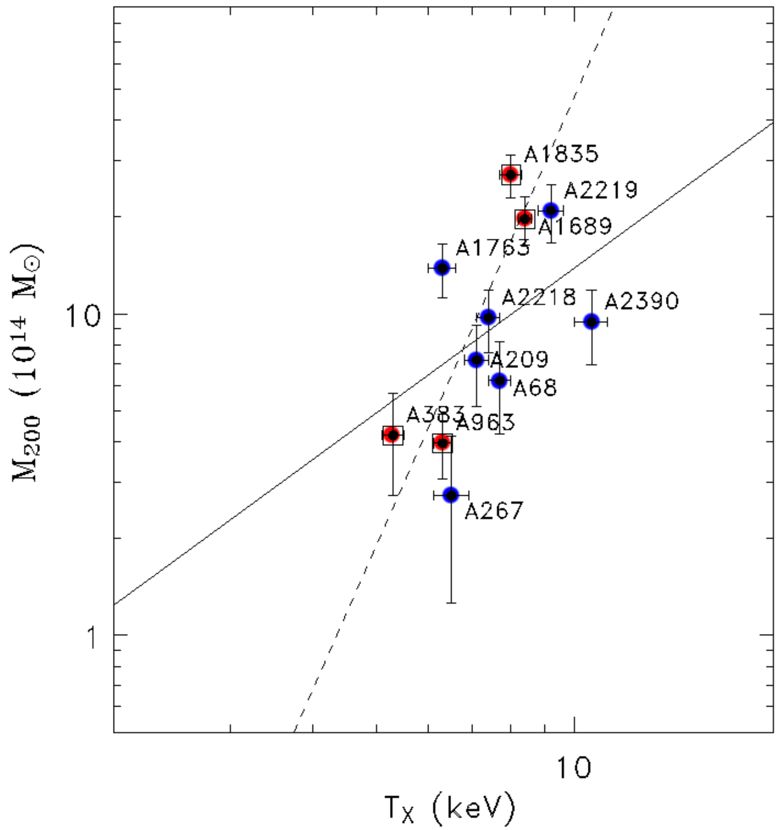
- M200 – TX:
- Normalisation of the M-T$^{3/2}$ relation (compatible with simulations)

$$M_{200}/10^{14}M_{\odot} = 0.44^{+0.39}_{-0.21}\left(\frac{T_{\mathrm{X}}}{1\,\mathrm{keV}}\right)^{3/2}$$

or best fit slope 4.6 +/- 0.7 (poorly reliable

Influence of the cooling core clusters?
Intrinsic scatter in the relation (due to various histories of clusters)?

Statistics are still small ...

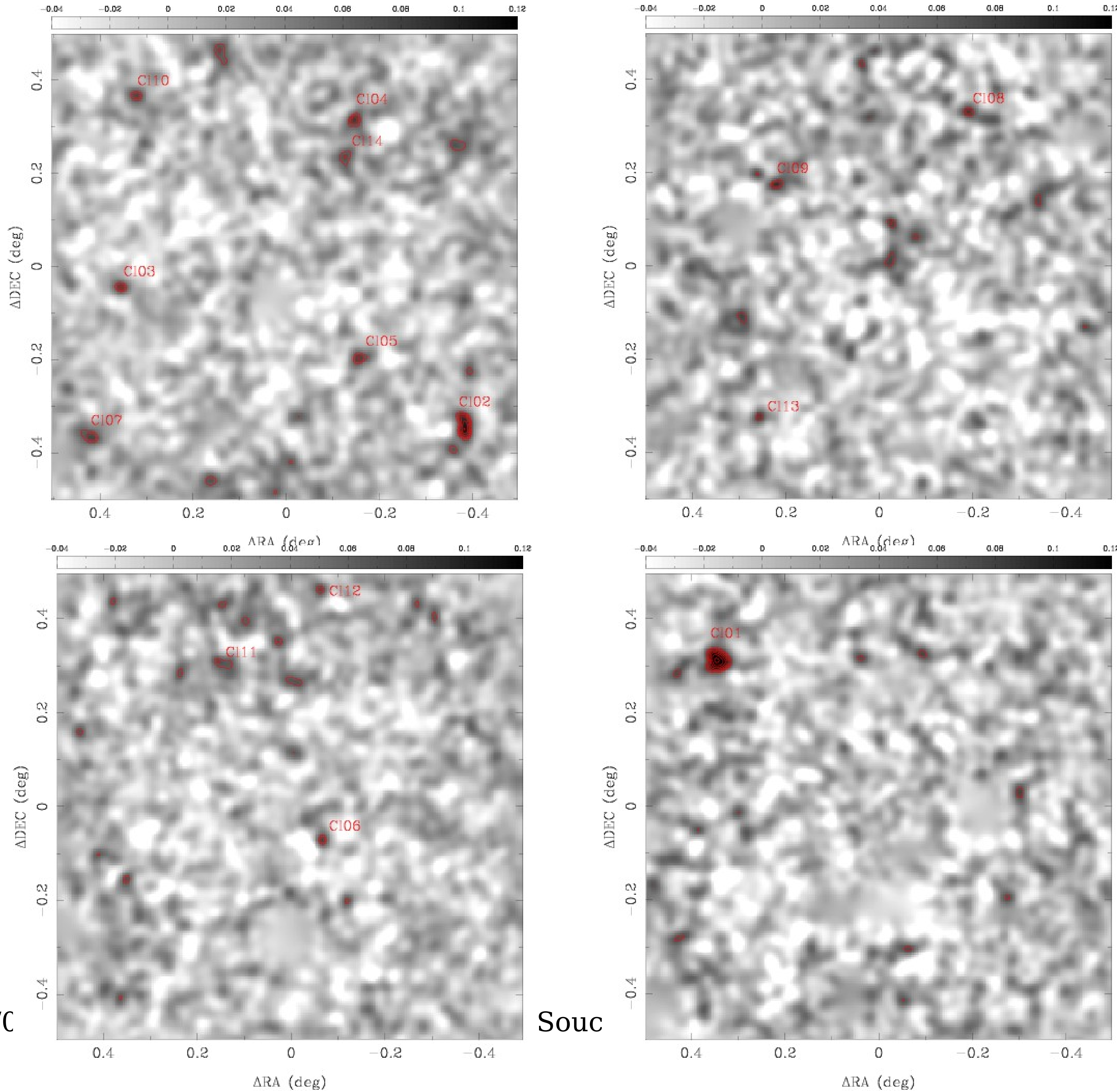


Another sample: weak lensing detected clusters in the CFHTLS

- A pioneering work by Gavazzi and Soucail, using the 4 sq. degrees fields of the CFHTLS-Deep, observed in 5 bands
- Shear measurements obtained with the KSB method on the i' images (depth i'~25.9)
- Convergence maps built for each of the 4 fields, with estimate of the local SNR.
- Detection of mass over-densities

46 peaks with SNR > 3
5 peaks with SNR > 5
detection level fixed at SNR=3.5 : 14 detections

Observatoire Midi-Pyrénées OMP

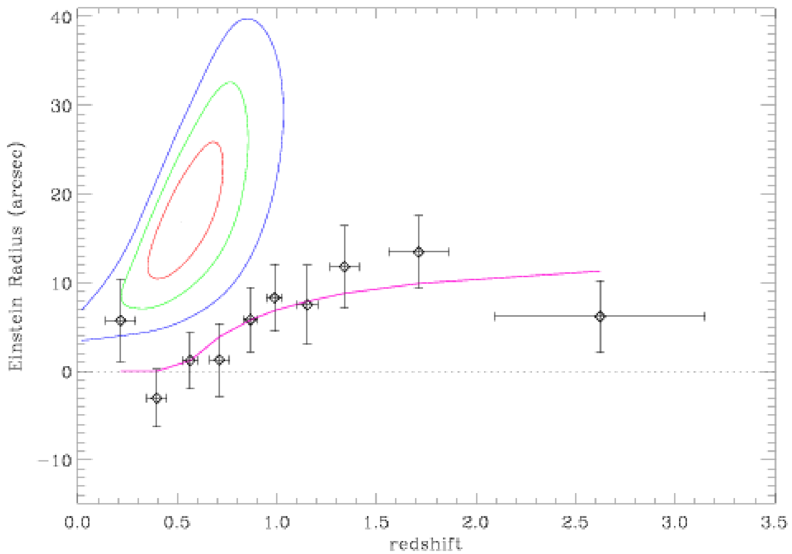

C110
C104
C114
C103
C105
C102
C107
C108
C109
C113
C112
C111
C106
C101
ΔRA (deg)
ΔDEC (deg)

Souc

“Lens tomography”

- A photometric method for estimating the lens redshift
- Allows to test the reality of the detected peak

Application: 10 redshift bins for the sources (i'<26)



Fitting of the shear function

z_L=0.52 (+0.14,-0.11)

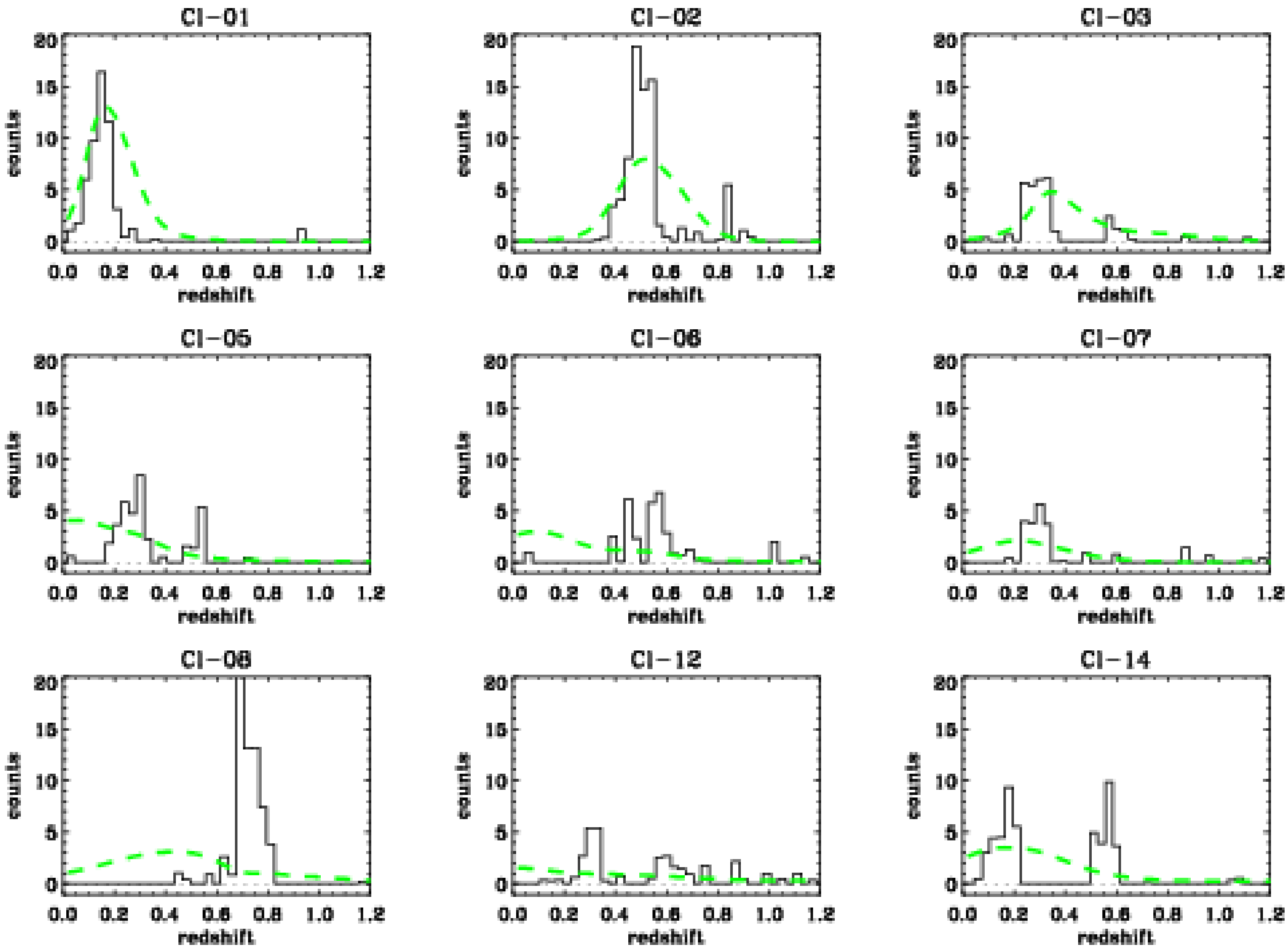
q_E = 17'' (+5.5'', -4.5'')

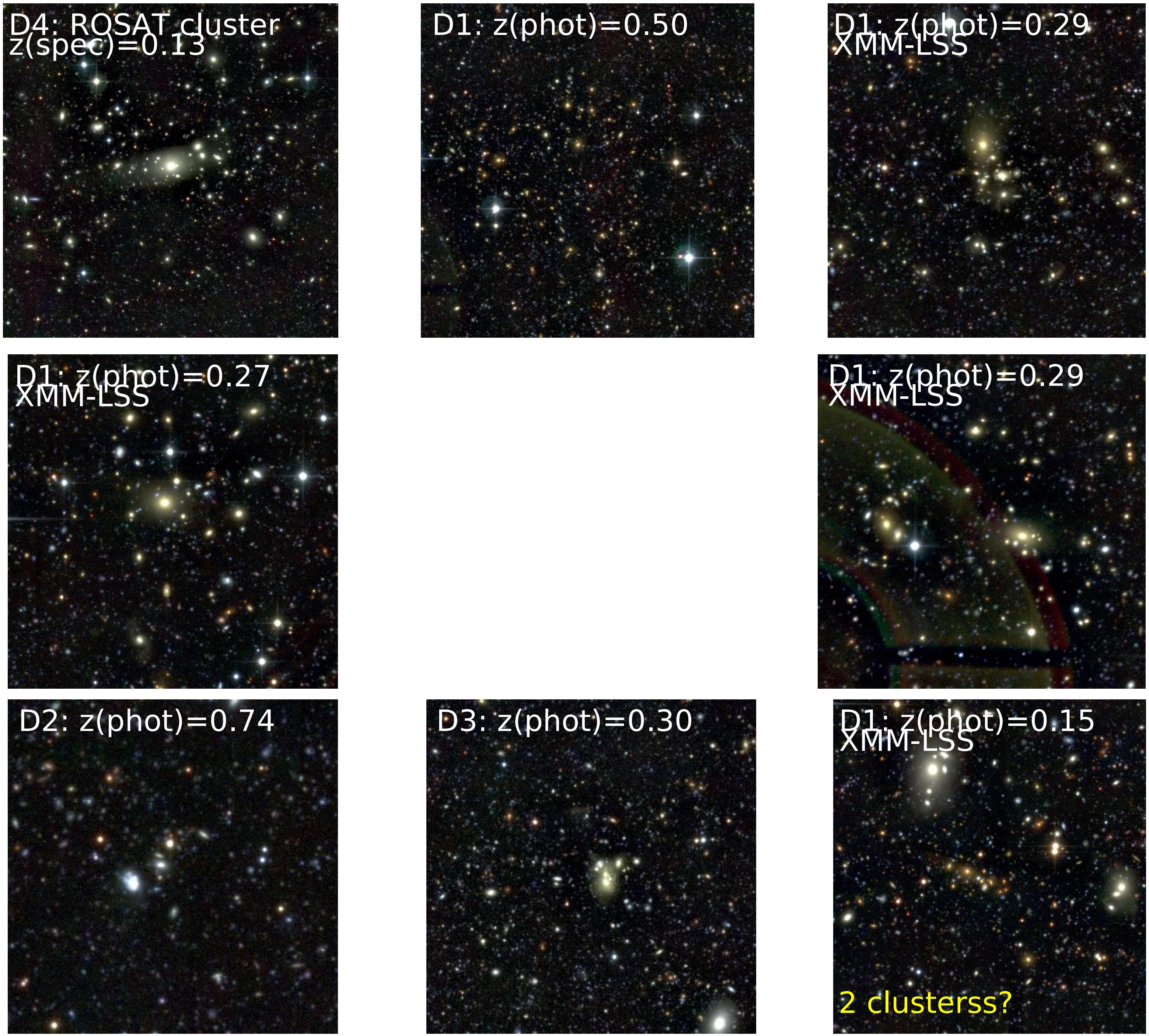
s_V = 760 +/- 110 km/s

Results on the 14 peaks:

- No massive clusters with σ_V>800 km/s (No Abell clusters in the CFHTLS-Deep fields)
- 2 peaks without convergence of the tomography (Cl-04 et Cl-12). Noise peaks or superposition of clusters?

Optical couterparts and photometric redshifts

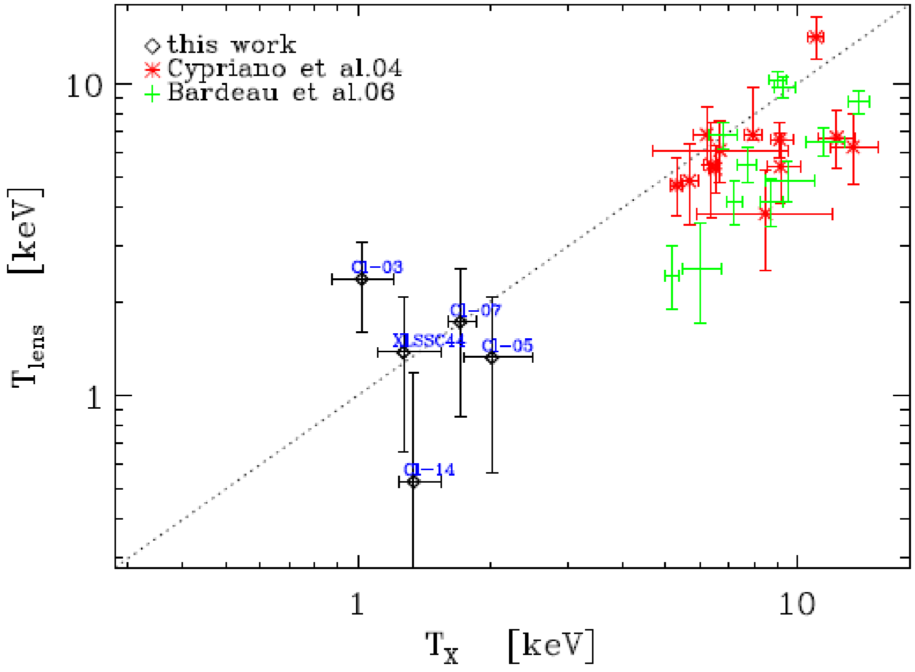



D4: ROSAT cluster
z(spec)=0.13
D1: z(phot)=0.50
D1: z(phot)=0.29
XMM-LSS
D1: z(phot)=0.27
XMM-LSS
D1: z(phot)=0.29
XMM-LSS
D2: z(phot)=0.74
D3: z(phot)=0.30
D1: z(phot)=0.15
XMM-LSS
2 clusterss?

Comparison wih X-rays. Scaling laws

- D1 lies within the XMM-LSS field
- 7 detected peaks in D1 (SNR>3.5), 4 are measured in X-rays (+1 recently observed by XMM) and 2 do not have counterparts (noise?)
- .Low mass clusters: another mass range probed by WL, thanks to the depth of the data
- Comparison between TX and Tlens

$$k_B T_{\mathrm{lens}} = \mu m_H \sigma_V^2$$



Conclusions

- Lensing is a powerful tool to calibrate the scaling relations in clusters but:
  - Difficulties in the determination of accurate lensing masses (Calibration issues in the mass measurements coming from instrumental effects on galaxy shapes measurements, dilution of the signal by cluster galaxies contamination, uncertainties in the source redshift distribution)
  - Statistical samples still small, individual effects still dominant. Strong need for large samples of clusters
  - Mass-selected clusters: mostly limited to the high mass range (>5 10^{14} Msol)

- Future expectations will come from space (Planck, SNAP ...)

My good old friends ...

Example of D1 field