Lensing, Dynamics and X-ray of Clusters of Galaxies

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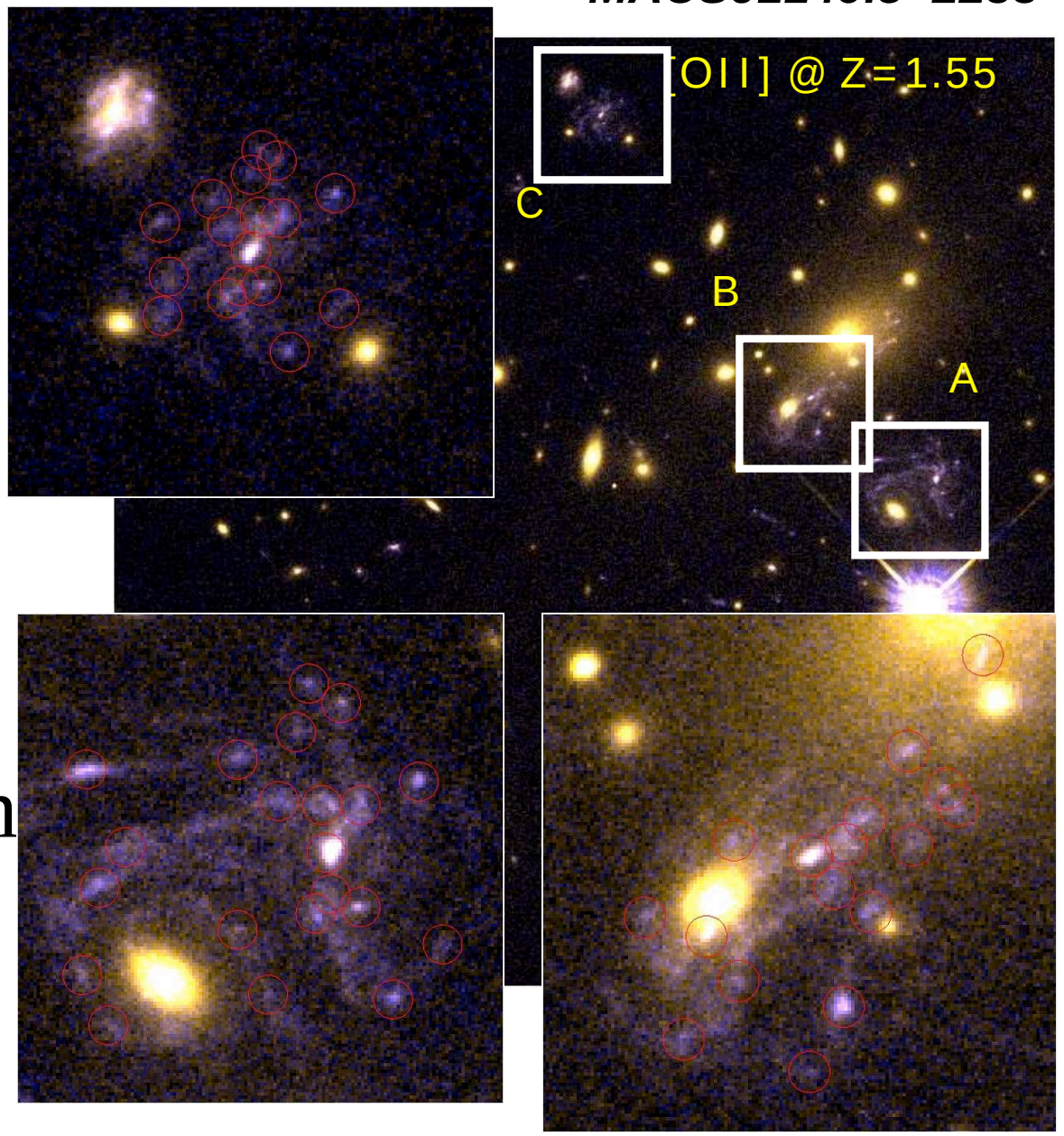
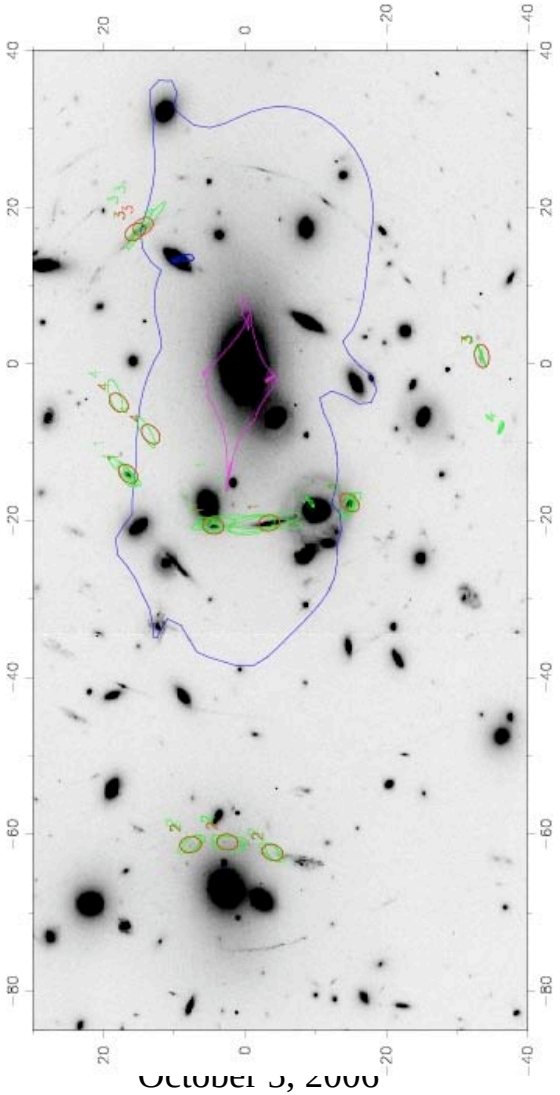
and many others

Outline

- Strong & Weak Lensing
- Lensing in massive X-ray clusters
- Cluster/groups in COSMOS
- Future prospects

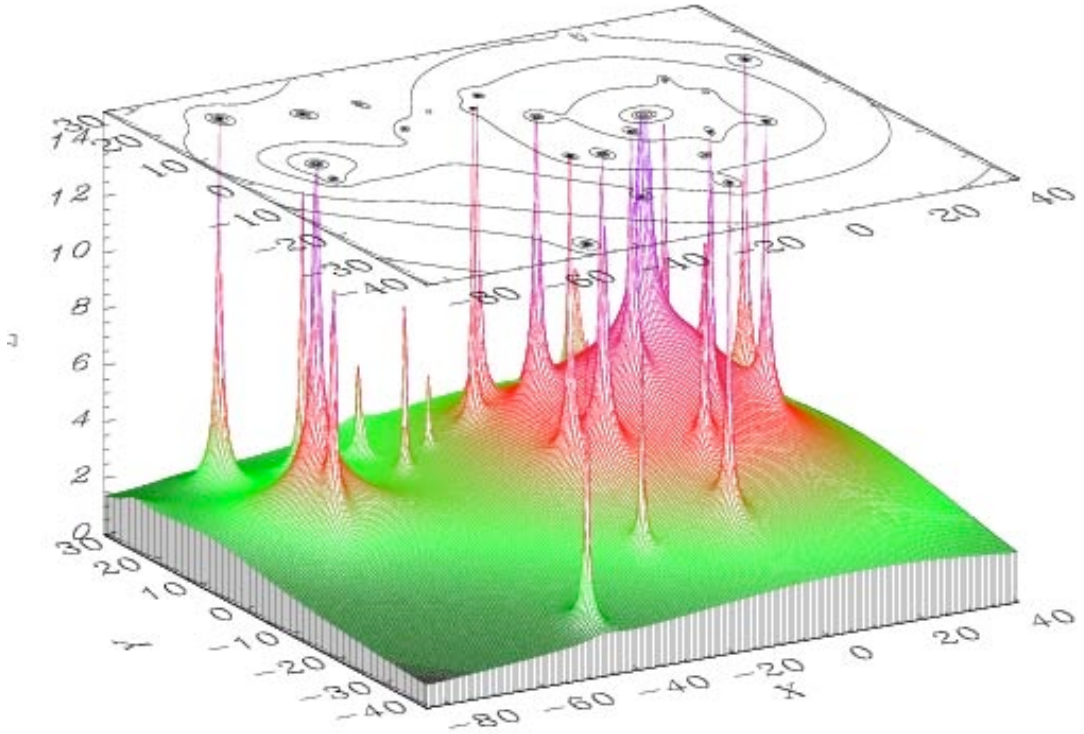


Strong Lensing: Mass Reconstruction



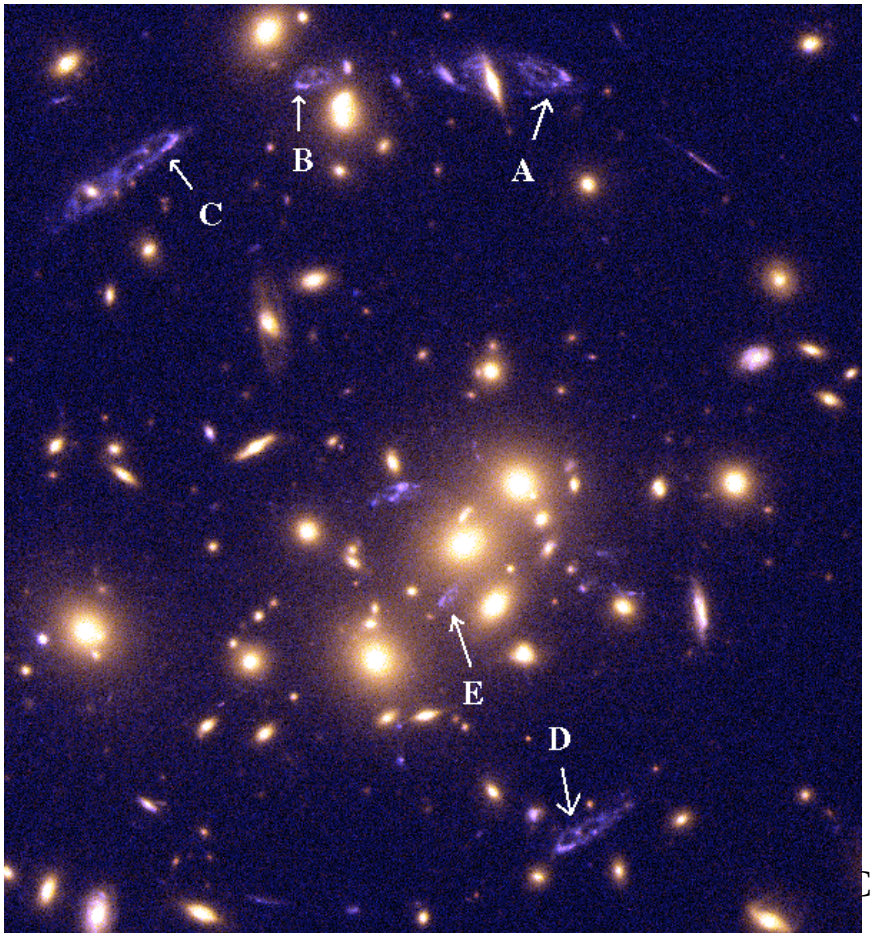
- Not many constraints => Parameterized mass distribution,
- *Galaxy scale mass components are essential =>*

  Galaxies are included using scaling relations (FJ, FP) and represent with their DM halos ~10% of the total mass

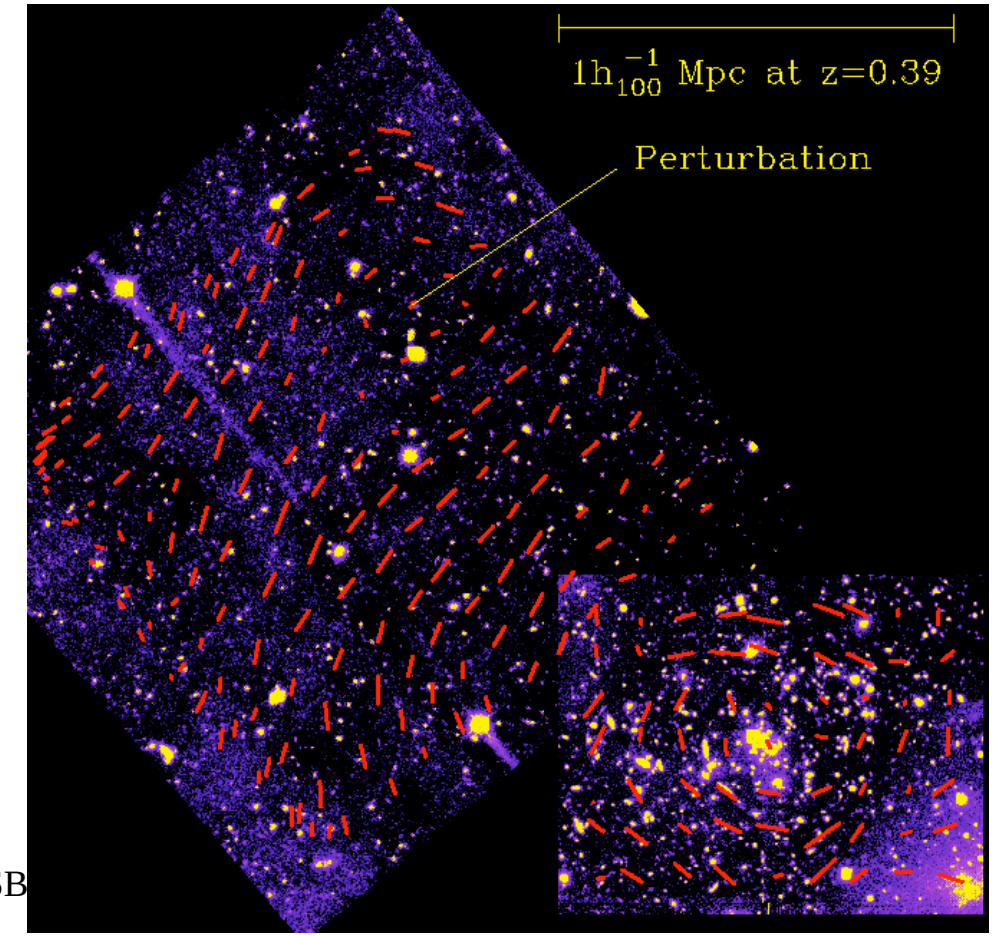


Coupling Strong & Weak Lensing

Absolute central mass, and inner slope



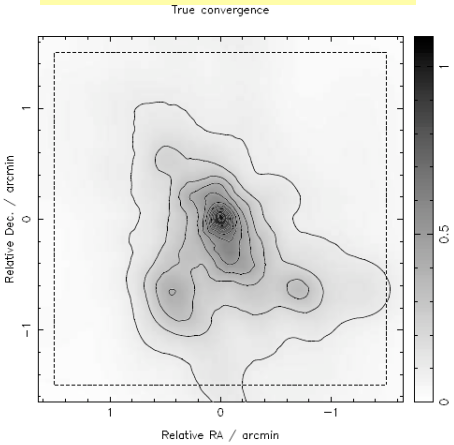
relative total mass and slope



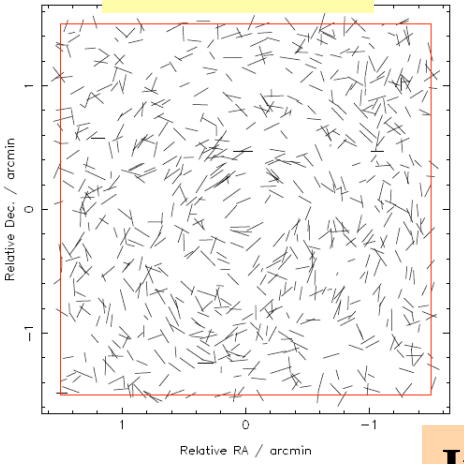
Cluster Mass reconstruction

Marshall 2006

Simulation data



Shear field

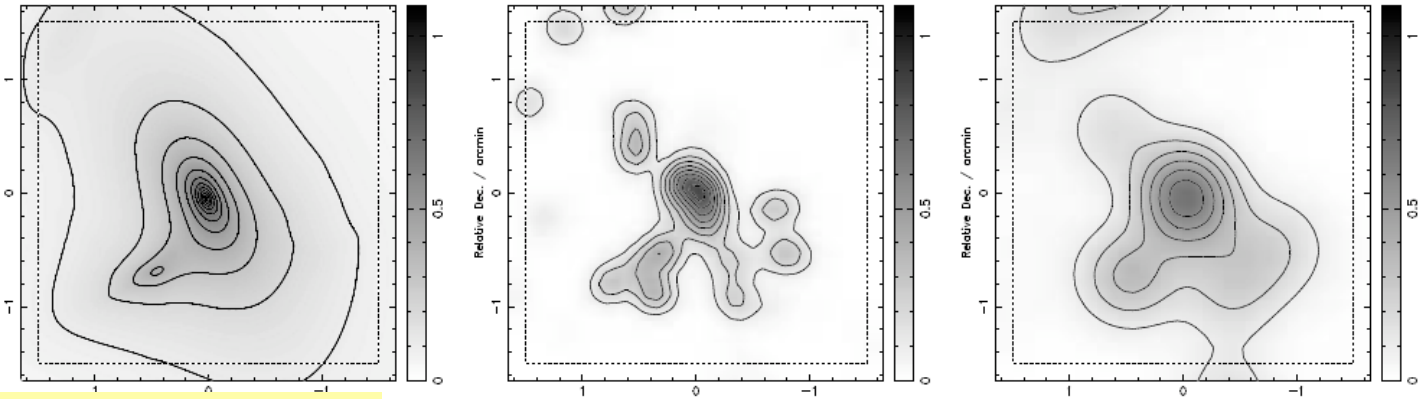


Multi-scale mass reconstruction are necessary. Different possible implementation: *wavelet* or using ***blobs*.**

The latter can combine easily strong+weak lensing data using **MCMC techniques**
Useful to cope with complex shape and add external priors

Implementation in:
www.oamp.fr/cosmology/lenstool/

Jullo et al 2007



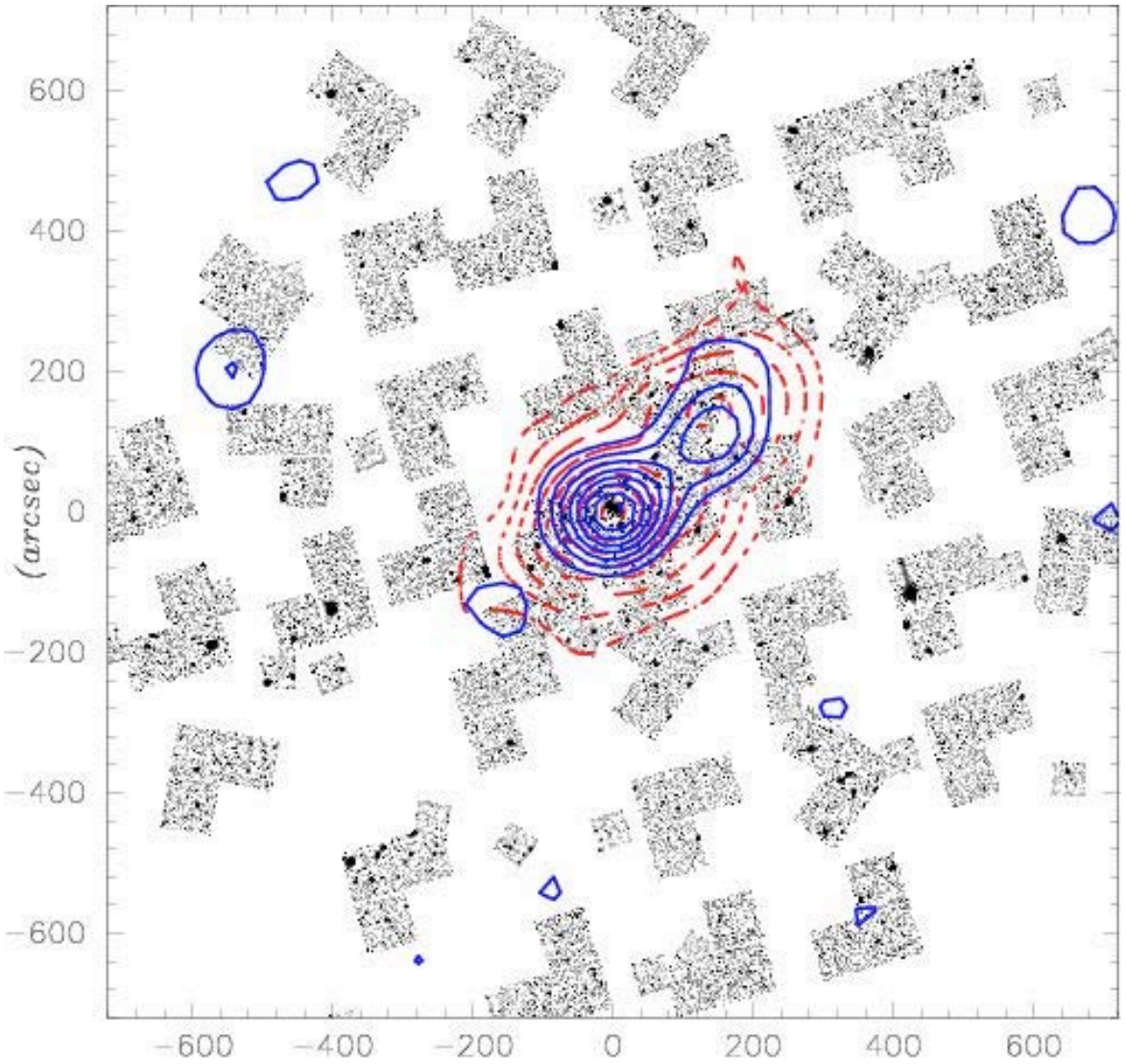
Atomic Inference

Classical 2D single scale reconstruction

An example from space: Cl0024+1654 HST wide field sparse mosaic

- **76 orbits, 38 pointings**
- **Probe regions up to ~5Mpc**

Aim: learn cluster physics of clusters by comparing with other mass estimates: X-ray, dynamics



Czoske et al 2002, **Treu et al 2003, Kneib et al 2003,** Moran et al 2007, Natarajan et al 2007

0024: Shear Profile

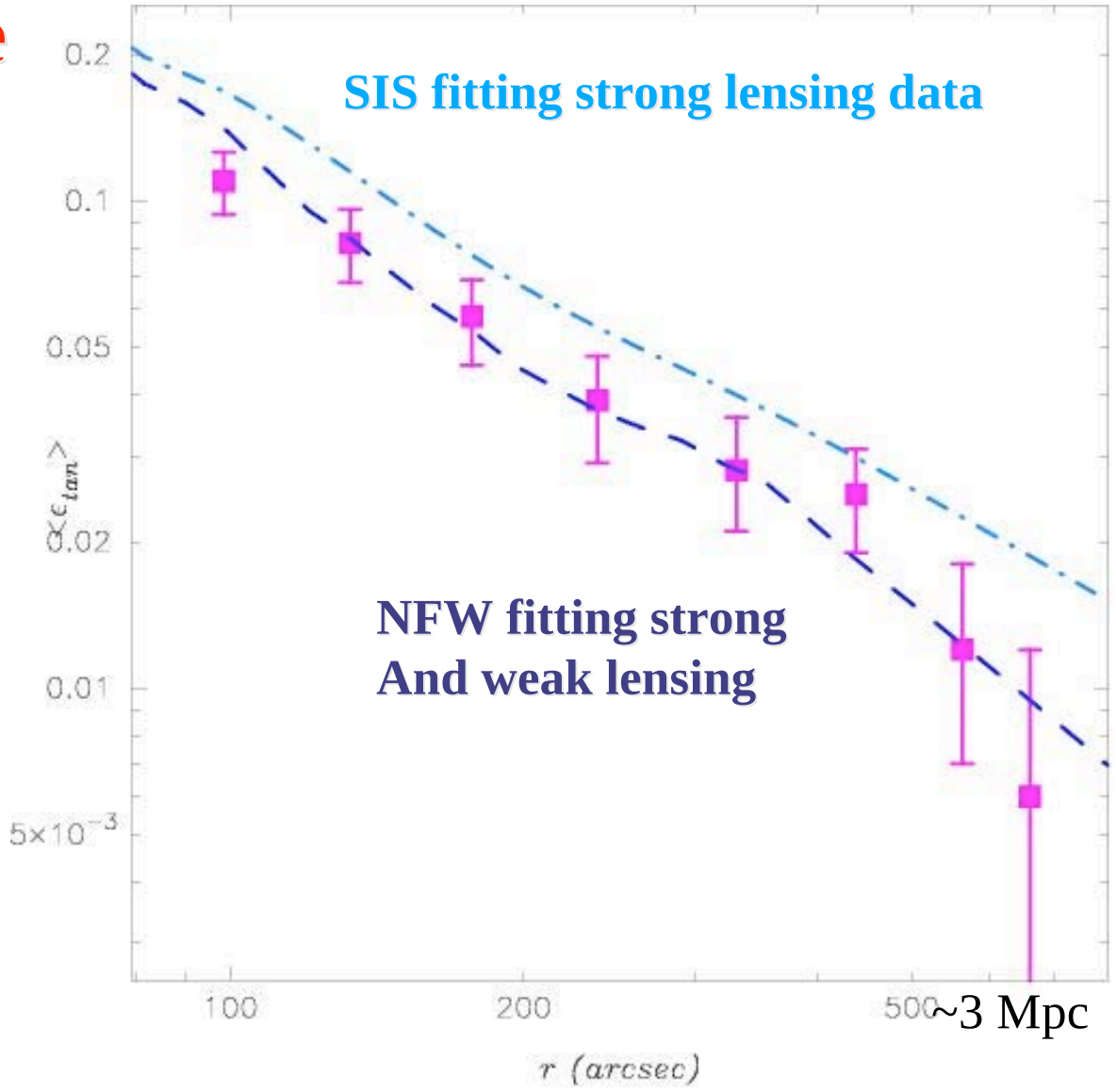
•Extrapolate strong lensing models at large scale

•Rule out SIS model

• NFW (with large **c~20**) or Power-law are favored

•Large ‘c’ unexpected!

- ➢Line of sight alignment/merger?
- ➢Very old structure?
- ➢Baryon contribution?
- ➢Background galaxy selection?



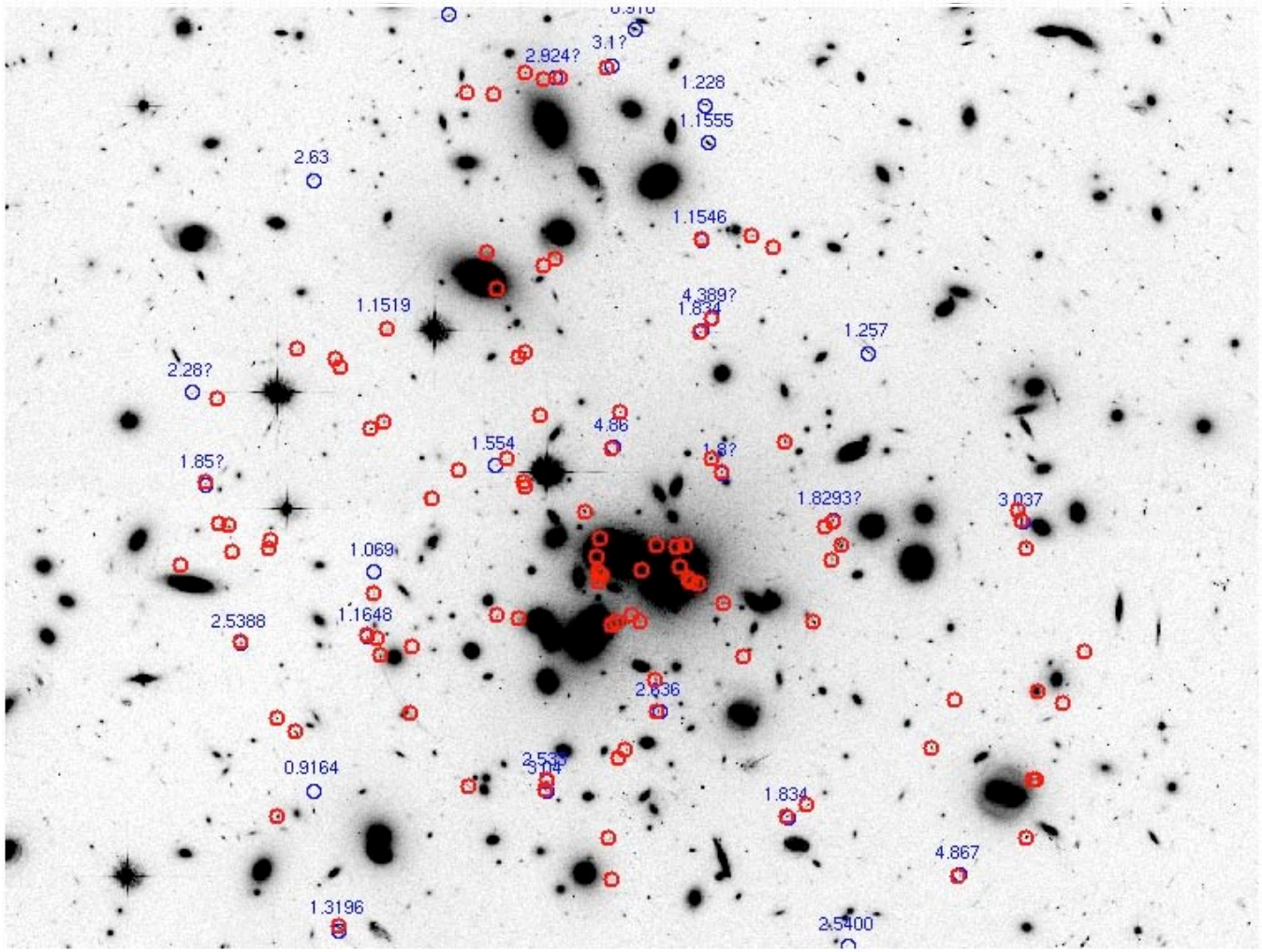
~3 Mpc

Deep Spectrocopy on Abell 1689

Richard et al 2006

- Broadhurst et al 2005 found 30 multiple image systems,3 with spec-z. high concentration **c~14**
- Now we have

~21 systems with spectro-z out of **37** identified multiple image systems.

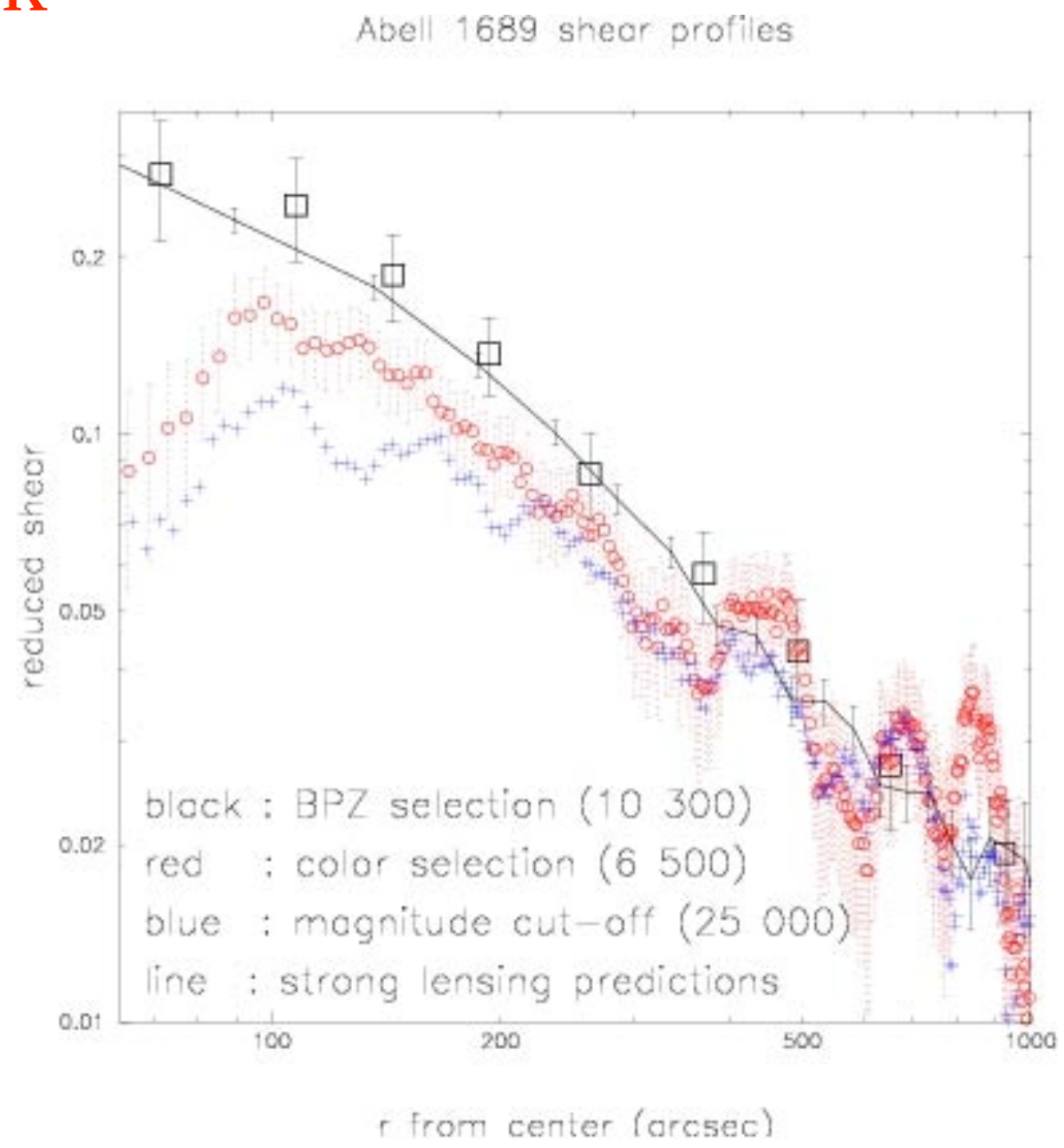


Strong+Weak lensing

Limousin et al 2007

- *background source selection is **critical** to measure acurate mass*
- Photo-z selection gives similar results to strong lensing
- ***Improved lensing constraints, revised concentration c~7***

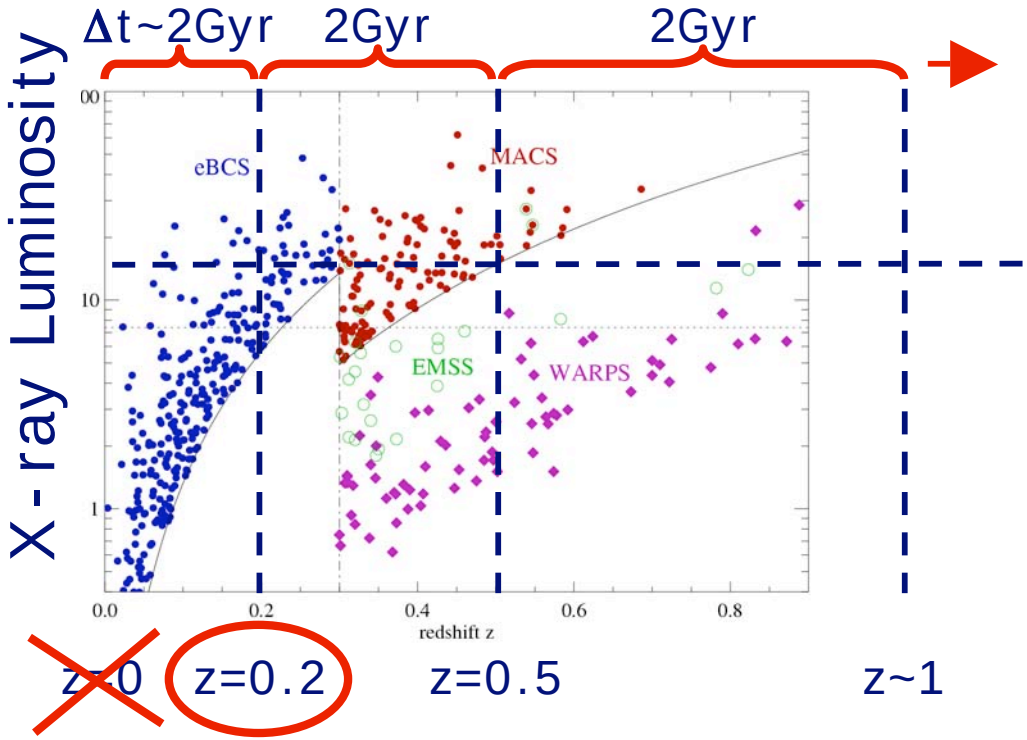
Abell 1689 weak lensing vs. strong lensing model



Questions for Cluster Physics and Cosmology

- What are the total mass and structural properties of massive clusters (mass profile/distribution)?
- How mass and structure of clusters relates to the global thermodynamics (Tx, Lx, S, gal. velocities)?
- How do cluster substructure and thermodynamics evolve with redshift?
- Implications of cluster mass and substructure for Cosmology?

How?: Multi-wavelength/epoch study



- z=0.21+/-0.04
- L_x>8x10^{44}erg/s

- Study of 10 clusters at z~0.2
  - HST/WFPC2, F702W, 7.5ksec
  - Chandra, ACIS-I(S), 4-40ksec, XMM
  - UKIRT, UFTI, 9ksec
  - CFHT12k, BRI, weak shear

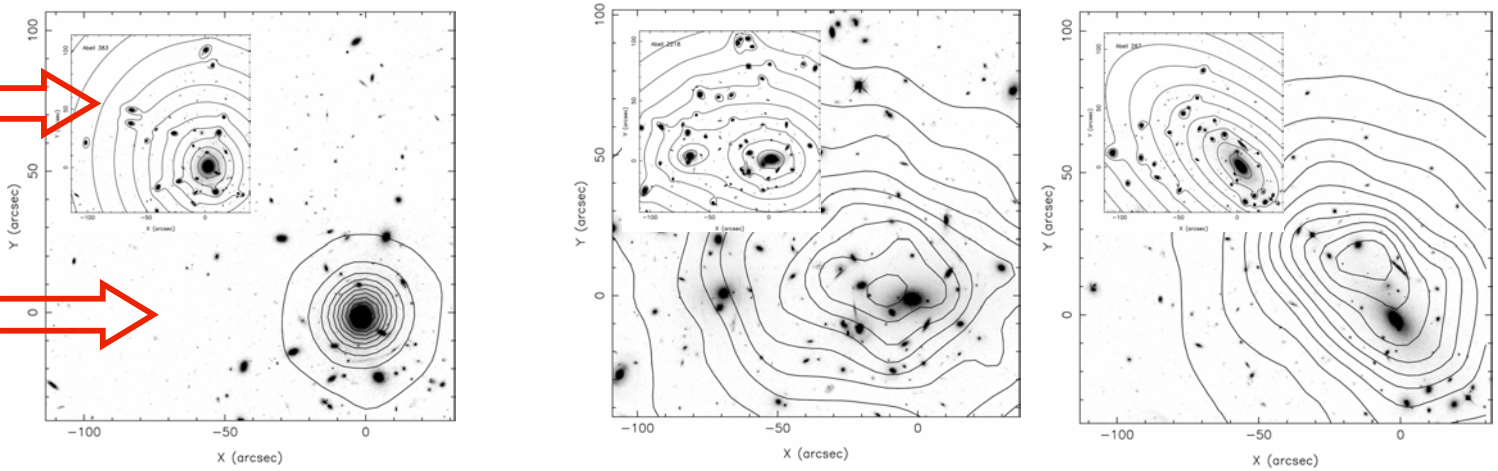
A68	
A209	
A267	
A383	
A773	
A963	Ellis et al. 1991
A1763	
A1835	
A2218	Kneib et al. 1996
A2219	Smail et al. 1995

Quantitative structural classification

Smith et al., 2005

Mass [Lensing]

ICM [X-ray]

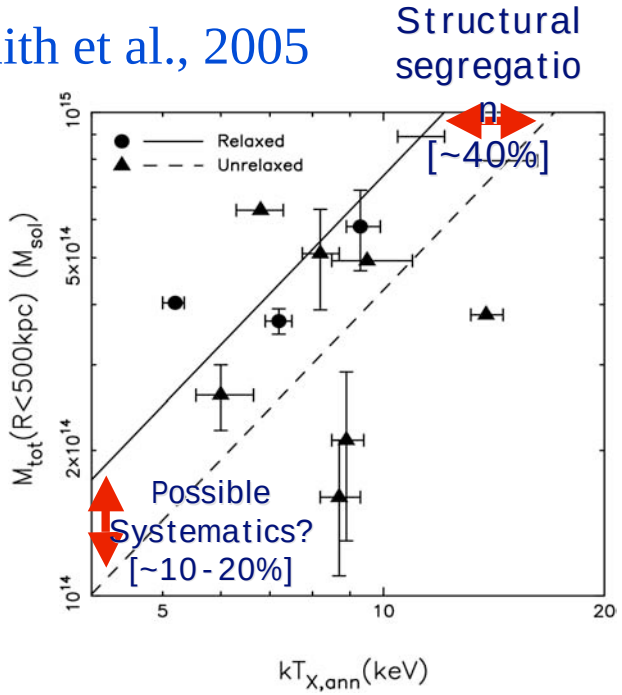


	Relaxed	Typical Unrelaxed	Atypical Unrelaxed
N_{dm}	1	2	1
M_{cen}/M_{tot}	0.97±0.01	0.77±0.01	0.96±0.01
T_{tot}/T_{ann}	0.8±0.1	1.0±0.1	1.0±0.2
Δr (arcsec)	<1	10±2	22±1

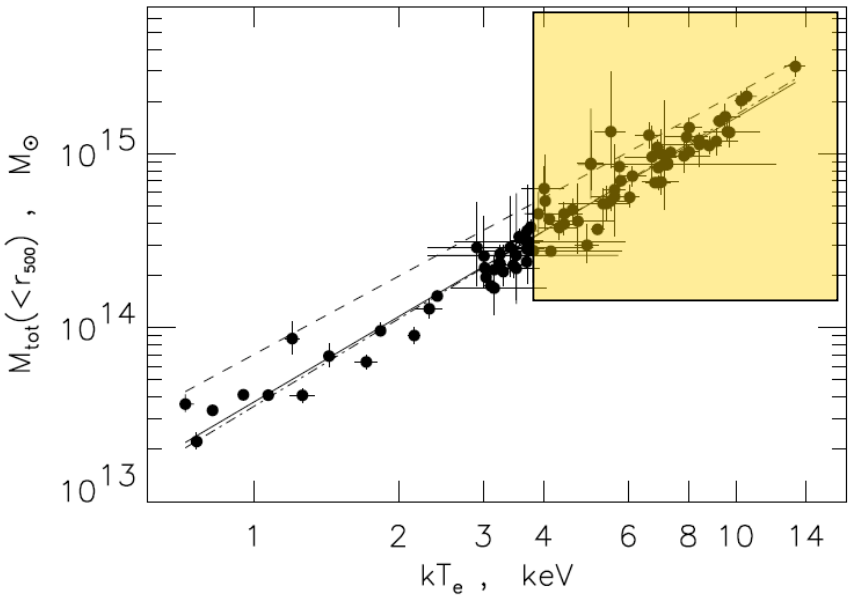
- 70% of X-ray luminous cluster cores at z=0.2 are not relaxed, showing lots of structure.

M-T relation or M-T scatter plot?

Smith et al., 2005

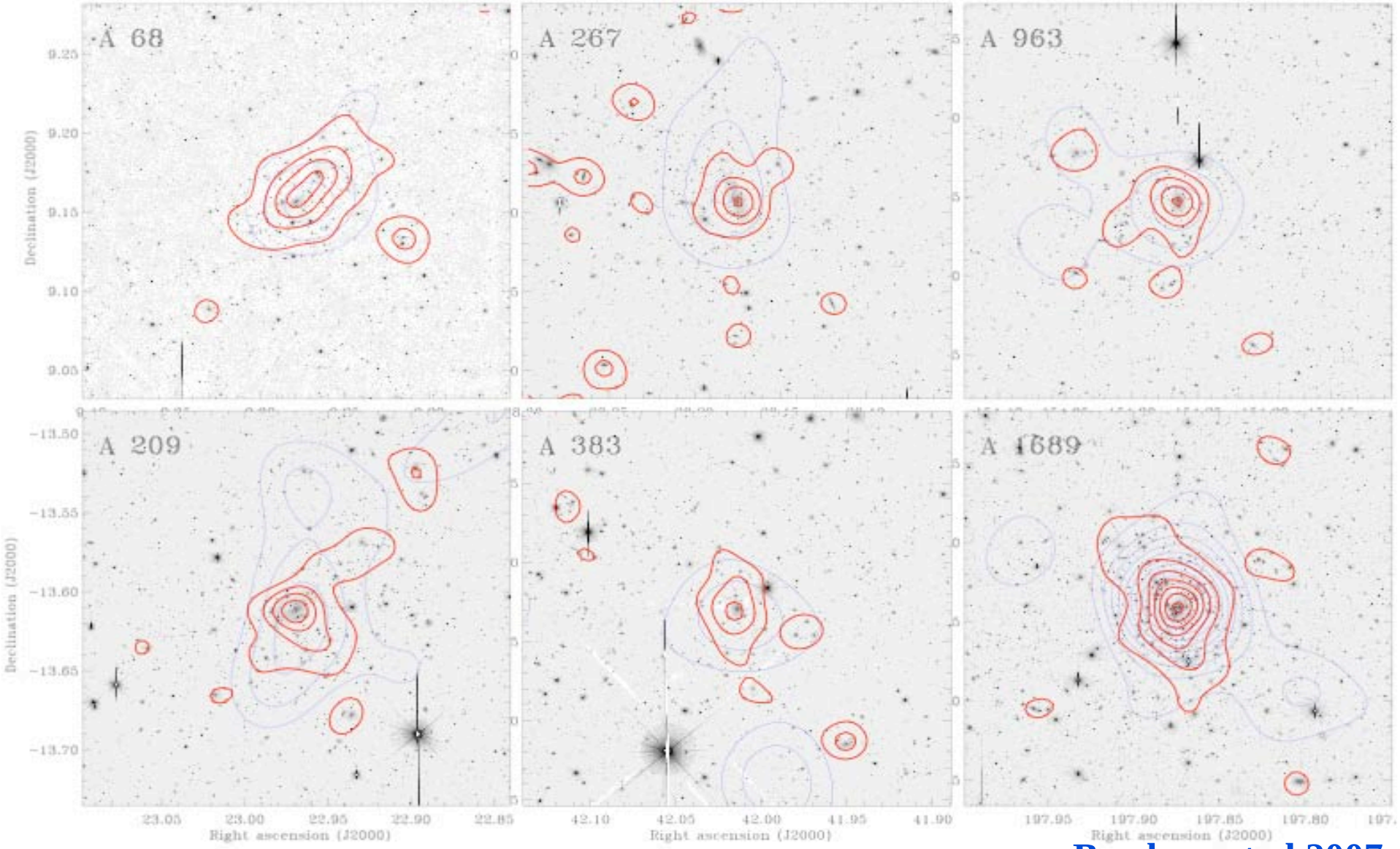


Finoguenov et al., 2001



- Unrelaxed clusters are 40% hotter than relaxed clusters (2.5σ)
- Scatter consistent with hydro simulations of cluster-cluster mergers (Ricker & Sarazin 2001, Randall et al. 2003)

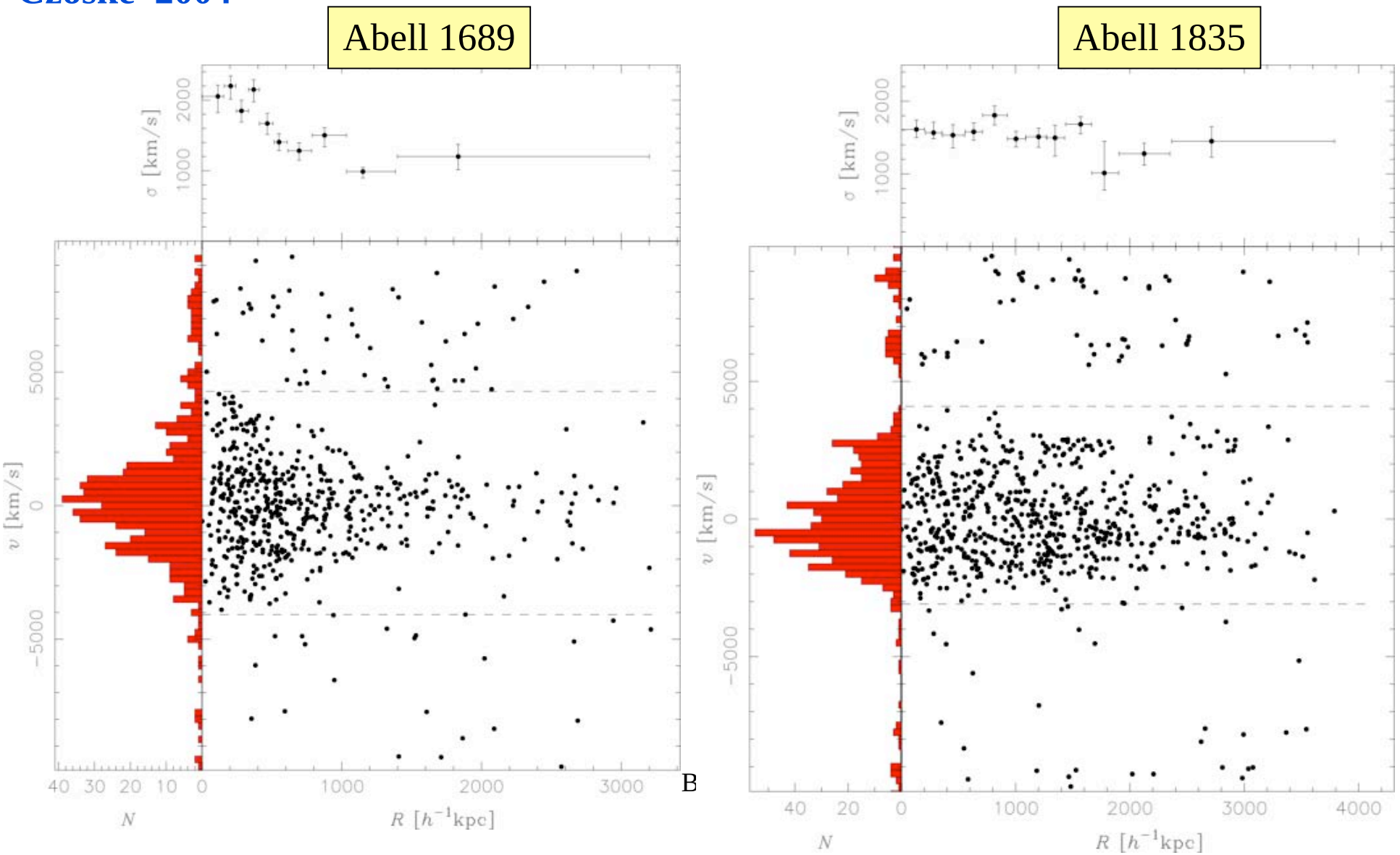
Better agreement with weak lensing?



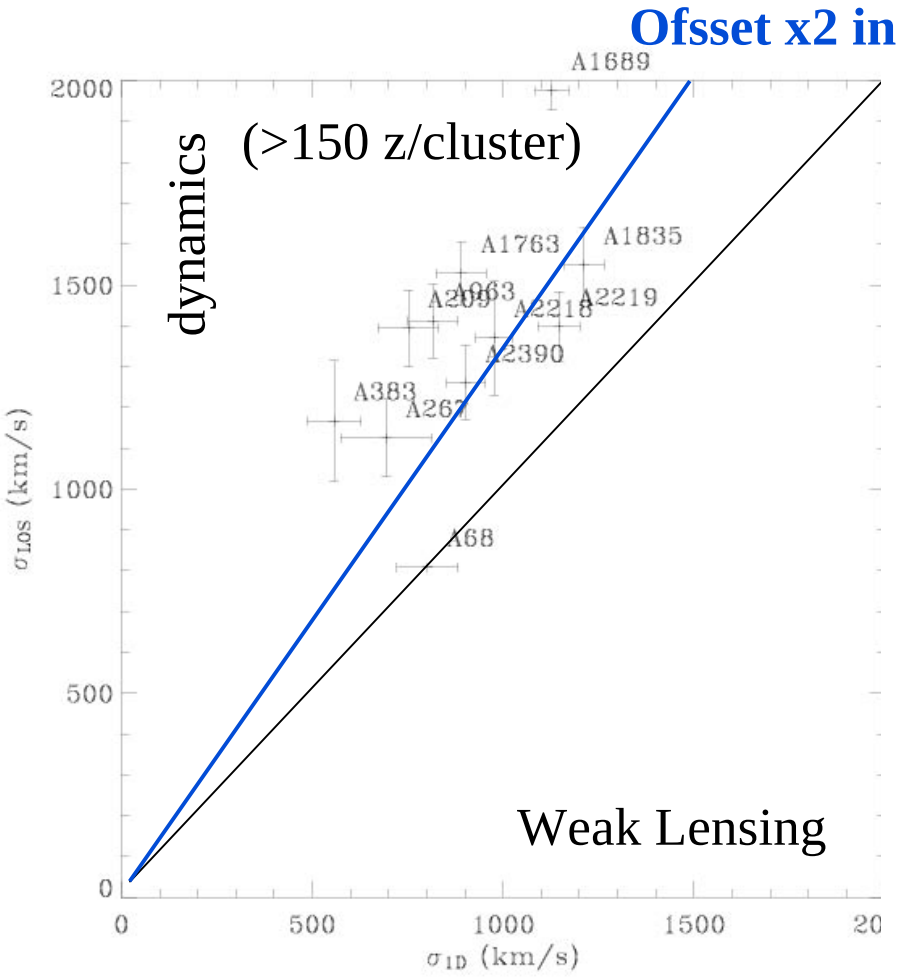
Bardeau et al 2007

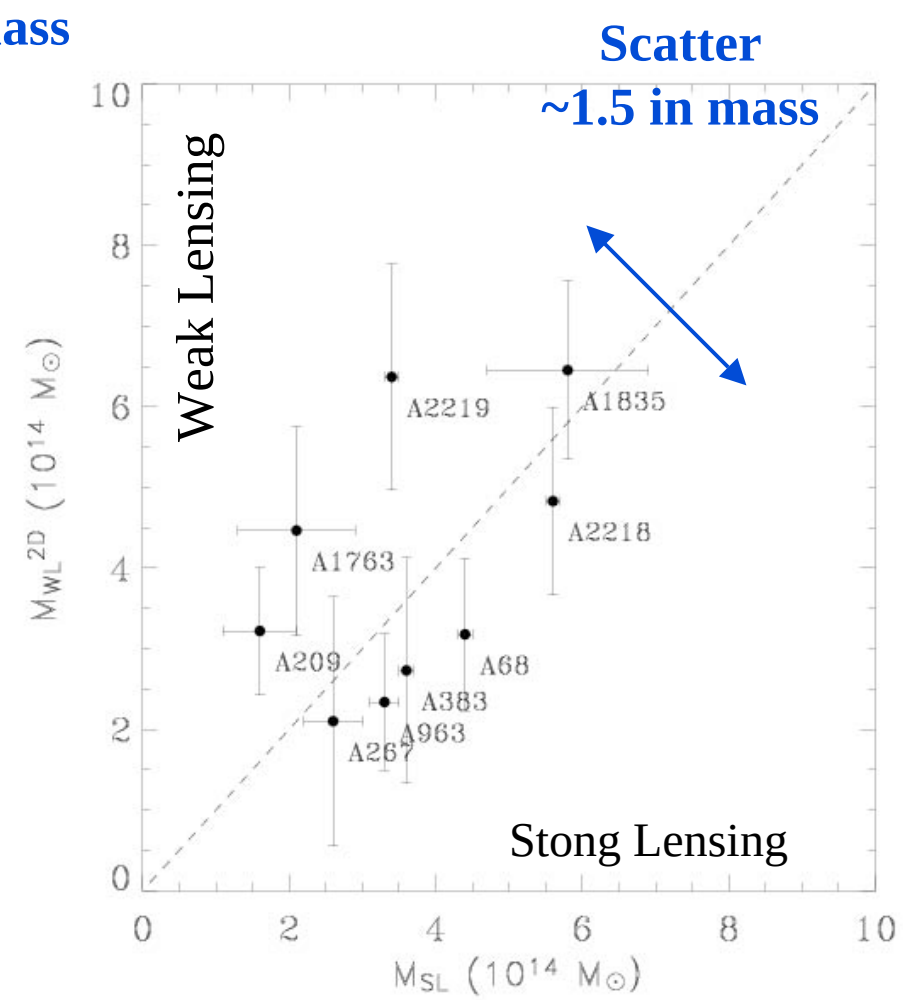
Galaxy velocities - not simple distribution!

Czoske 2004

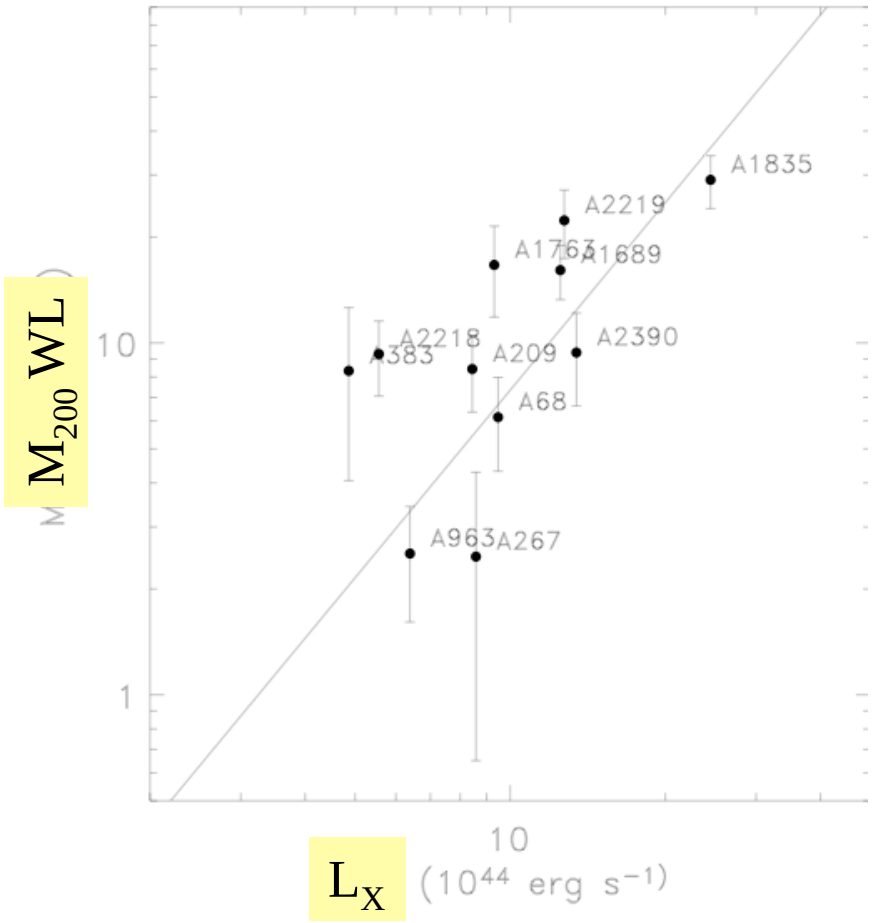


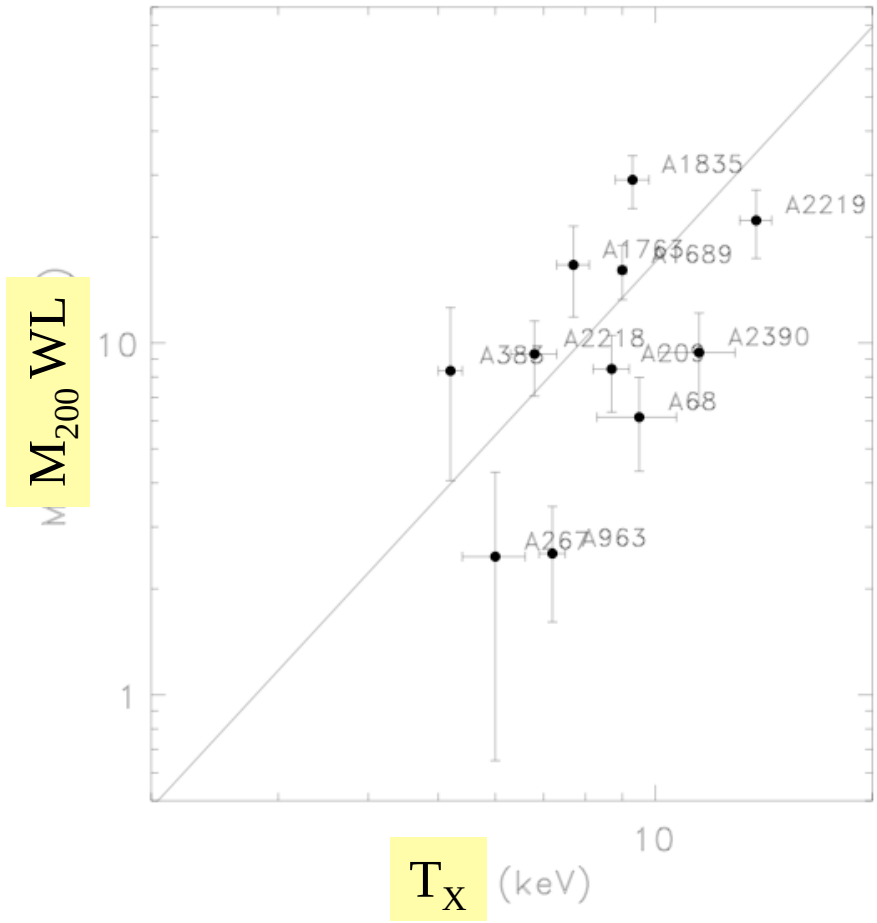
Comparing mass estimates





Comparing lensing and X-rays





Better agreement with weak lensing?

- Offset between dynamics and mass:
  - *Likely sign of merger activity*; optical selection is in question ?
  - systems are still dynamically young?
- Scatter between Tx and Mass: we can probably do better (by including strong lensing) but results are limited by cluster substructures.
- ***Ideally, need better data and statistics*** **(ie more data!)**

⇒Go from sample of 10's to sample of 100's (more clusters at different redshift and X-ray temperature => evolution)

⇒Ultimately, need of wide field space observatory

More Lensing Clusters ! Snapshot with ACS

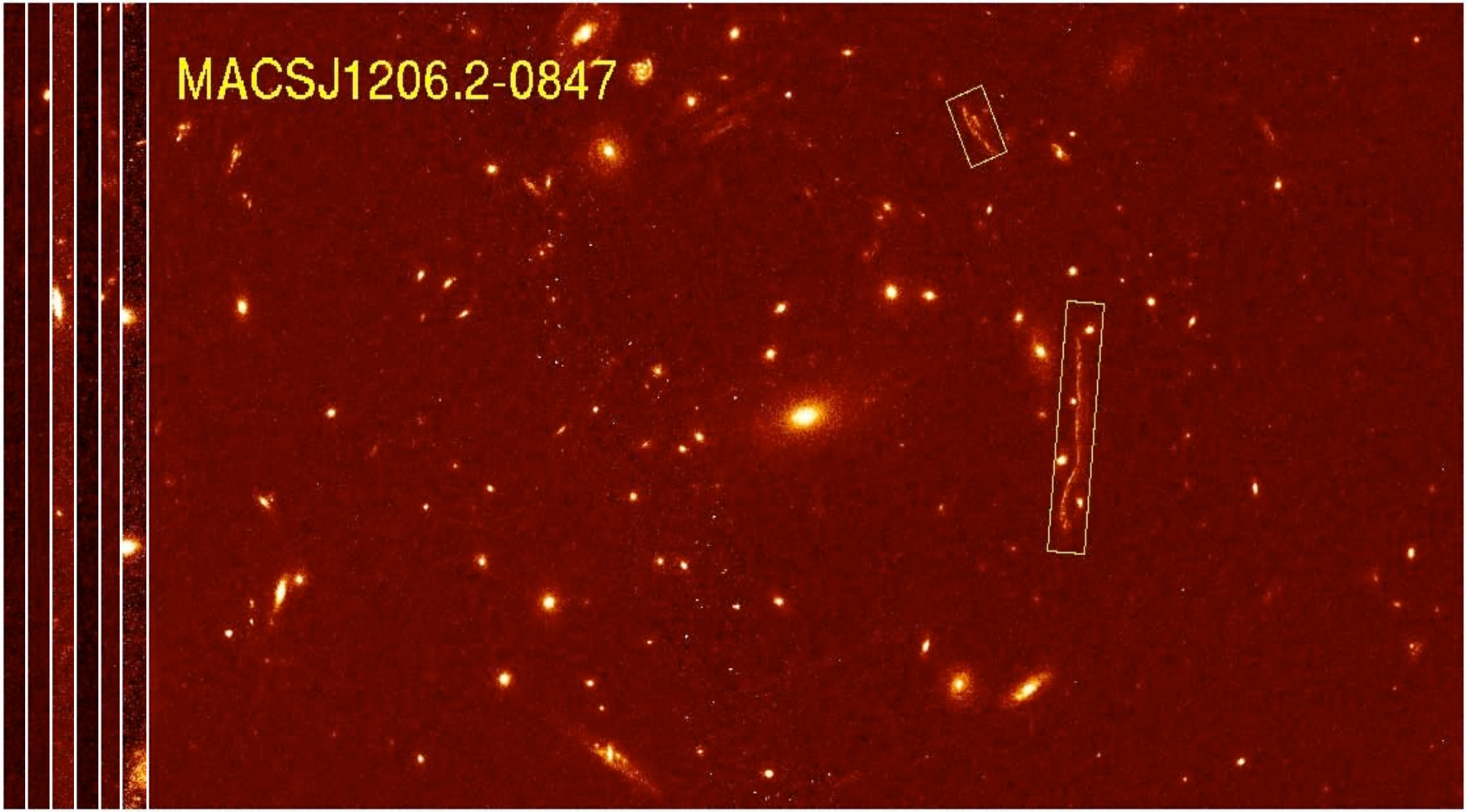
MACS: Ebeling et al (cycle 14+15) LOCUSS: Smith et al (cycle 15)

- List of: 124 MACS(z>0.3), 150 LOCUSS (0.15<z<0.3) clusters to be observed with HST/ACS in SNAP mode in F606W ~half an orbit
- Aim at finding effective lensing clusters and strongly distorted arcs (statistics and magnified sources)
- ***34 clusters observed*** - *almost half of them show obvious strong lensing!!! => could expect ~100 new strong lensing clusters in ~2 years (providing ACS works well).*
- **Will give a comprehensive (lensing) view of X-ray luminous clusters >2x10^{44} erg/s**

MACS Snapshot ACS

Ebeling et al (GO: 10491)

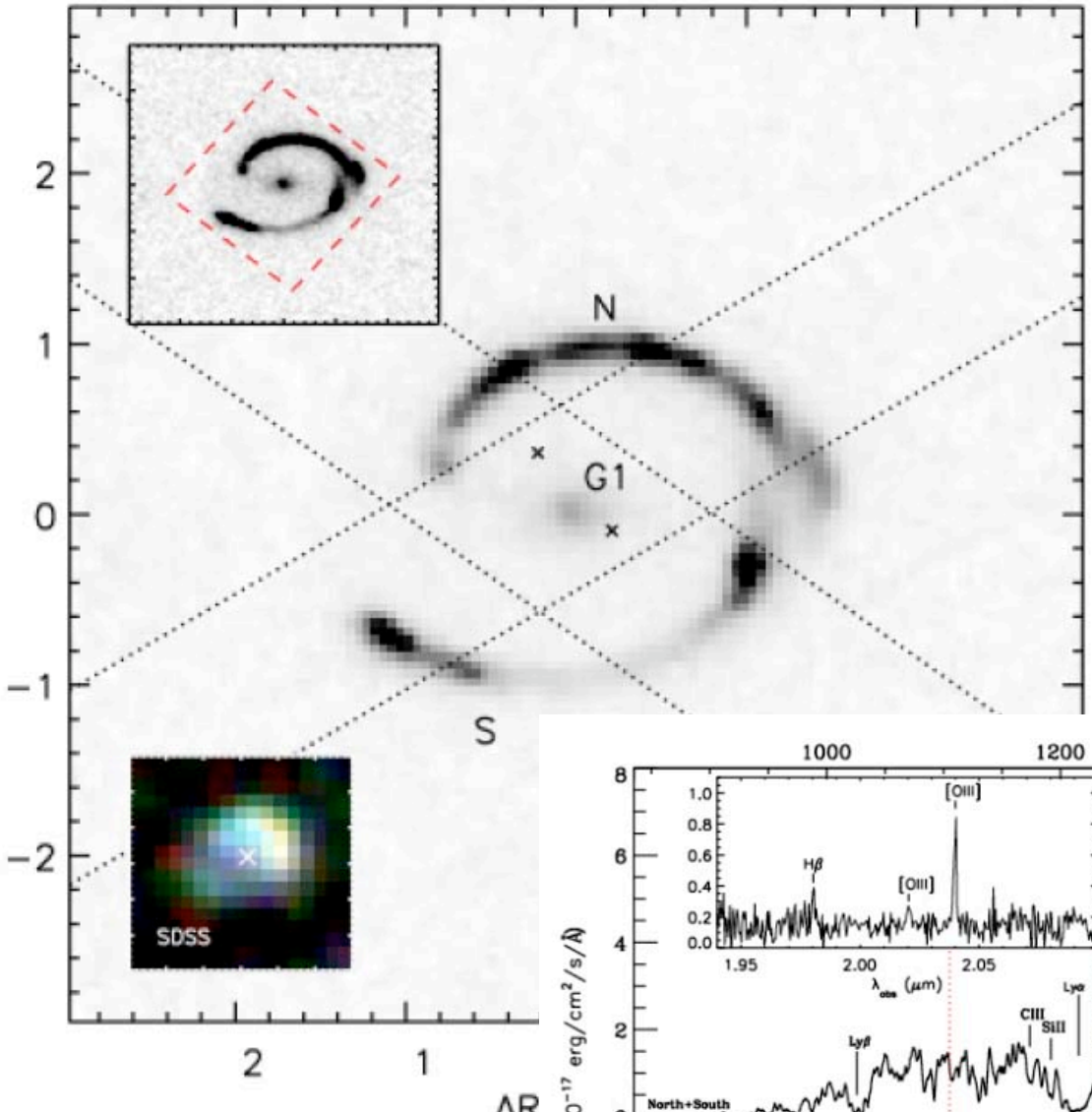
First Strong Lensing IDs

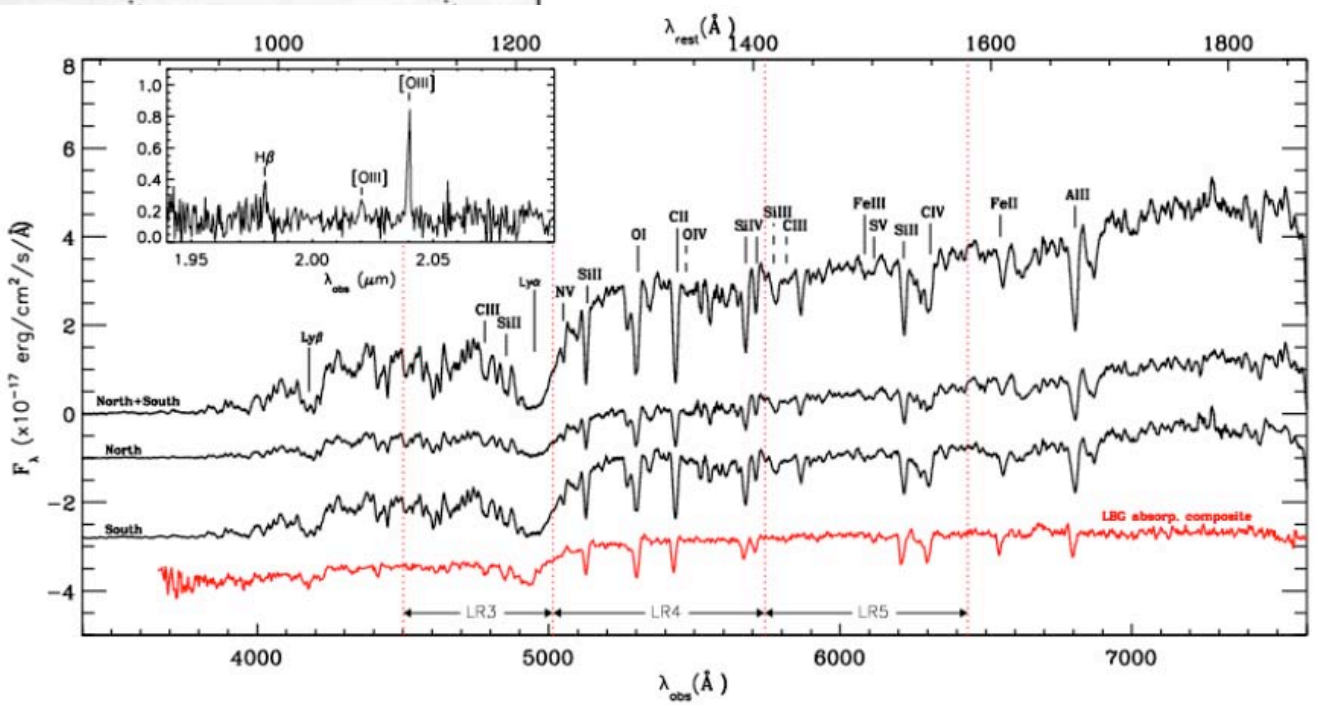


The Cosmic Eye

Smail et al 2007

A z~3 LBG brighter than CB58!

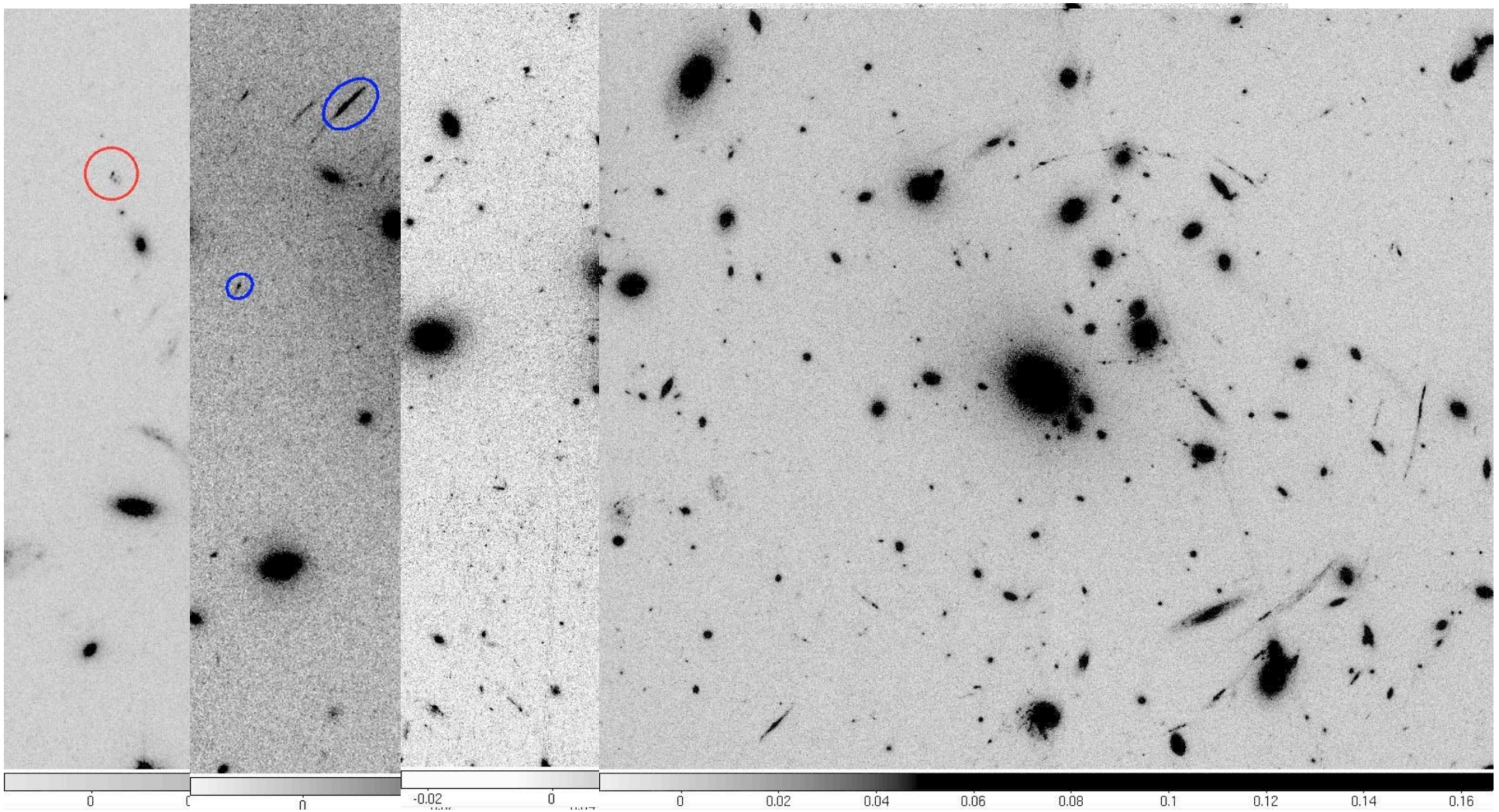




LOCUSS Snapshot ACS

Smith et al (GO: 10881)

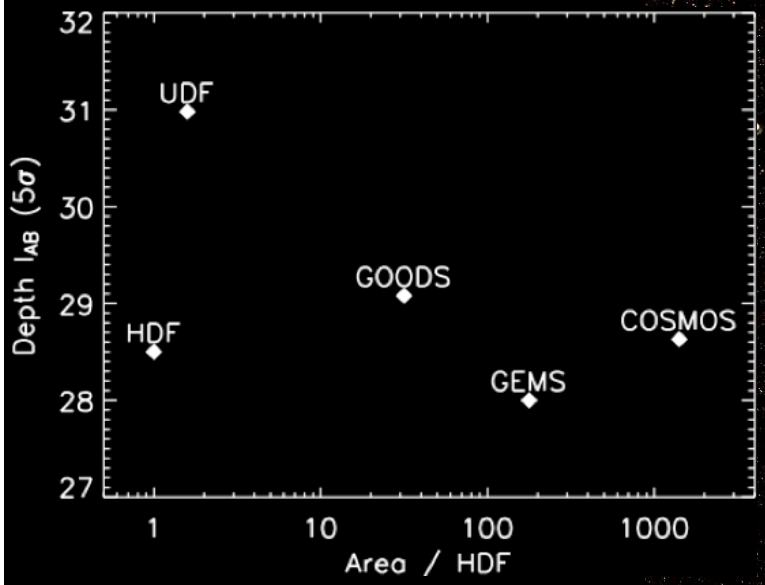
First Strong Lensing IDs



COSMOS: "Cosmic Evolution Survey"

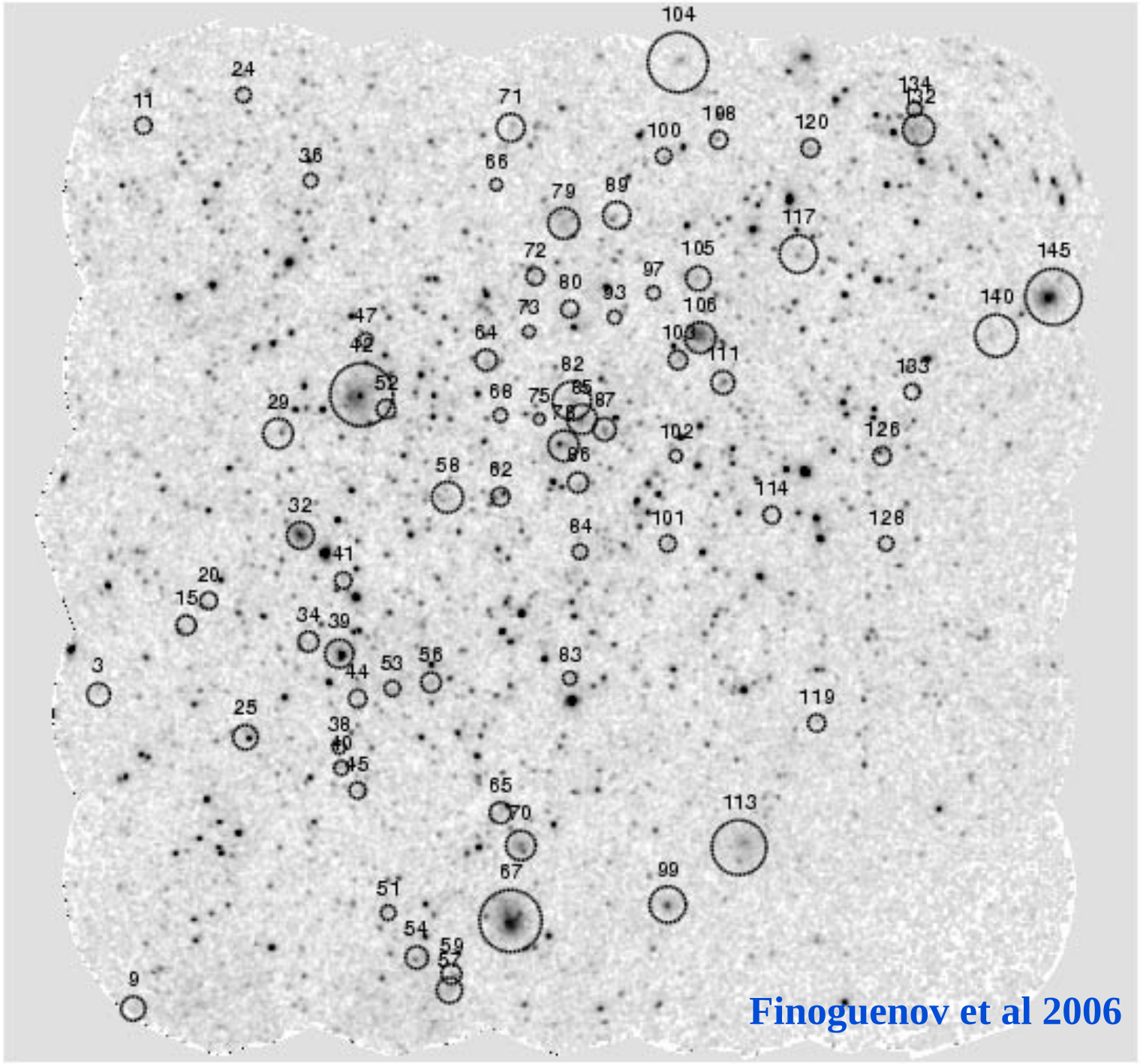
Largest ever HST survey

- 587 contiguous ACS fields
- 2 square degrees
- 2 million galaxies
- Depth I_{F814}<26.6 (at 5σ)



Public data!

http://irsa.ipac.caltech.edu/Missions/cosmos.html

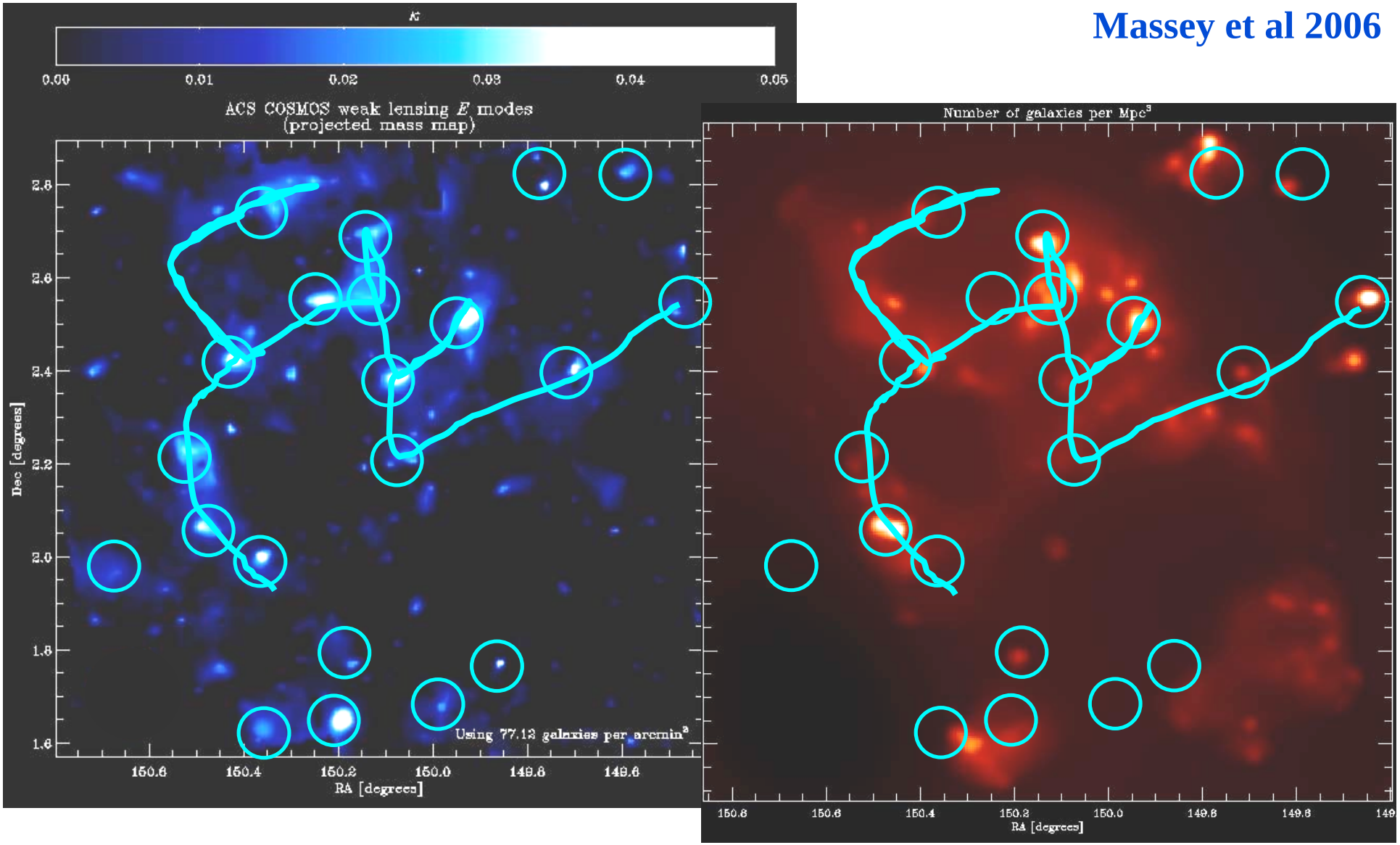


Finoguenov et al 2006

XMM COSMOS

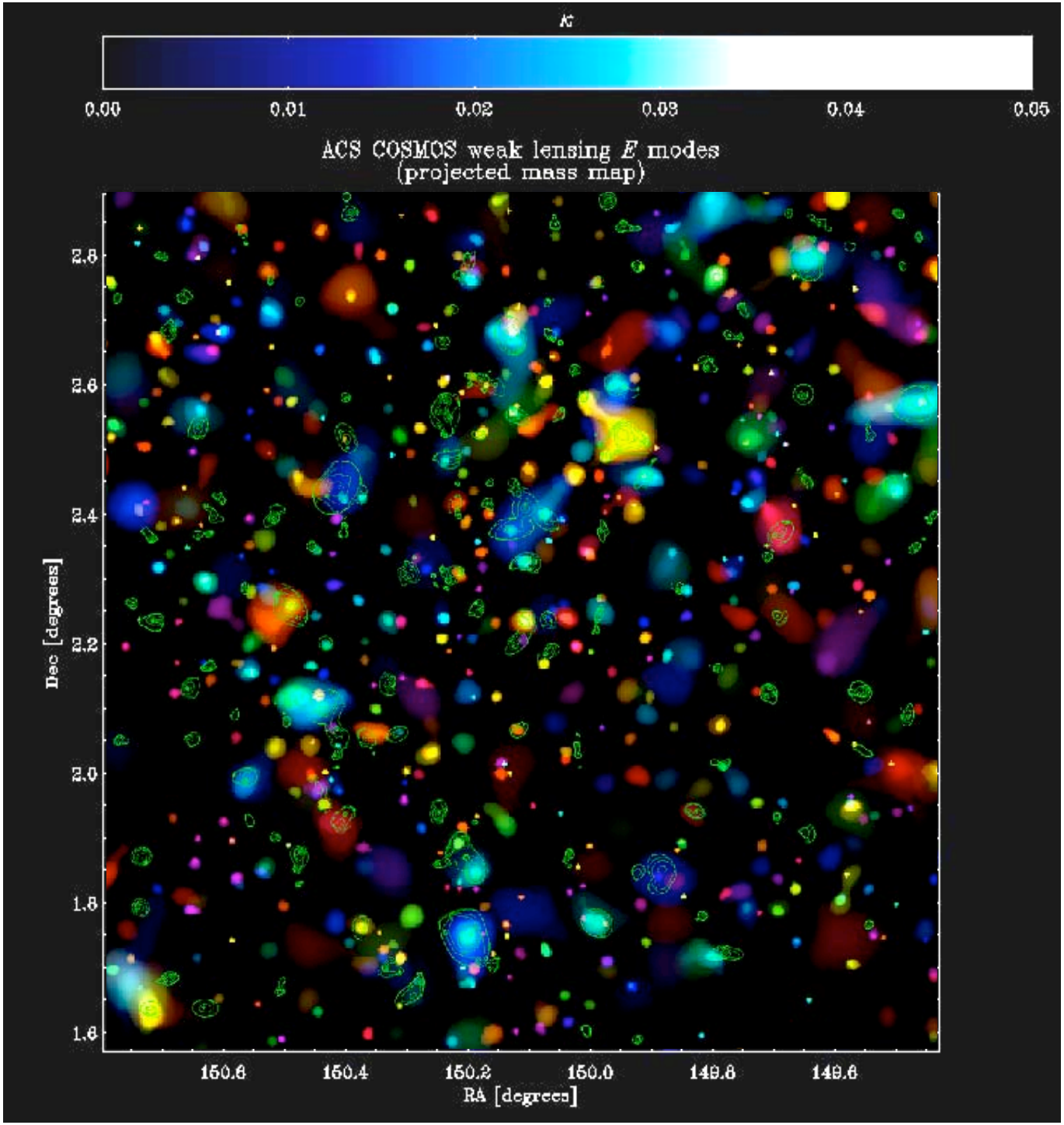
Mass vs light

Massey et al 2006

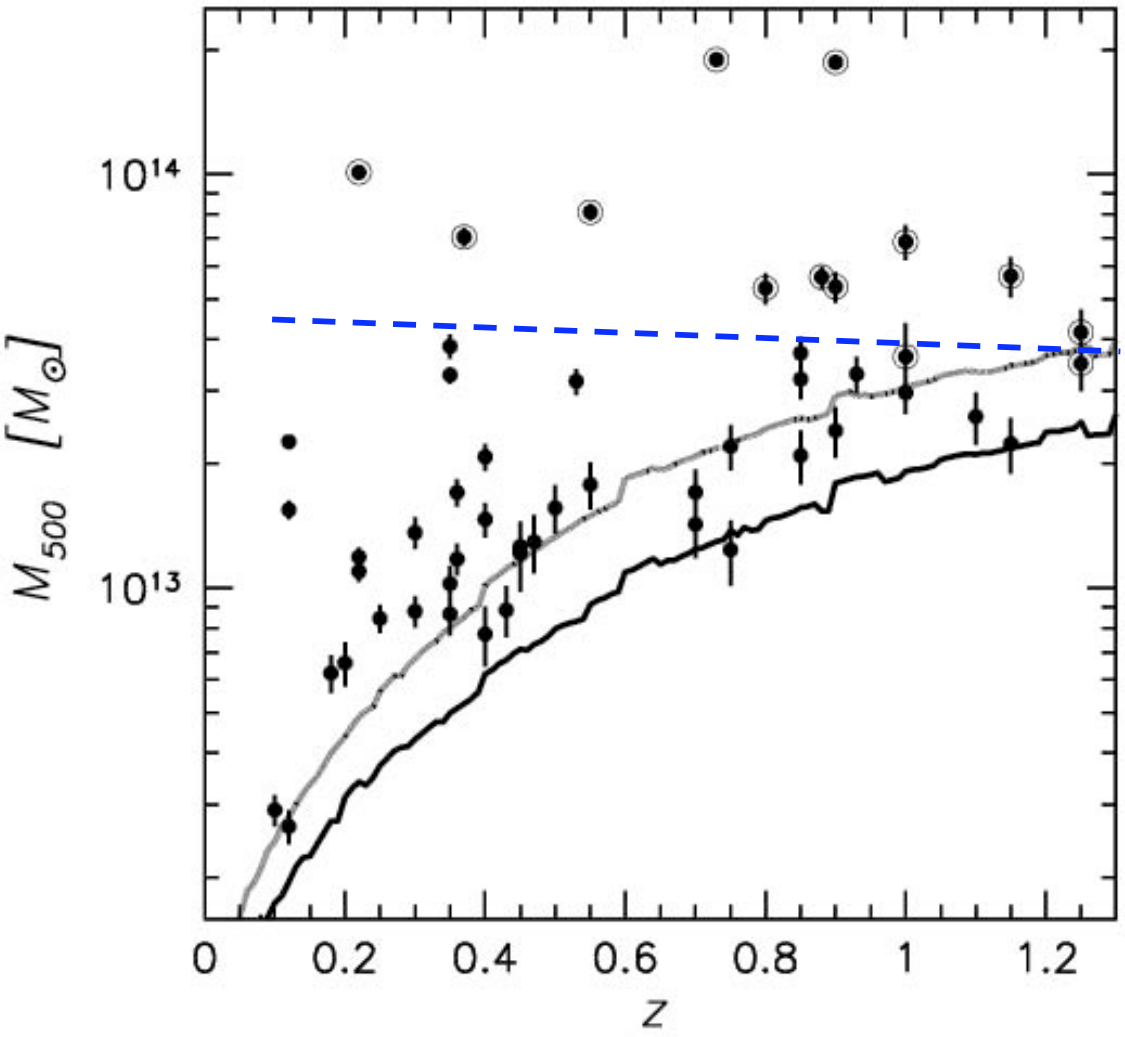


Lensing Mass Map vs. X-ray identified groups

October 5, 2006

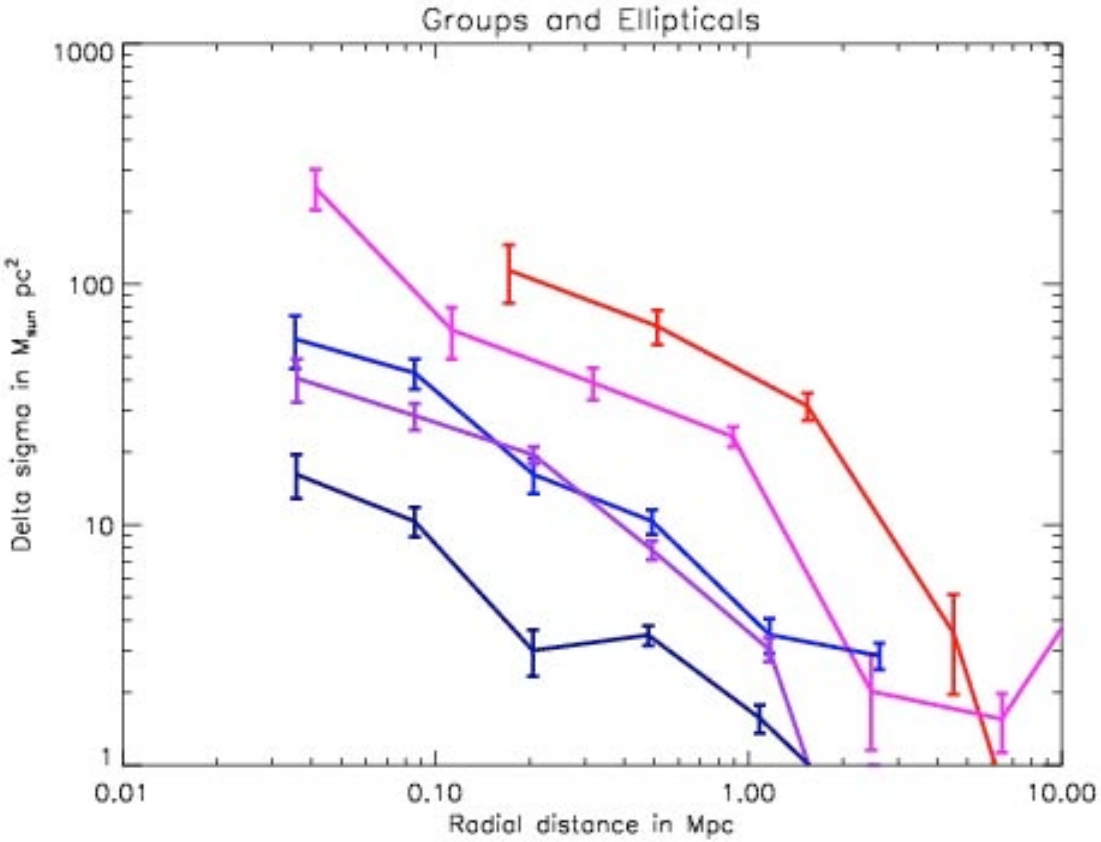


COSMOS: X-ray selected clusters with weak lensing detection



Effective lensing sensitivity for a direct analysis

A first sketch of the Dark Matter Mass Function



Surface Mass density

Radial distance Mpc

GROUPS: M_{500} >3.10^{13}

GROUPS: M_{500} <3.10^{13}

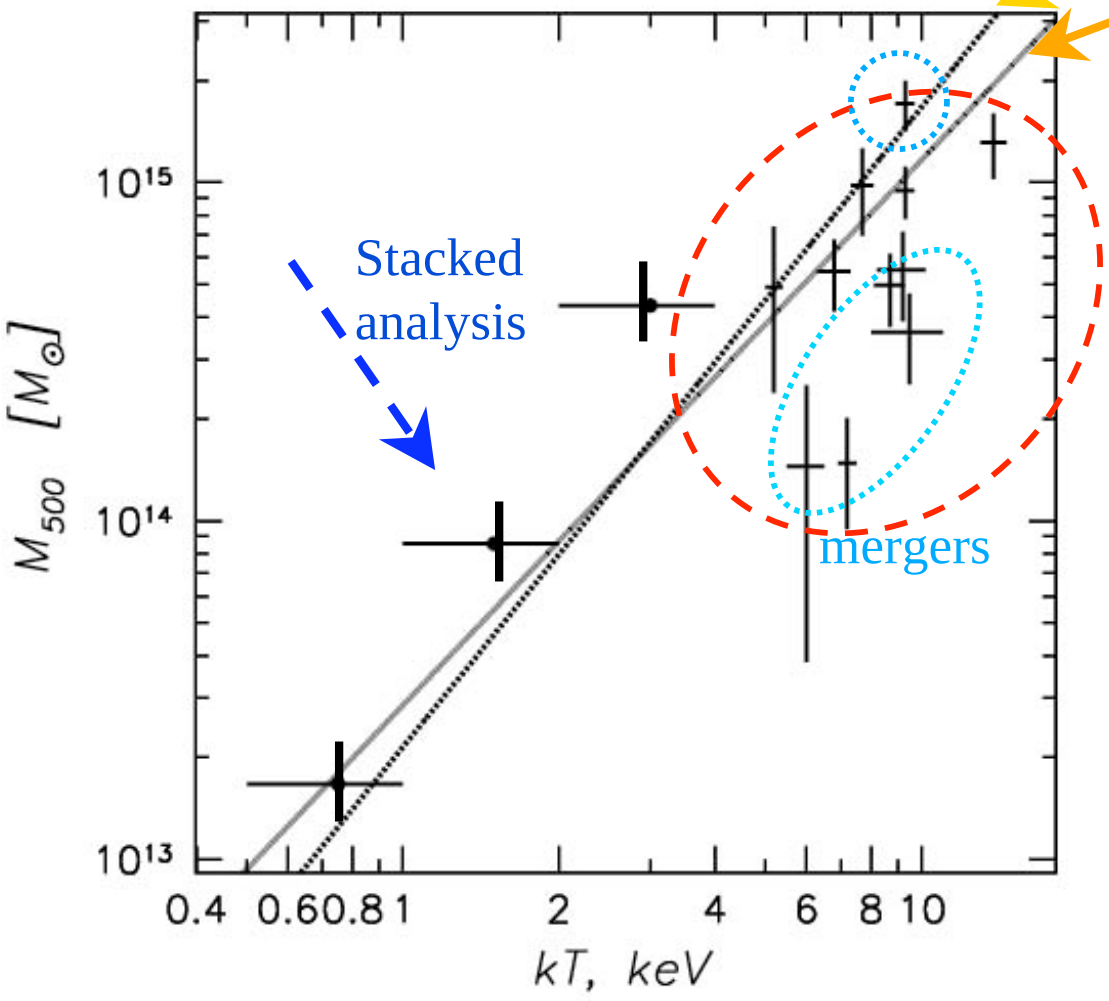
E: -25< M_V <-23.5

E: -23.5< M_V <-22

E: -22< M_V <-16

Leauthaud et al 2007

M(lensing)-T relation



- Merger clusters scatter more from the M-T relation
- Luminosity selection is contaminated by the low-mass clusters

Finoguenov et al 2007

Conclusions

Lensing is the tool to measure total mass in clusters

- **Strongly-constrained cluster lenses can provide constraints on DM profiles from <100 kpc scales up to few Mpc; important to contrast with other techniques (X-ray, dynamics)**
  - ➢ baryon/DM physics - see the bullet cluster and Dave's Sand work
  - ➢ Gravitational telescope (Roser's talk)
  - ➢ Cosmography (Jullo's poster)
- **Combining cluster surveys and field surveys we can hope to build and calibrate the Mass-Temp relation, and measure the mass function** (as a function of time, merger, substructures, etc …)

The End