1st Subaru Intl. Conference

Subaru Weak Lensing Study of Merging Clusters of Galaxies

Reference:

Okabe & Umetsu 2008, PASJ in press (astro-ph/00702649)

Keiichi Umetsu

(Academia Sinica IAA [ASIAA], Taiwan)

Collaborator: **Nobuhiro Okabe** (Tohoku, Japan)

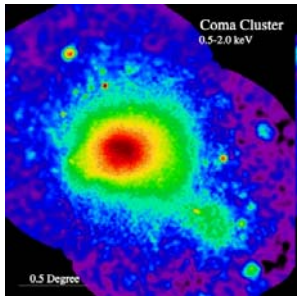
Introduction: Clusters of Galaxies

Baryons

$M_{baryon} \sim 20\ \% M_{tot}$

Stars (In galaxies)

$M_* \sim$ a few % M_{tot}



ICM (hot baryons)

$M_{ICM} \sim 20\ \% M_{tot}$

DM governs the Dynamics

Dark Matter

$M_{DM} \sim 80\ \% M_{tot}$

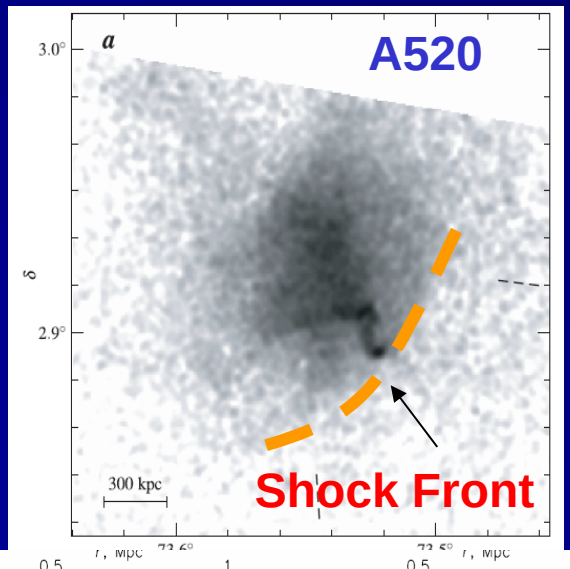
Total mass distributions could be derived from X-ray data alone:

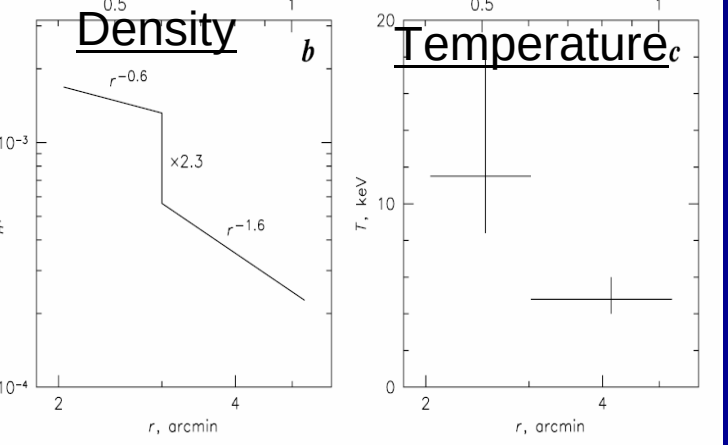
$$\frac{1}{\mu m_p n_g(r)} \frac{dP_g}{dr} = -\frac{d\Phi}{dr}$$

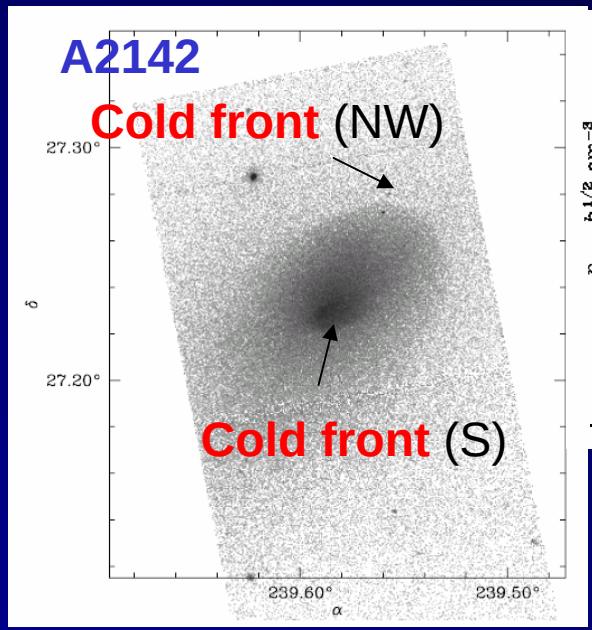
... but with the hydrostatic equilibrium assumption

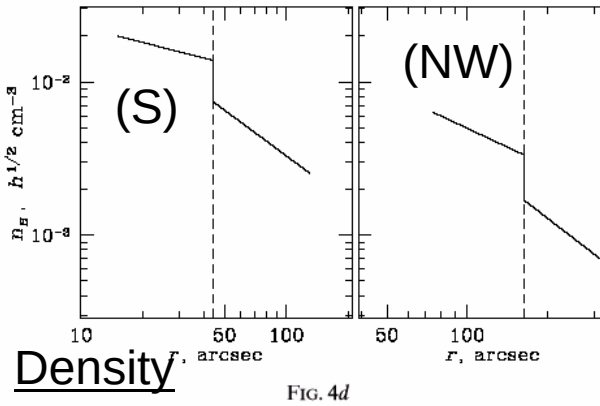
2. Motivation

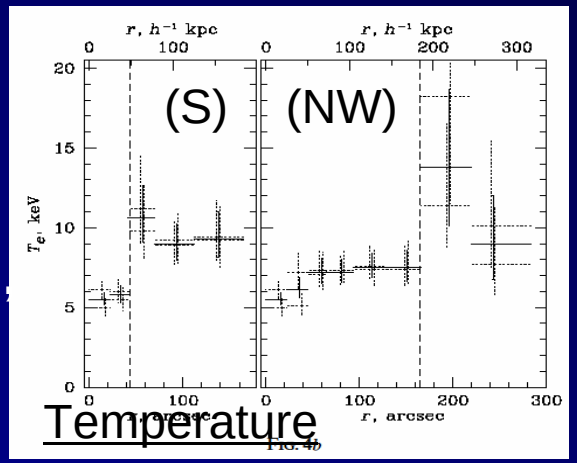
Chandra and XMM-Newton X-ray satellites have revealed complex ICM structures associated with cluster mergers:











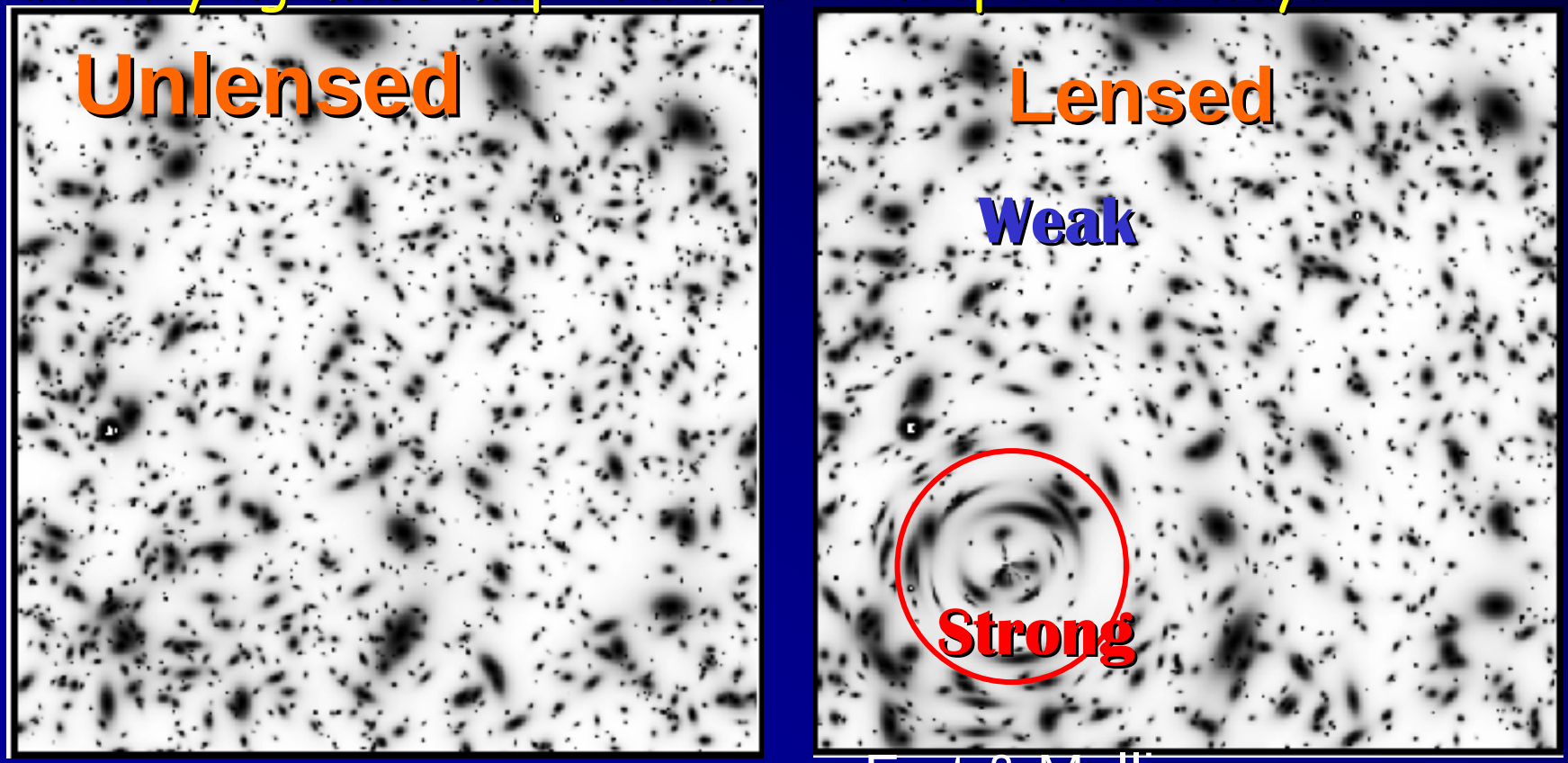
Cold Fronts = "contact discontinuities", associated with a dense cold core

Far from hydrostatic equilibrium!!

3. Method: Gravitational Lensing

The images of BG sources carry the imprint of $\Phi(x)$ of intervening cosmic structures:

WL distortions of BG images can be used to derive the underlying mass map in a model independent way!!

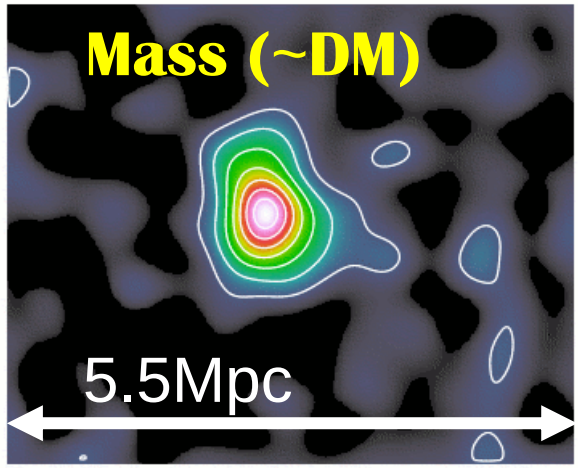


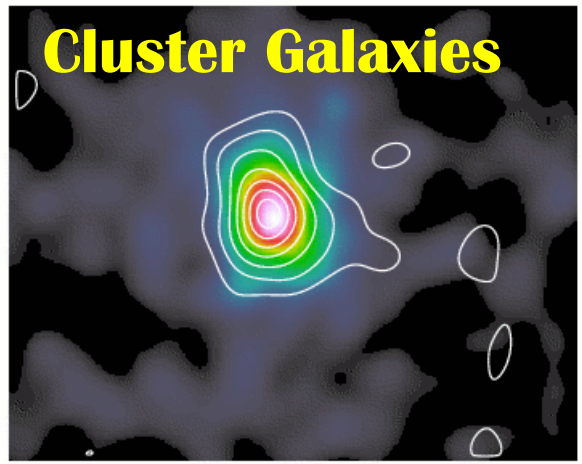
Fort & Mellier

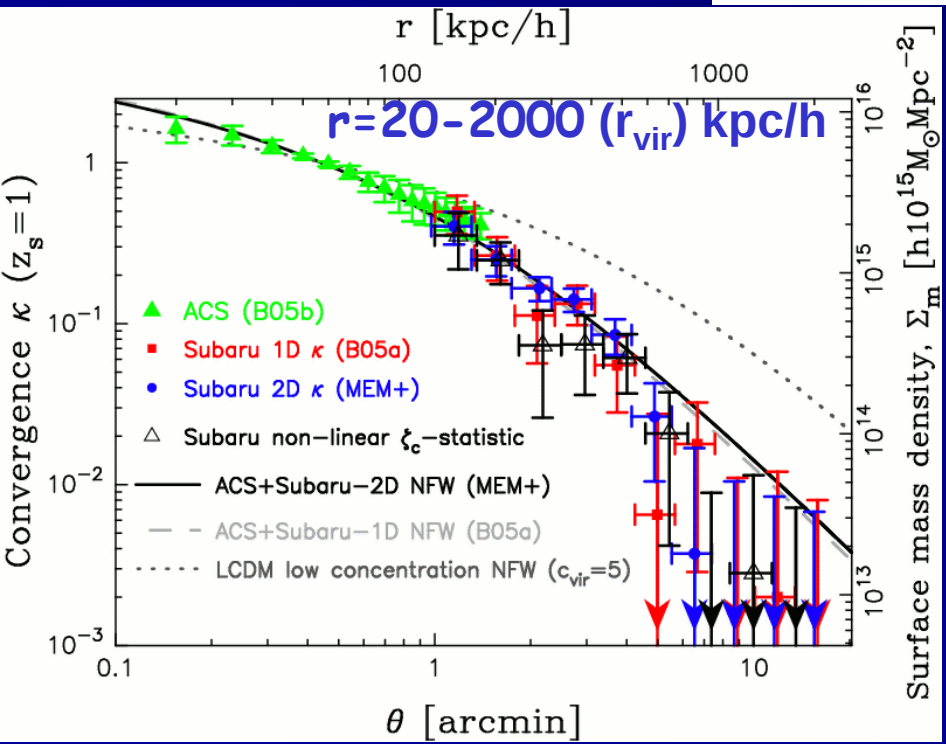
Power of Subaru Weak Lensing

A1689 (z=0.183)

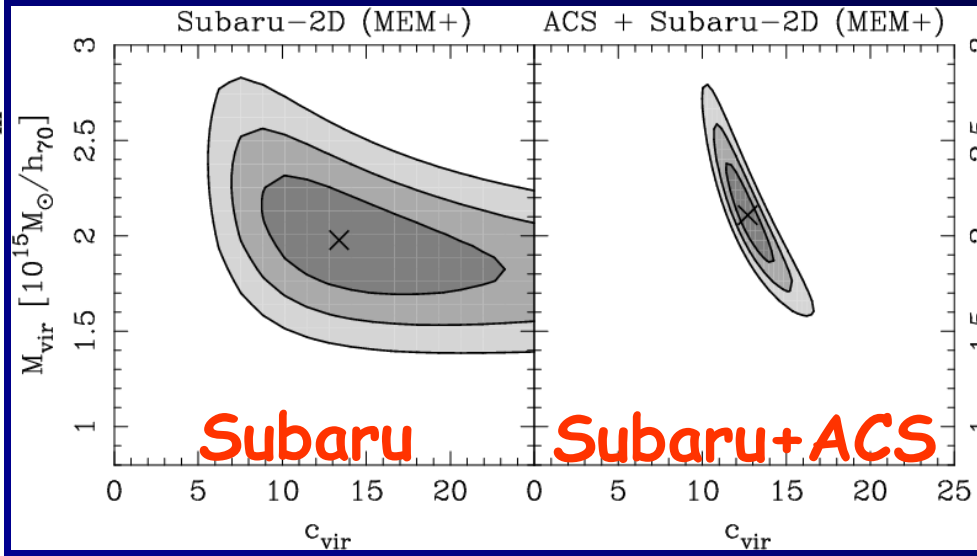
A relaxed, massive cluster with large Einstein radius θ_E=45" (z_s=1)





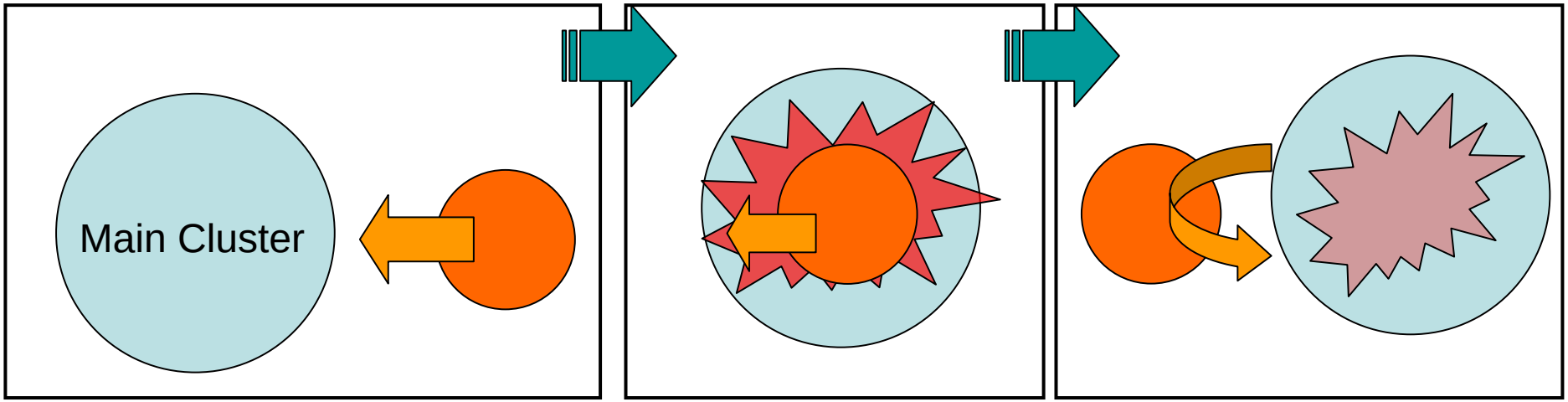


Umetsu & Broadhurst 2007, ApJ submitted



4. Distributions of Mass and Baryons in "Merging Clusters"

Various Merging Stages



Mergers are driven by Φ (Mass~DM)…

What is the relation between Mass (~DM) and Baryons during the merging process??

Cluster Targets

Merging clusters with detailed Chandra ar XMM data in the local universe (z=0.05-0.3)

S05A-159 (PI: Okabe)

Table 2. Cluster X-ray Features

Cluster	z	Type	1 arcmin (kpc/h_{70})	Components	T_{ave} (keV)
(1)	(2)	(3)	(4)	(5)	(6)
A754	0.0542	On-going	63.1		10.0 ± 0.3 [a]
A1750	0.0860	Binary	96.7	A1750C	3.87 ± 0.10 [b]
				A1750N	2.84 ± 0.12 [b]
A1758	0.2790	Binary	254.0	A1758N	8.2 ± 0.4 [c]
				A1758S	$6.4^{+0.3}_{-0.4}$ [c]
A1914	0.1712	On-going	174.9		10.9 ± 0.7 [a]
A2034	0.1130	Cold Front	123.2		7.9 ± 0.4 [d]
A2142	0.0909	Cold Front	101.7		8.1 ± 0.4 [e]
A520	0.1990	On-going	197.2	Archival data	7.1 ± 0.9 [a]

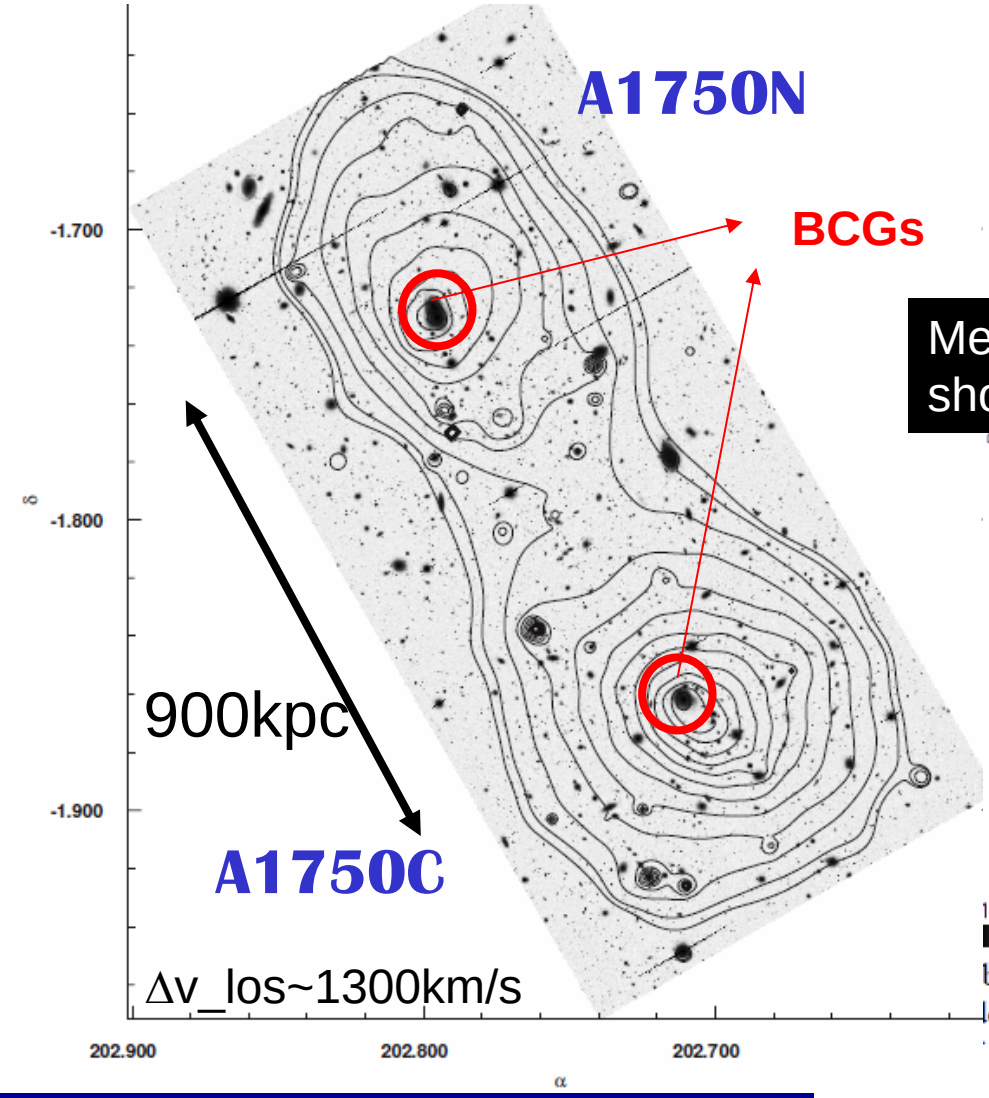
This talk

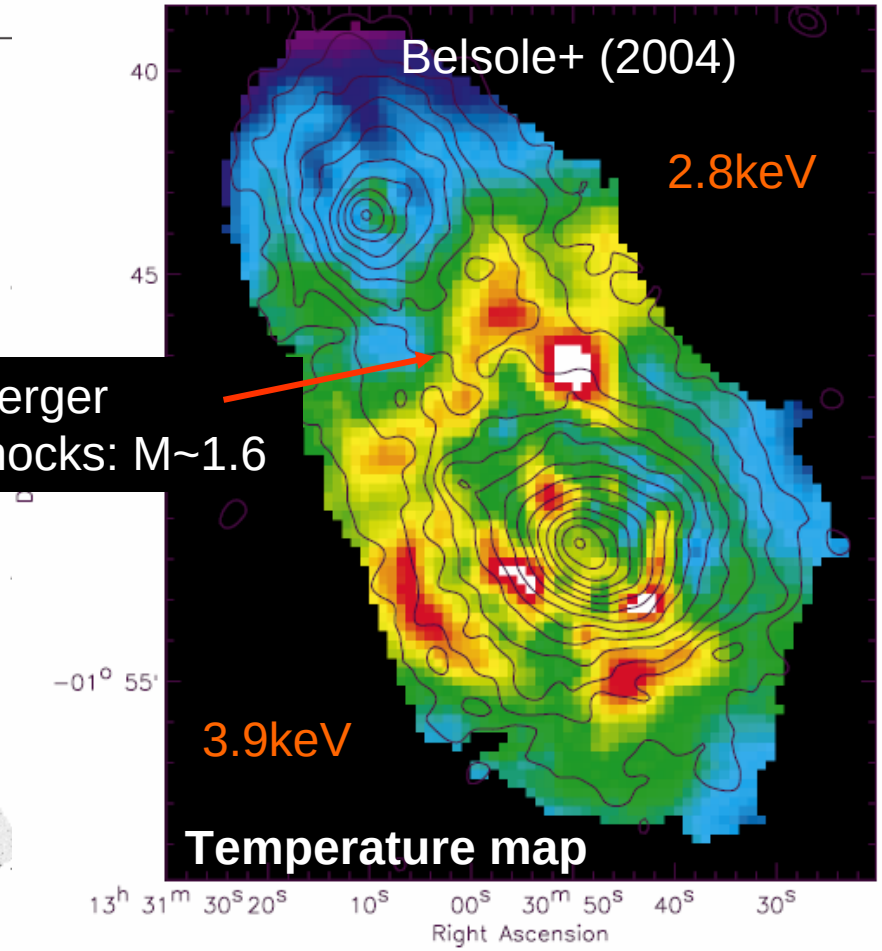
This talk will only focus on the results for the 3 merging clusters of different merging stages…

Pre-Merger (Binary)

A1750 (z=0.086) Optical vs. X-ray

Subaru image + X-ray contours (XMM)

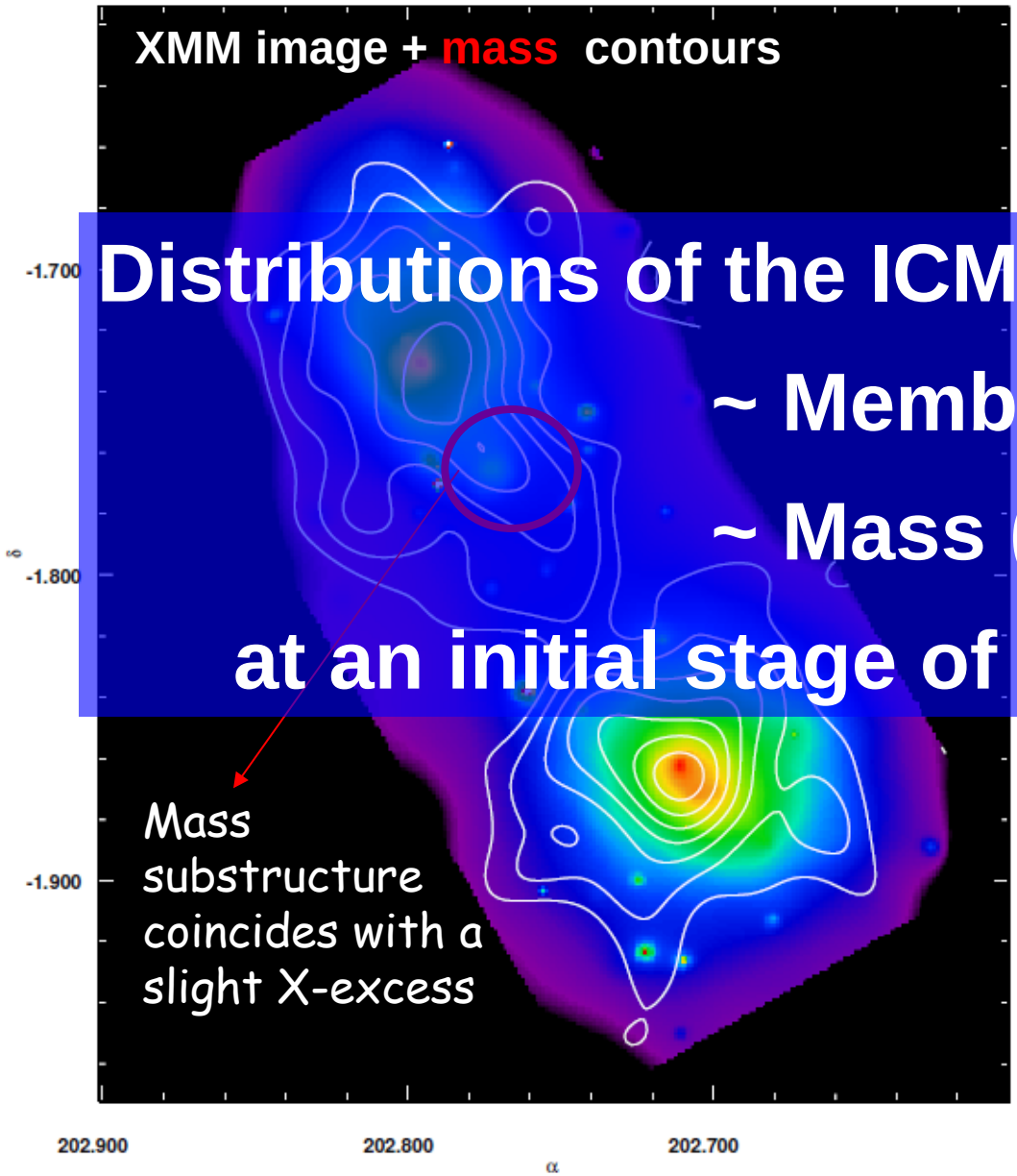


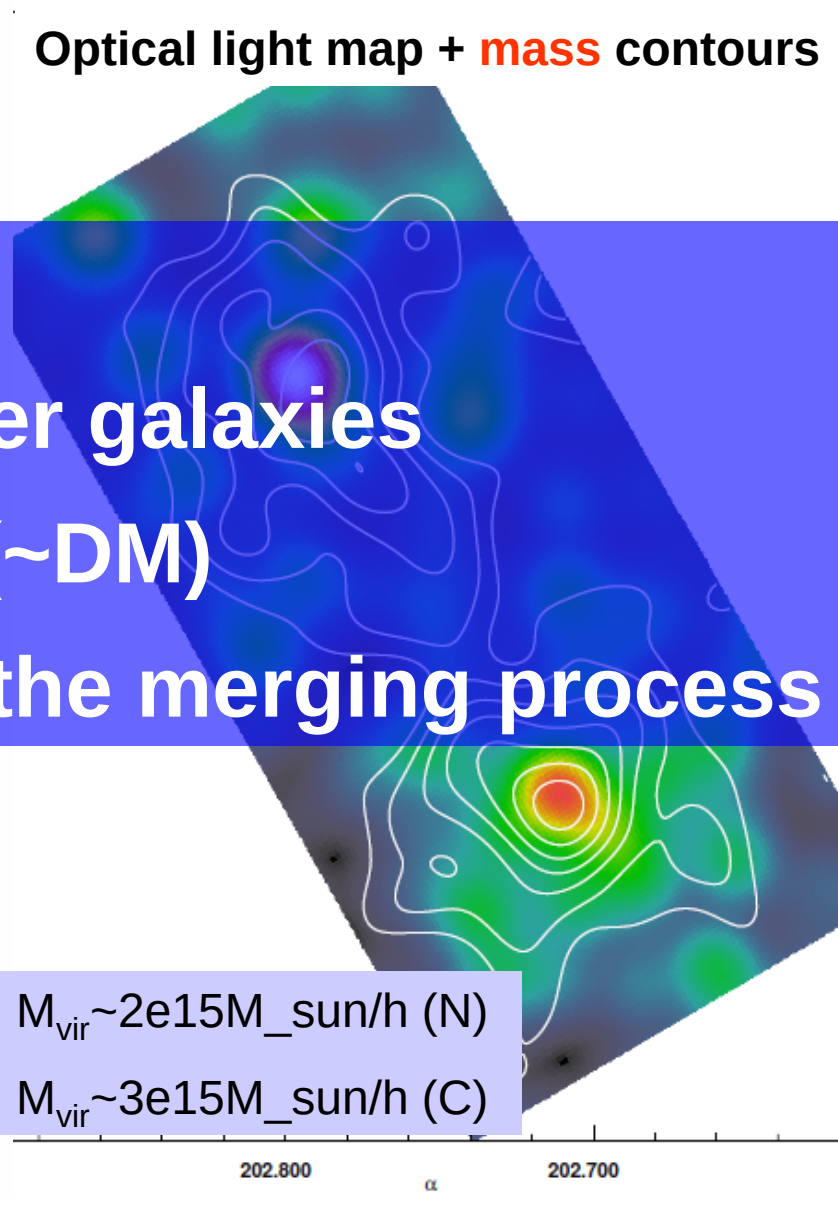


b) Temperature map derived by applying the wavelet algorithm as described in Sect. 4.2.2. This temperature map was obtained using data

Entropy excess in A1750C

A1750 (z=0.086) Mass vs. Baryons





Distributions of the ICM

~ Member galaxies

~ Mass (~DM)

at an initial stage of the merging process

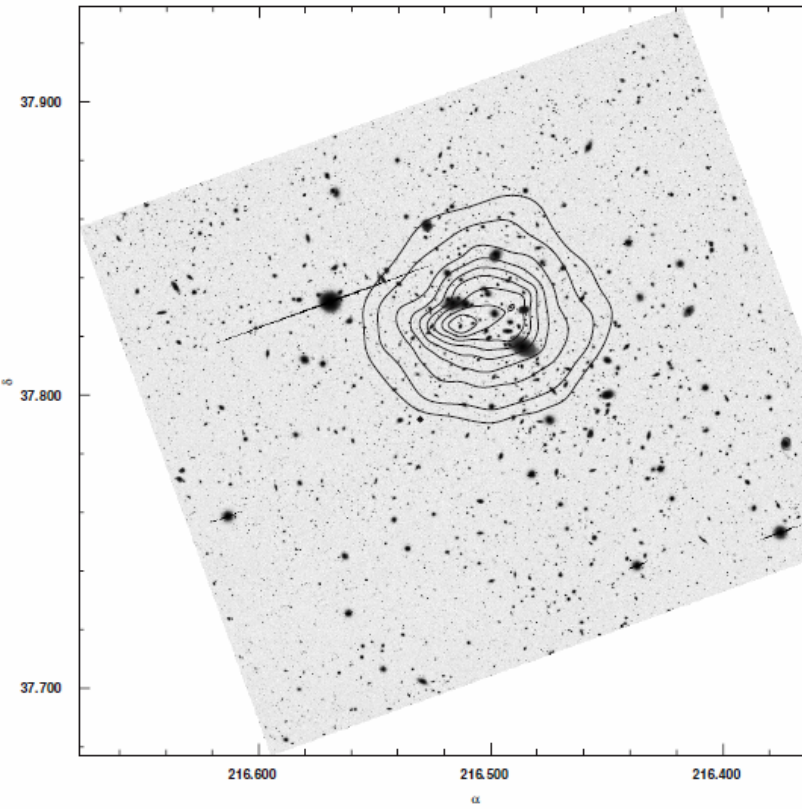
M_{vir}~2e15M_sun/h (N)

M_{vir}~3e15M_sun/h (C)

On-going Mergers

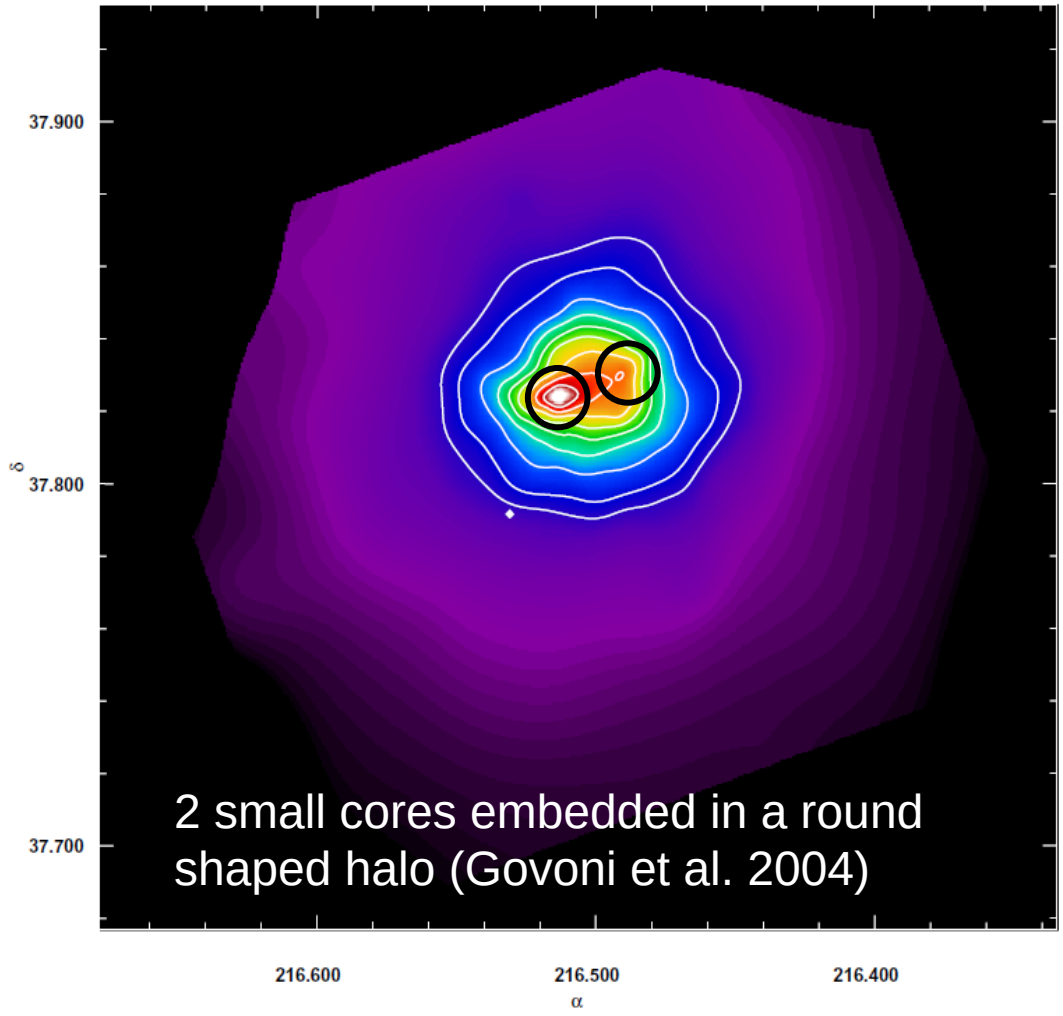
A1914 (z=0.172) Optical vs. X-ray

Subaru image + Chandra contours



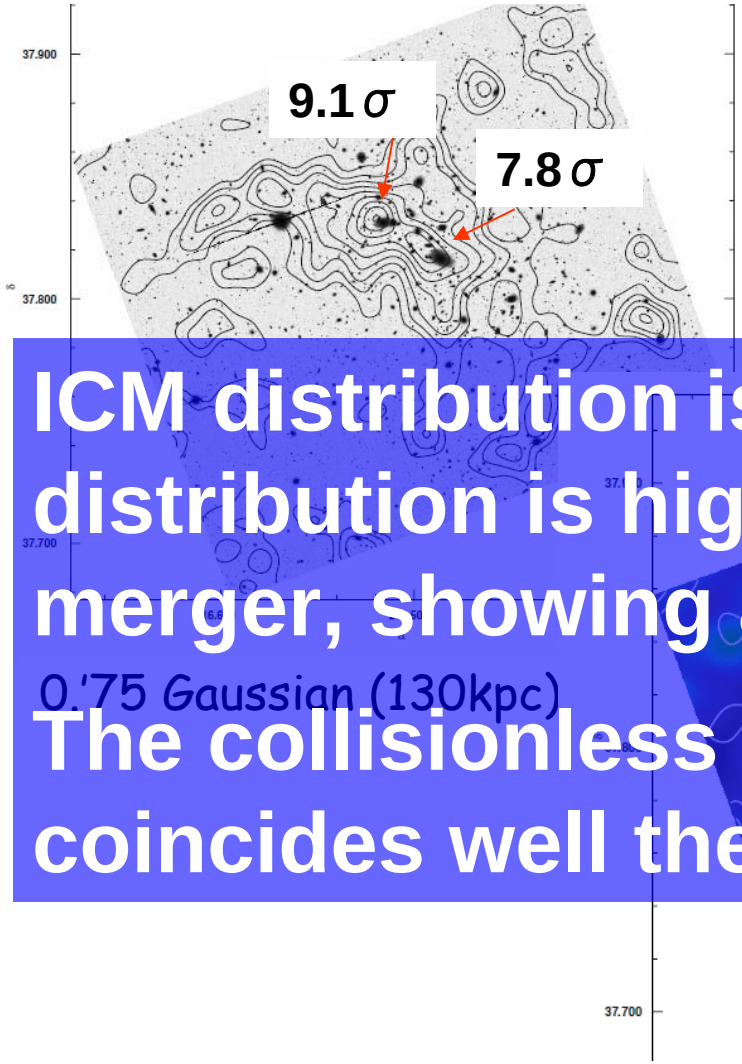
16'x16' (2.8Mpc on a side)

Chandra image + contours

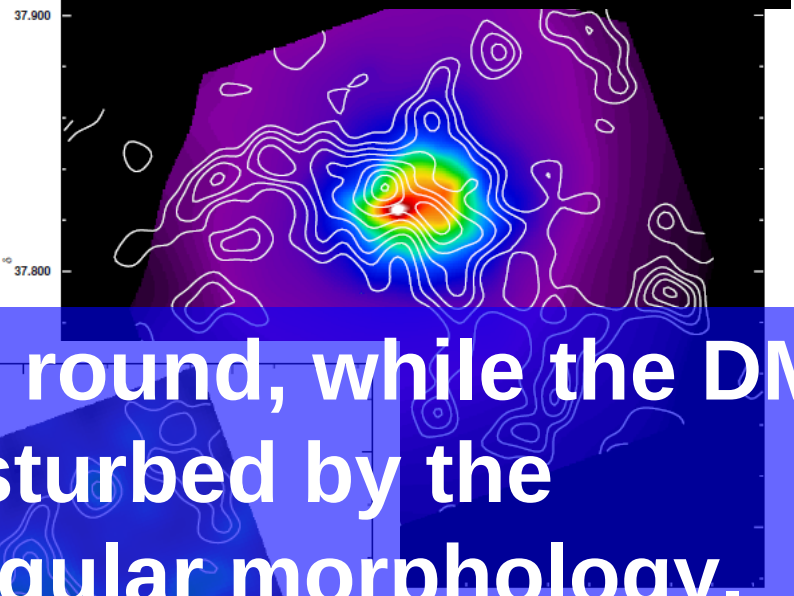


A1914 (z=0.172) Mass vs. Baryons

Subaru image + mass contours



X-ray image + mass contours



ICM distribution is fairly round, while the DM distribution is highly disturbed by the merger, showing an irregular morphology.

0.'75 Gaussian (130kpc)

The collisionless galaxy distribution coincides well the DM (~mass) distribution.

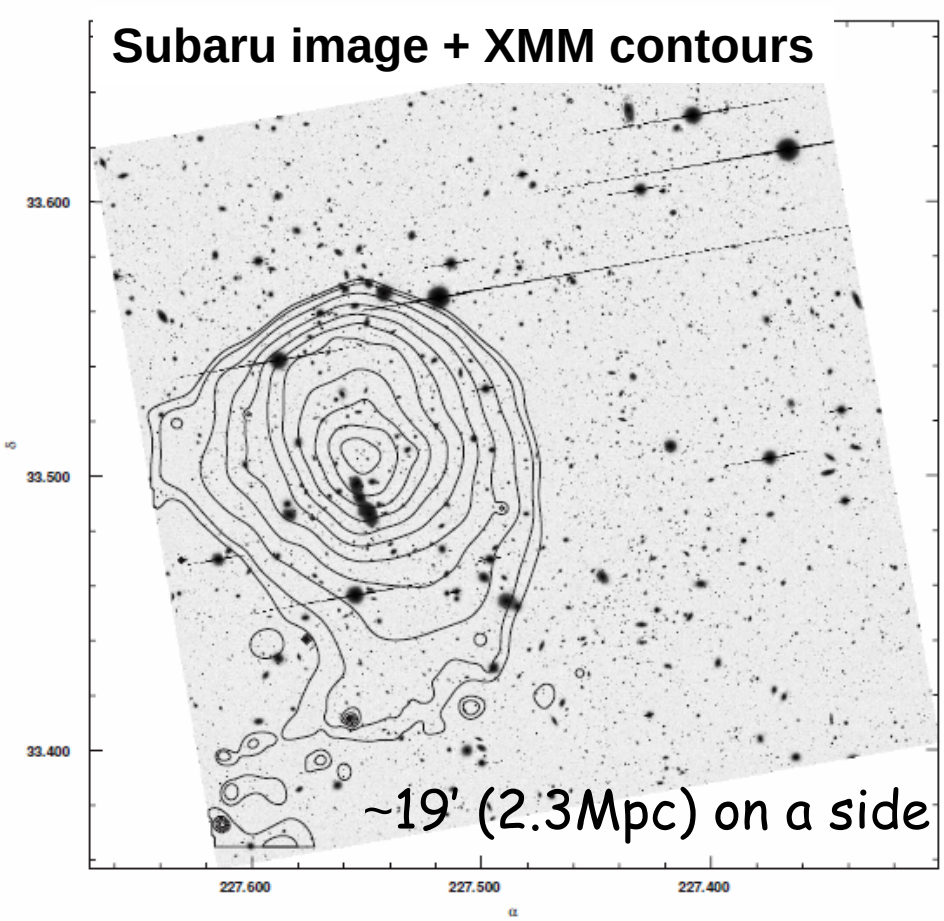
Merging structure (DM & Galaxies)

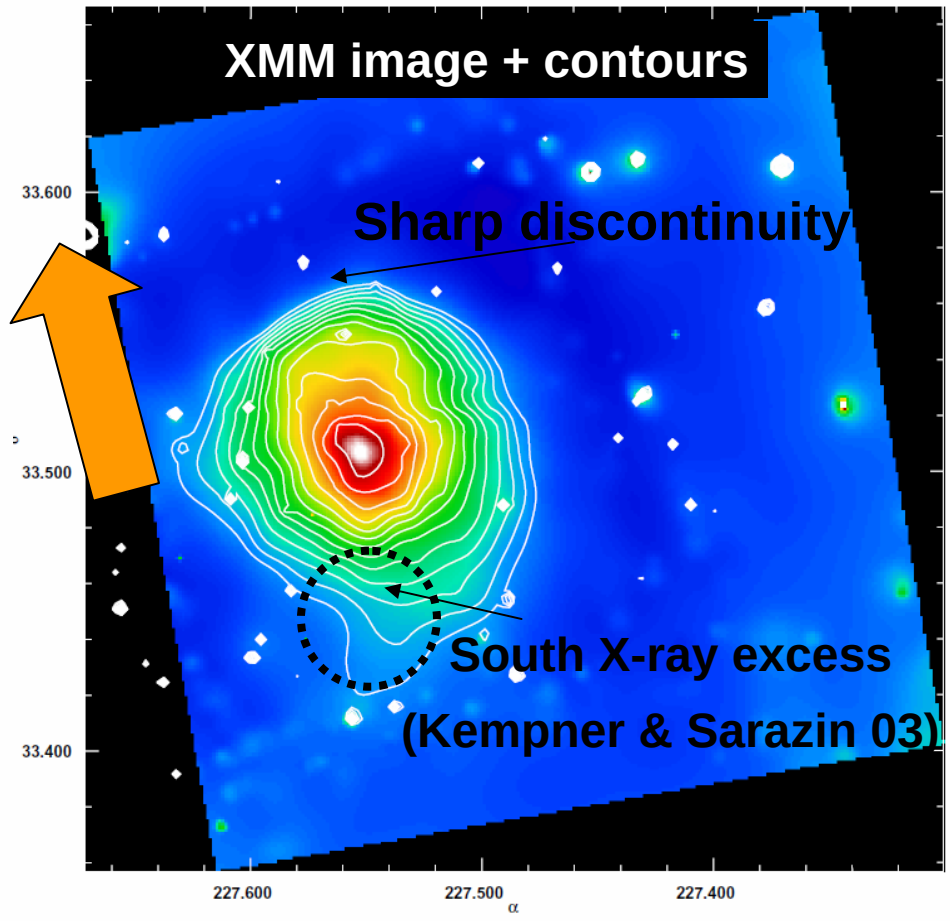
Light and mass peaks of the primary cluster coincide well

Optical light map + mass contours

Cold Front Clusters

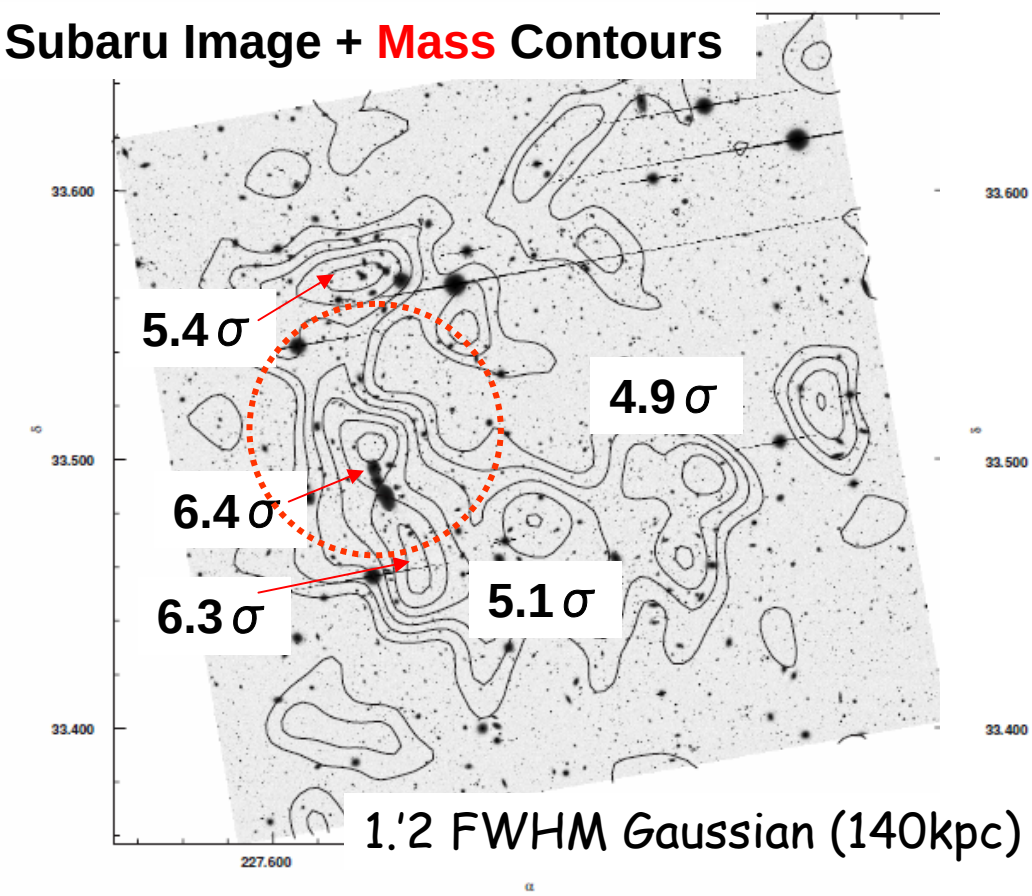
A2034 (z=0.113) Optical vs. X-ray

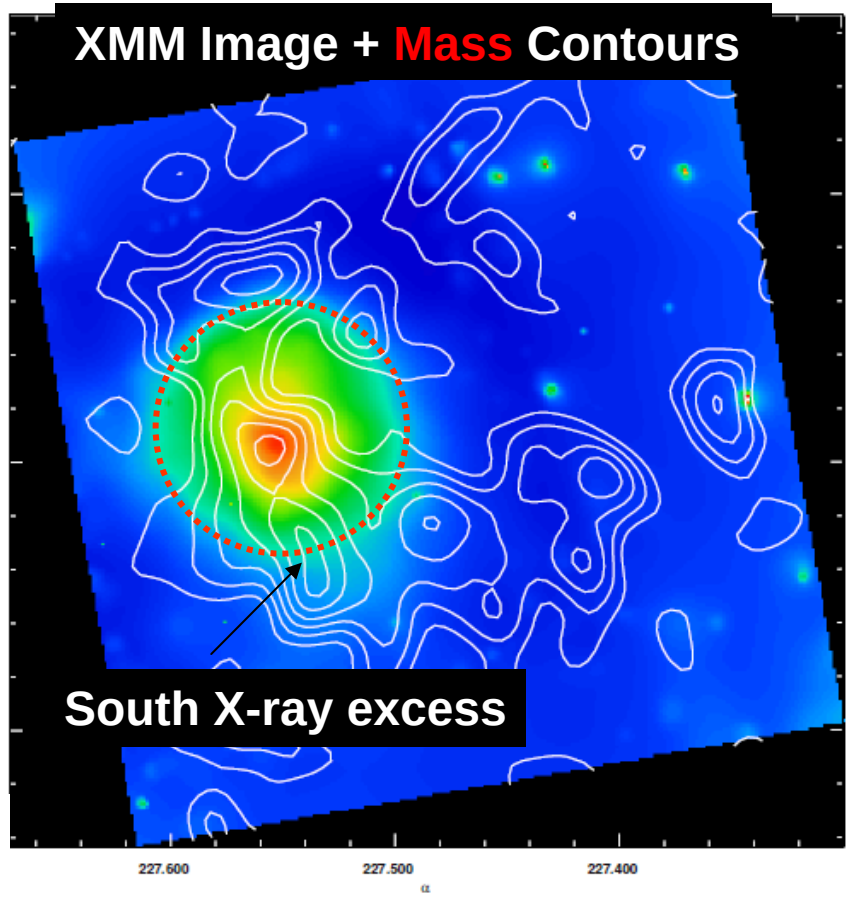




- Northern sharp-discontinuity in X-ray emission – but no significant jump in Tx
- Kempner & Sarazin 03 argued the excess emission likely to be a background structure

A2034 (z=0.1130) Mass vs. Baryons



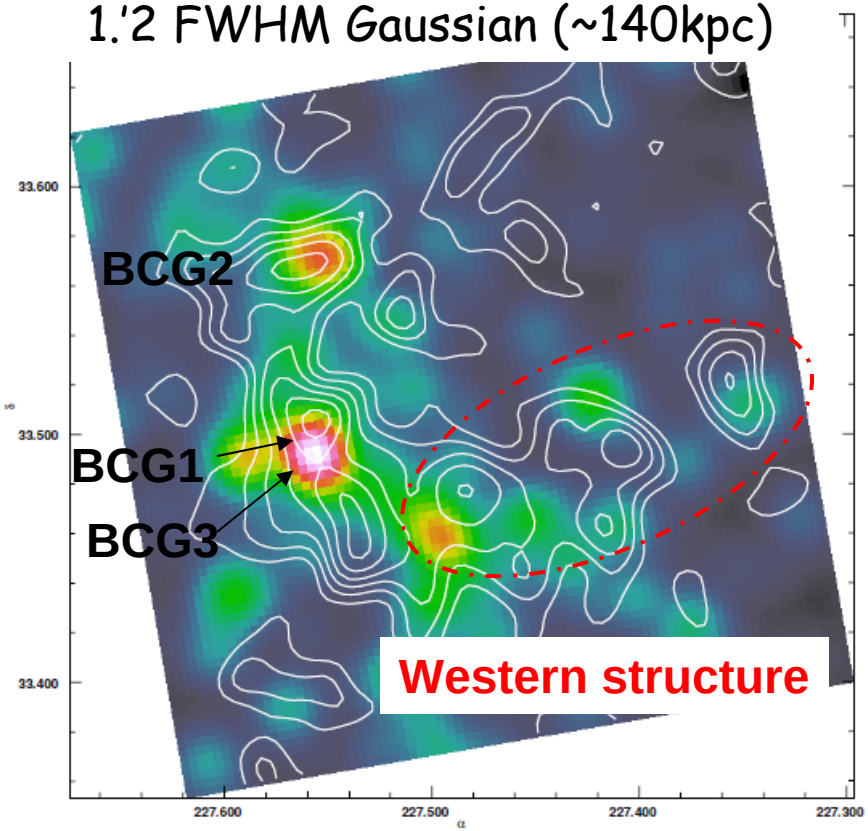


Detections of significant “mass clumps” associated with [1] **primary cluster** (6.4σ), [2] **northern structure** (5.4σ) ahead of the cold front, [3] **south X-ray excess** (6.3σ), **and (4) western structures**

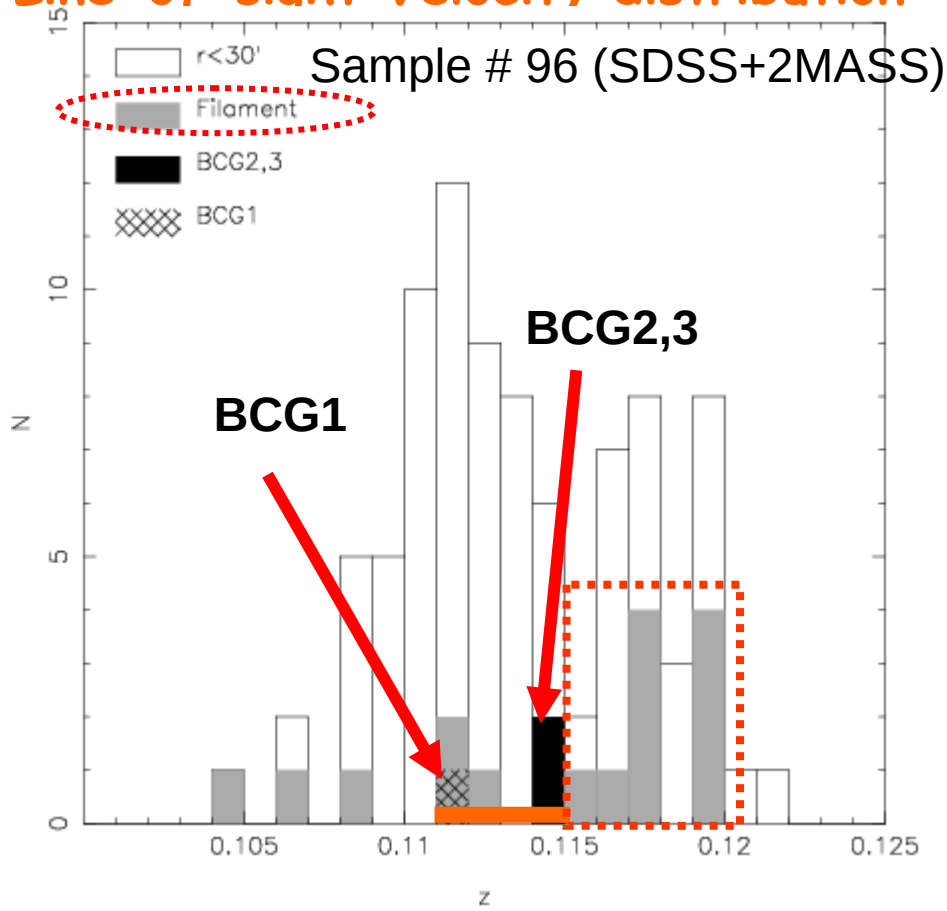
A2034 (z=0.1130) Filament?

Light map + mass contours

1.′2 FWHM Gaussian (~140kpc)



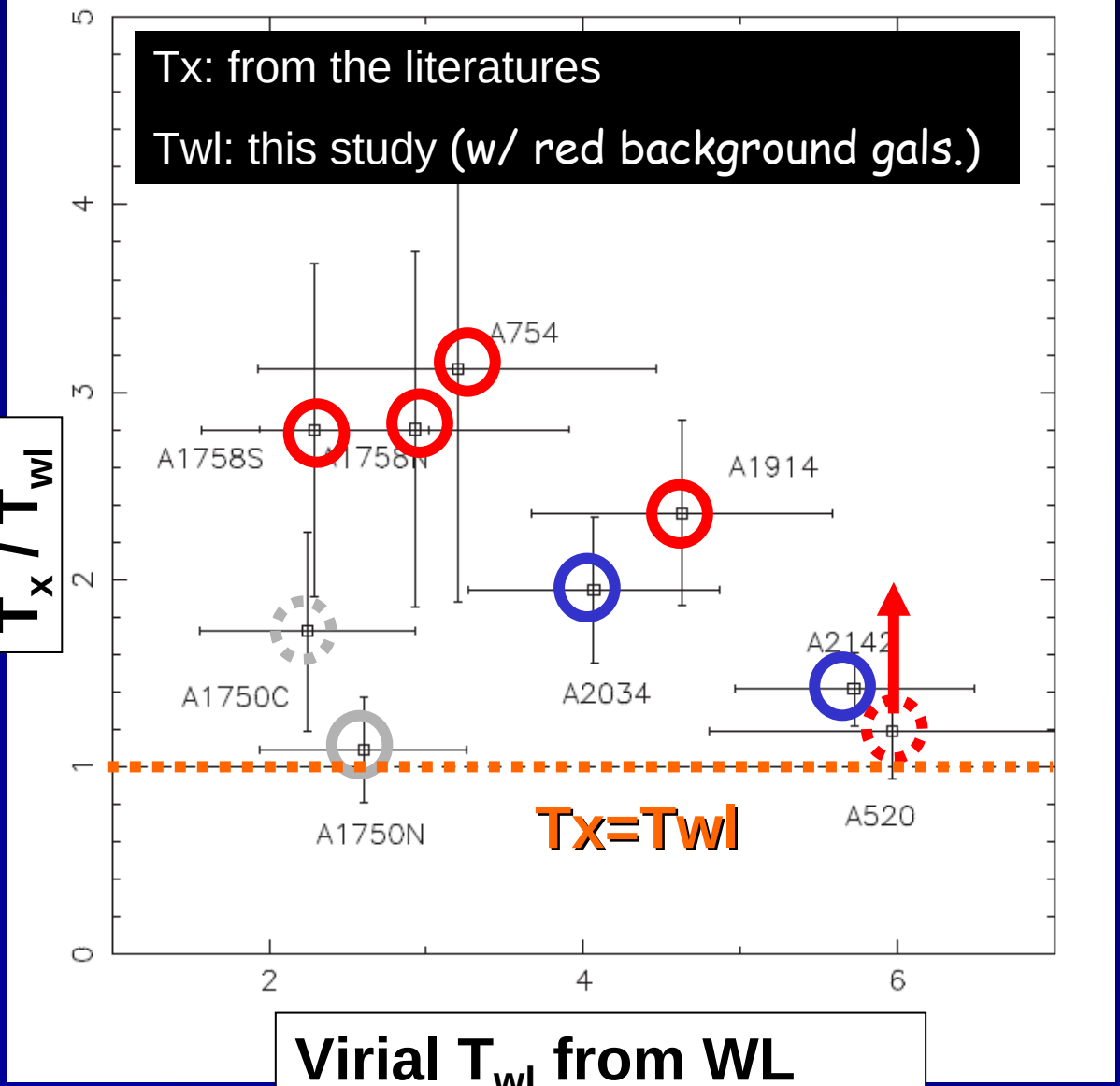
Line-of-sight Velocity distribution



"**Western mass structures**" found to be associated with **filamentary structure of background galaxies**

→ LOS com. separation of ~ 10Mpc/h (assuming v_pec=0)

4. Tx vs. WL-derived Virial Temperature



Ongoing

Cold front

Pre-merger

Tx is (2-3) times higher than Twl in ongoing mergers:

Merger boosts? (Sarazin & Ricker 02)

A1750C:: Entropy excess

A520:: Tx including the pre-shock (low-T) region, under-estimated by ~1.7

Summary

- **Joint WL/X-ray/Optical analysis**::
  - 1st systematic WL study of merging clusters
    cf. Clowe+ 04 on Bullet cluster; Bradac+ 06 on 1ES0657@z~0.3
  → Provides an important clue to understand the cluster merger
- **Distributions of Baryons & DM**::
  - **Initial phase**: ICM and Galaxies tracing the Mass
  - **Ongoing**: "Mass ~ Galaxies" but highly irregular, offset from "ICM" in a various way
  - **Cold front**: DM clumps always found in front of dense cores (all of 3 cold fronts) as found in the Bullet Cluster (Clowe+04)
- **Cluster global properties**::
  - Tx ~ Twl in a pre-merging phase
  - Tx ~ (2-3) Twl during mergers
    → **merger boosts**? (Sarazin & Ricker 02; Rowley+ 04) as a function of dynamical-phase, initial merger conditions, & masses.

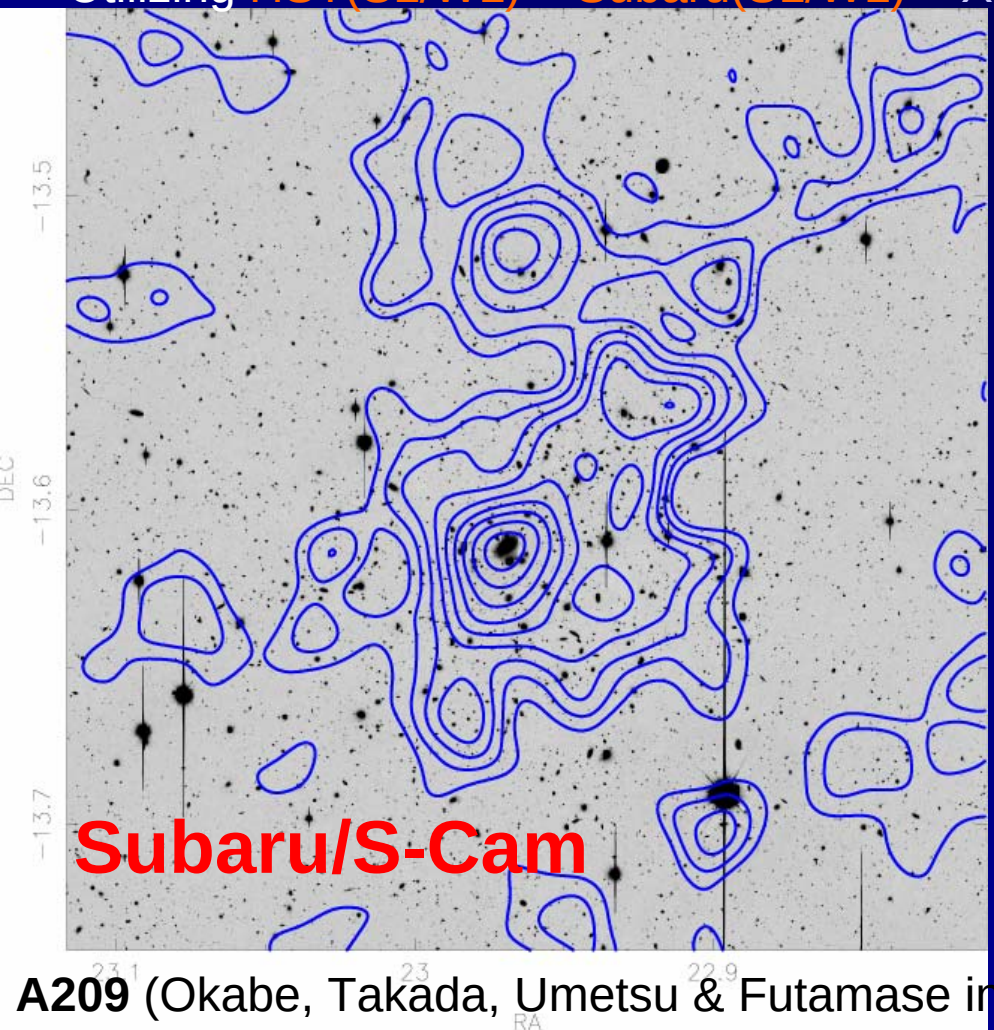
Future Work

Ongoing Project

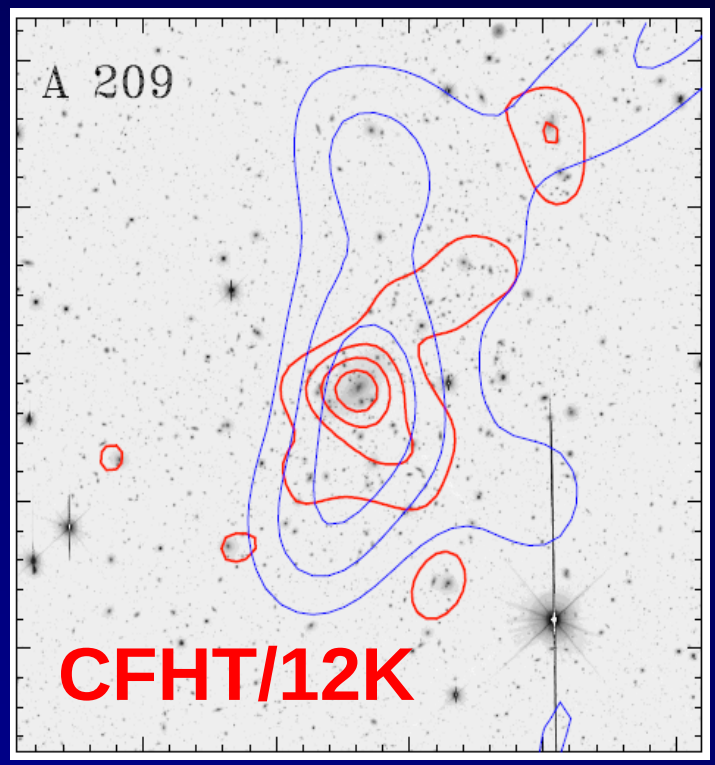
LoCuSS: Local Cluster Substructure Survey

Flux limited, unbiased sample of >100 clusters in the local universe
(Lx>5x10^44erg/s、0.15<z<0.3)

Utilizing HST(SL/WL) + Subaru(SL/WL) + XMM/Chandra + Spizter + SZ (SPT…)



WL analysis of 29 clusters completed



(Bardeau et al 2007)

A209 (Okabe, Takada, Umetsu & Futamase in prep)

Special Thanks to Lensing Collaborators

LoCuSS

- N. Okabe, M. Takada, T. Futamase (Tohoku) , G.P. Smith (P.I.)

AMiBA SZE + WL

- AMiBA Science Team (ASIAA, NTU/Phys)

See the AMiBA poster by K.Y. Lin

HSC WL Working Group

S. Miyazaki, T. Hamana, H. Furusawa, Y. Utsumi (NAOJ), M. Takada (Tohoku), K. Yamamoto (Hiroshima), H. Nishioka (ASIAA)

Fexion and HOLICs

- Y. Okura, T. Futamase (Tohoku)

Dark Halo Density Profiles

- T. Broadhurst, E. Medezinski (Tel Aviv)

FIN