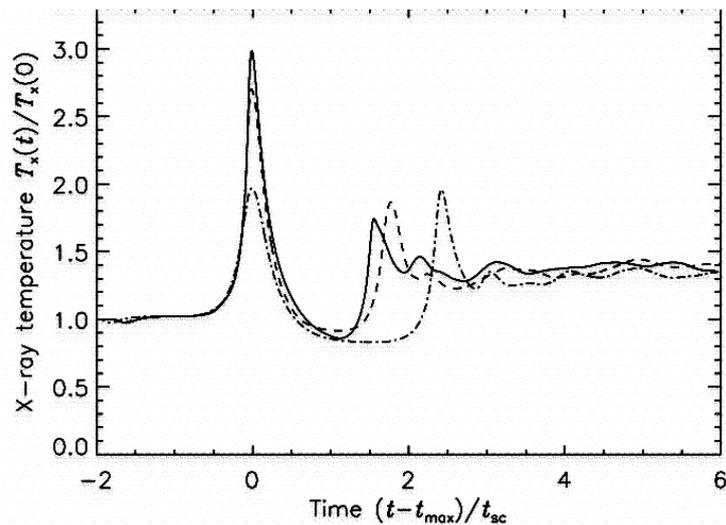
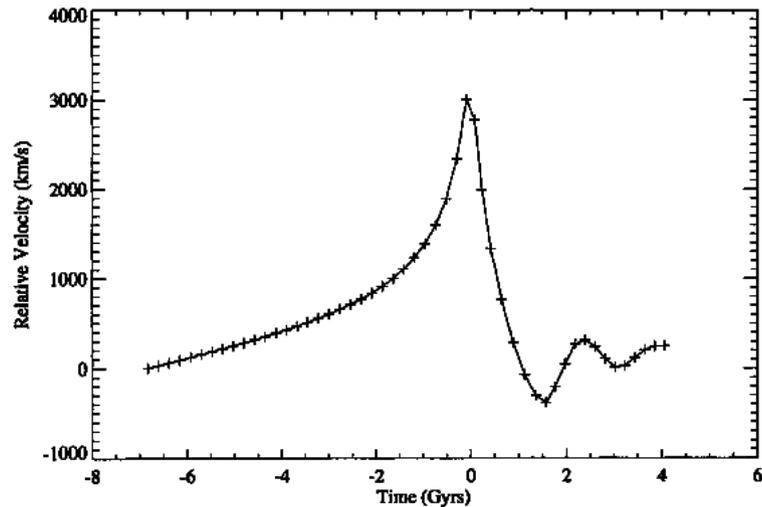


Context 3: cluster mergers & numerical simulations

During major merger,
enhancements in both σ_v and T_x .

Enhancement in σ_v depends on
the angle of view of the merging axis
(e.g., Simulations by Pinkney et al. 96).



Enhancements in T_x .
(e.g., Ricker & Sarazin 01).

CLUSTERS WITH RADIO HALOS AND RELICS

RADIO HALOS/RELICS:

RARE PHENOMENA (about 50 clusters).

Diffuse, ~ 1 Mpc size, radio emission,

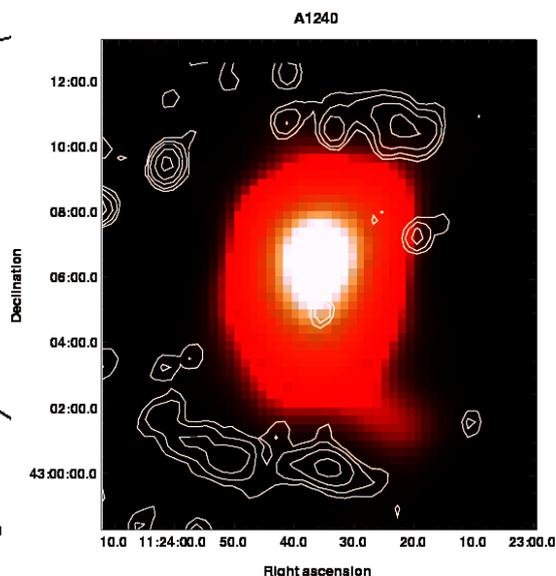
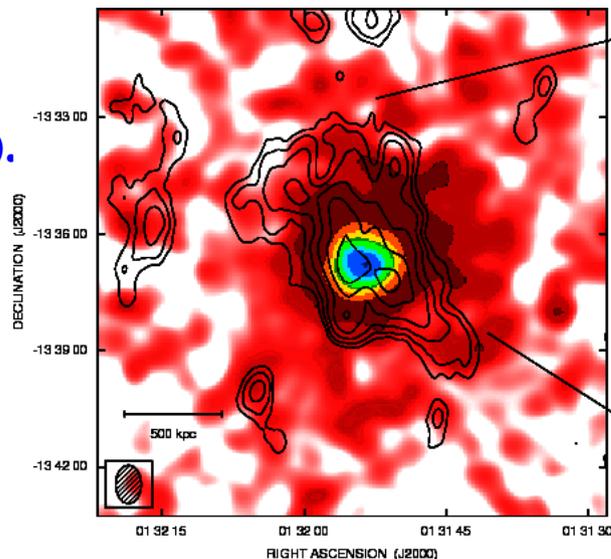
$P_{\text{Radio}} =$ of 10^{24-25} W/Hz at 1.4GHz,

synchrotron emission from e^-

(Lorentz factor 10^4 ,

Energy dens. 10^{13-14} erg/cm³)

in magnetic field $B=0.1-3 \mu\text{G}$.



Figs. A209 Giovannini et al.09; A1240 Bonafede et al. 09.

Problem: electrons cannot cover a 1Mpc scale!!!!

Primary electron reacceleration model:

CLUSTER MERGERS ipothesis (Tribble 1993).

Energetics: 10^{64} erg, 10% dissipated. Frequency: transient phenomena.

MERGERS: TURBULENCE+SHOCK WAVES.

(Life time of Radio emission is small, about 0.5 Gy, e.g. Skillman et al. 2010).

Individual and statistical studies using X-ray data. ($P_{\text{radio}} - T_X$, $P_{\text{radio}} - L_X$).

Optical data were poorly explored. I STARTED THE DARCA PROJECT

DARC program (2002-now)

<http://adlibitum.oat.ts.astro.it/girardi/darc>

Dynamical Analysis of Radio Clusters

M.G. (P.I.,UNITS), R. BARRENA(IAC),W. BOSCHIN (TNG),+...

Optical information coming from galaxies is complementary to X-ray information since galaxies (**collisionless**) and ICM (**collisional**) react on different time scales !

DATA FOR 20 CLUSTERS

(**>20nights spec.+10nights photo**)

Most SPECTRA at the **TNG**

IMAGING at the INT (+SDSS)

MULTIWALENGTH ANALYSIS

+**Chandra X-ray Data Archive;**

+use of X-ray, GL, Radio results.



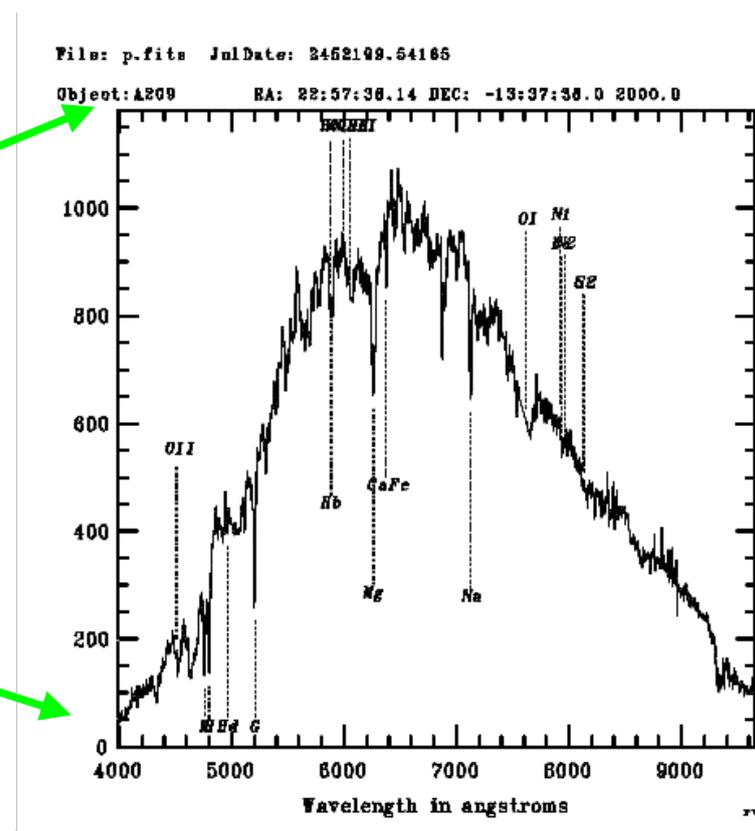
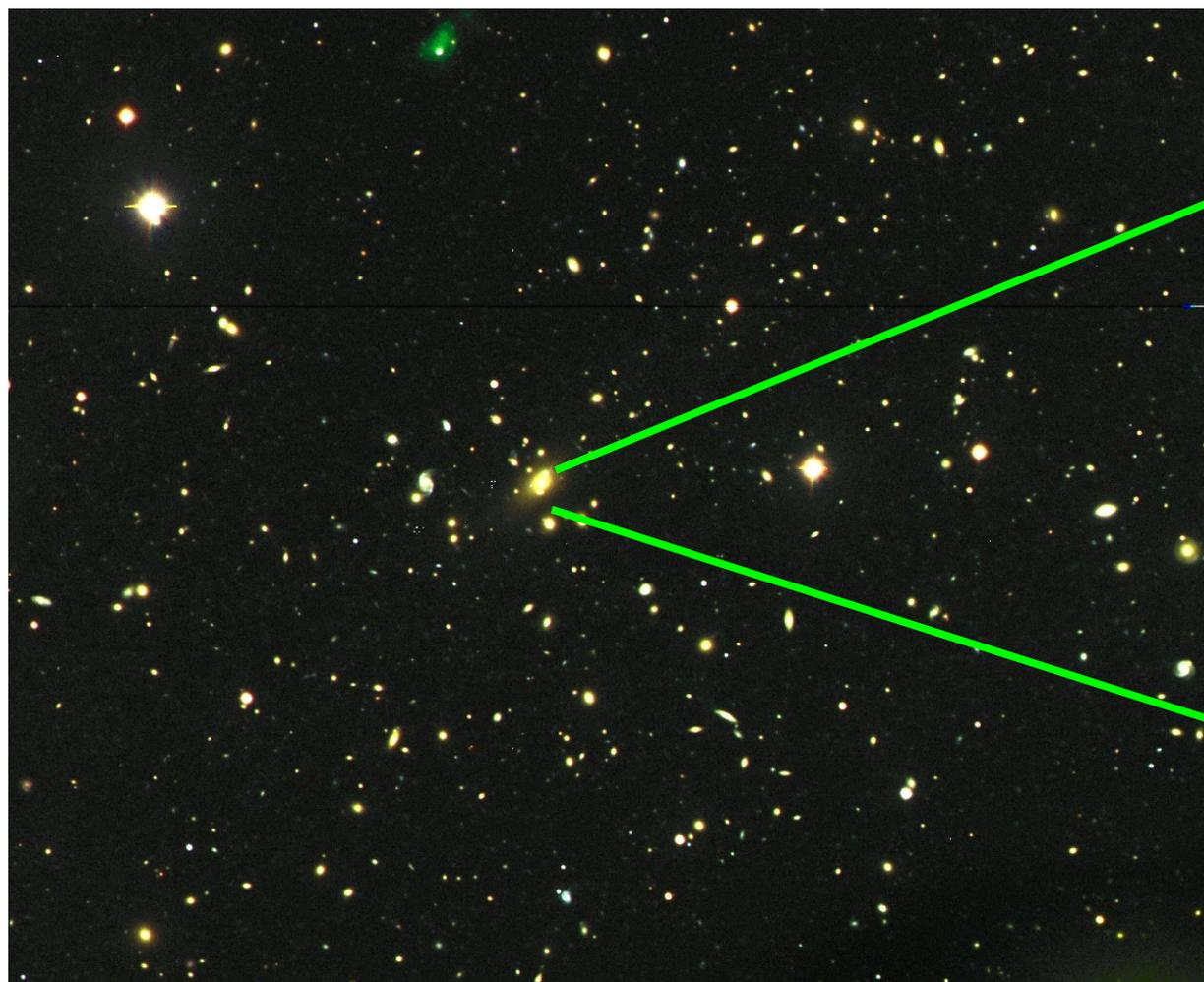
Main info: galaxy positions and LOS velocities $v=cz$ + magnitude, color, spectral type.

Out to a radius of about $0.7-1 R_{200}$: 80-100 member galaxies with z .

Out to $> 2 R_{200}$ likely members (red sequence or col-col plane).

Pilot project:

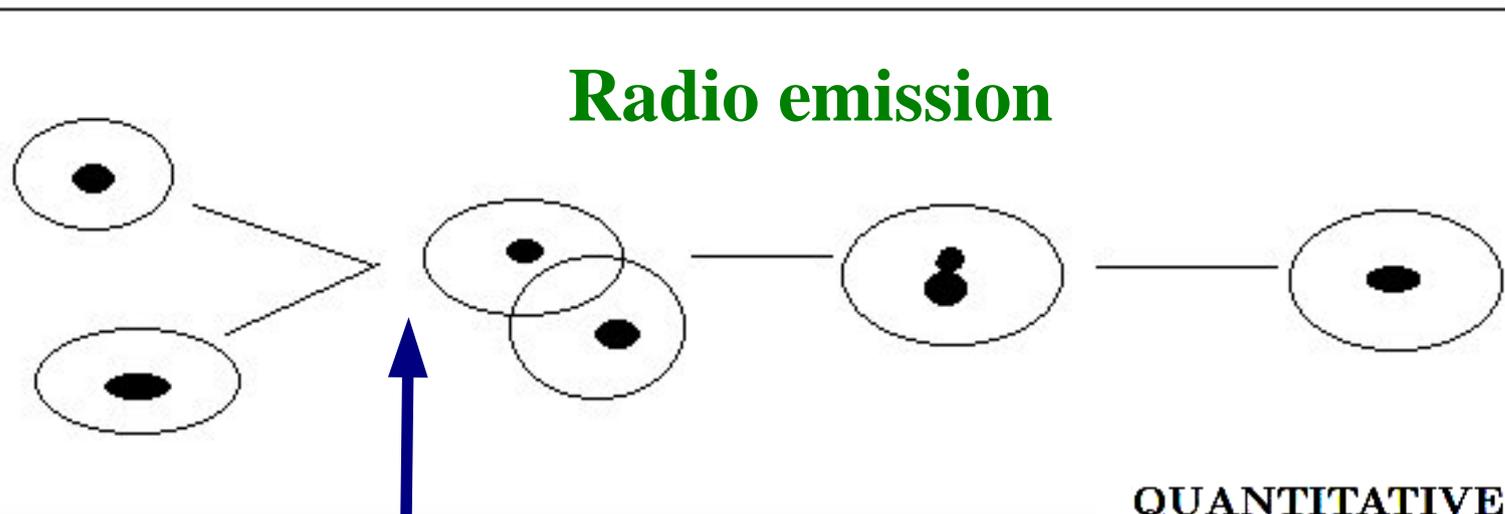
A209 ESO NTT photometry+multi object spectroscopy (Mercurio, MG, et al 2003)



Ongoing DARCS program

- A209 Pilot, Mercurio et al. 2003, $z=0.21$, $T_x=10\text{keV}$, NTTspectra+phot., Chandra arch.)
- A2219, Boschin et al. 2004, $z=0.22$, $T_x=10\text{keV}$, TNG+CFHTarch. , Chandra arch.
- A2744, Boschin et al. 2006, $z=0.31$, $T_x=8\text{keV}$, NTTarch.+lit. spectra
- A697, Girardi et al. 2006, $z=0.28$, $T_x=10\text{keV}$, TNGspec+INTphot.,Chandra arch.
- A773, Barrena et al. 2007, $z=0.22$, $T_x=9\text{keV}$, TNGspec+INTphot., Chandra arch.
- A115, Barrena et al. 2007, $z=0.19$, $T_x=8\text{keV}$, TNGspec.+INTphot.
- A610-A725-A796, Boschin et al. 08 $z=0.1$, poor cls, WYFOS@WHTspec+SDSS+INTphot.
- A520, Girardi et al. 2008, $z=0.20$, $T_x=8\text{keV}$, TNGspec.+CNOCSpec
- A959, Boschin et al. 2009, $z=0.29$, $T_x=7\text{keV}$, TNGspec.+SDSS
- A1240, Barrena et al. 2009, $z=0.19$, $T_x=6\text{keV}$, TNGspec.+INTphot., Chandra arch.
- A2294 Girardi et al.2010, $z=0.17$, $T_x=10\text{keV}$,TNGspec+INTphot,Chandra arch.
- A2345 Boschin et al.2010, $z=0.18$,TNGspec+INTphot,Rosat HRI arch.
- A545 ongoing analysis $z=0.16$,TNGspec+INTphot,XMM arch.(+S.DE GRANDI)
- A1995 catalog prepared
- A1758 catalog prepared
- A2254 data reduced
- A1914 data reduced
- A1351 data reduced

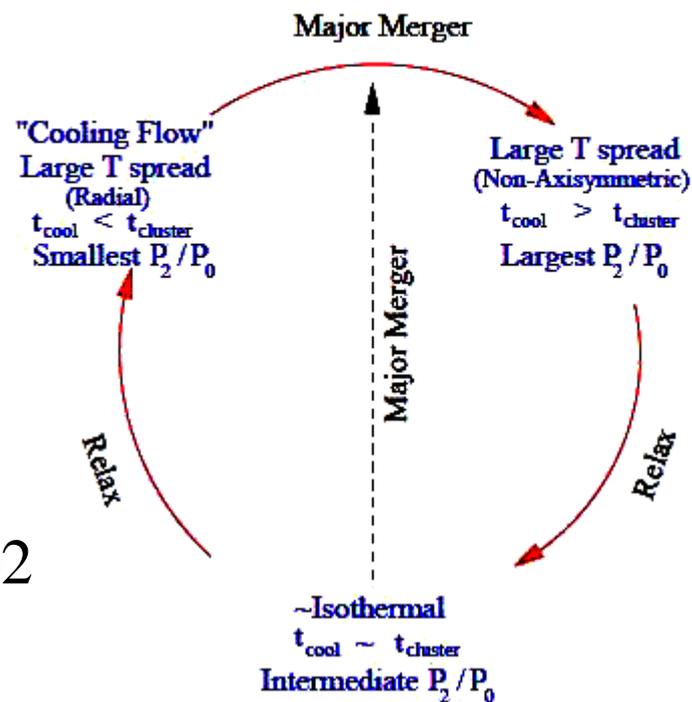
Possible evolutionary sequence:



Then,
relaxation.

Core-core passage

QUANTITATIVE CLASSIFICATION OF TEMPERATURE MORPHOLOGY

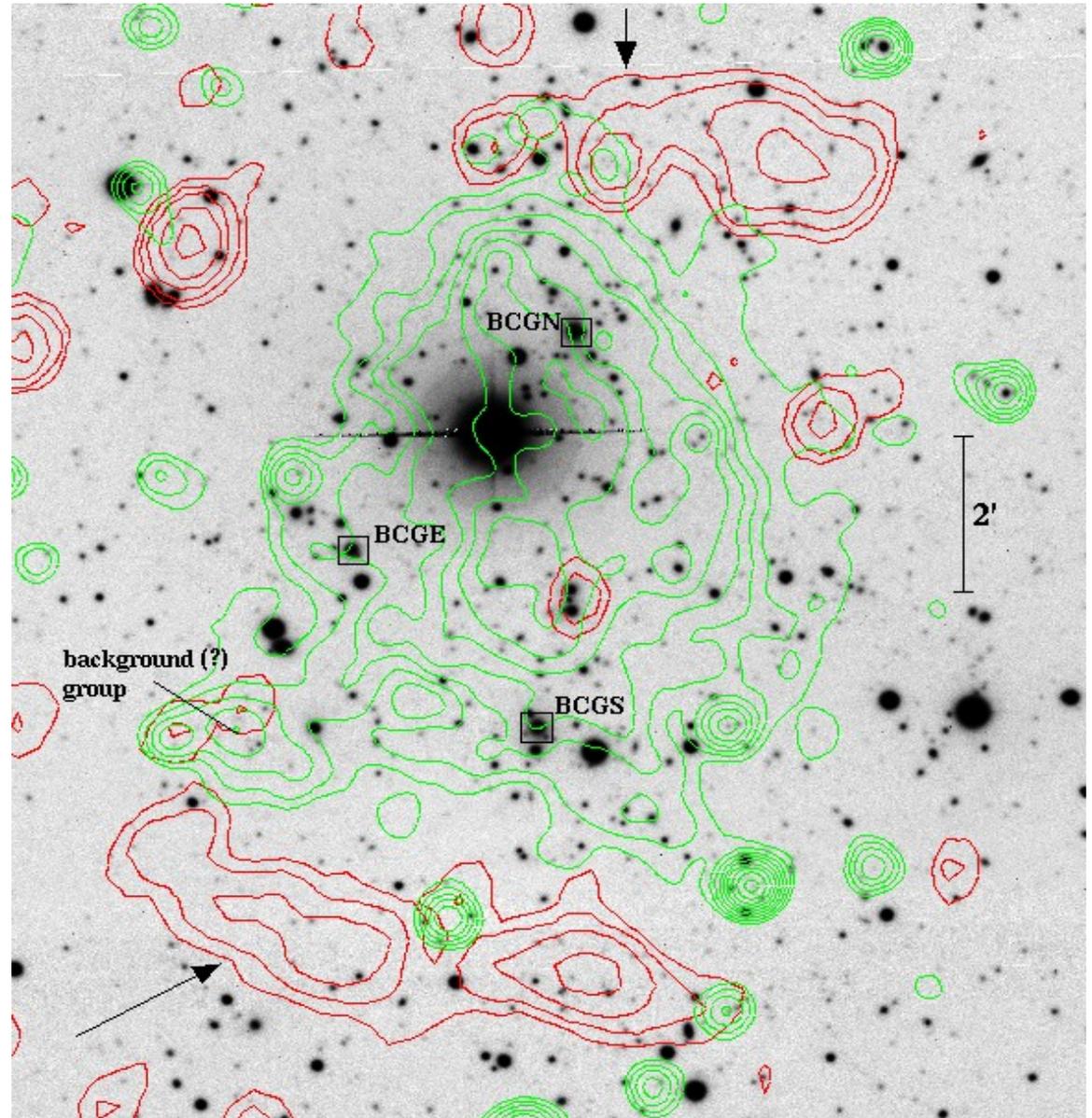
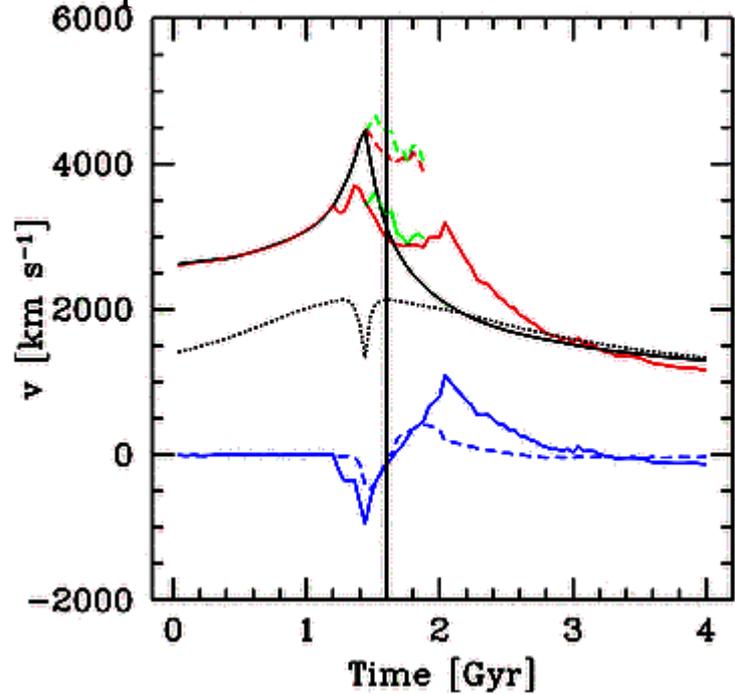


Buote 2002

A1240 with two Symmetric Radio relics (Barrena et al. 09)

**A MERGER OF TWO SUBCLUSTERS,
MOSTLY IN THE PLANE OF SKY.**

Velocities of different components
Mastropietro & Burckert 08.



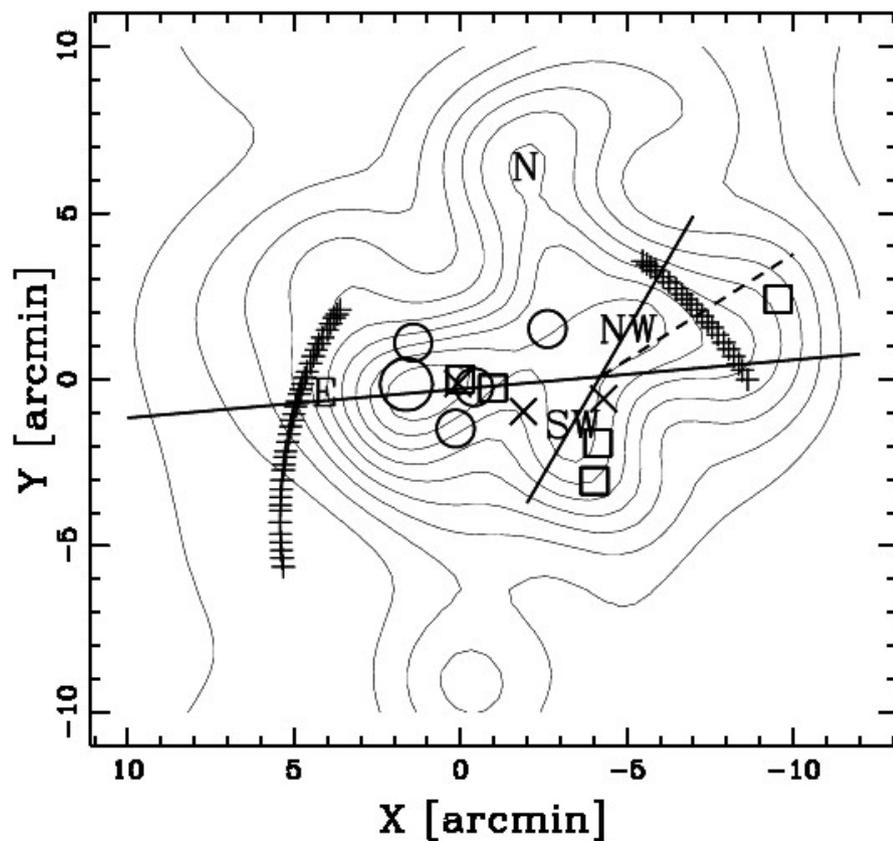
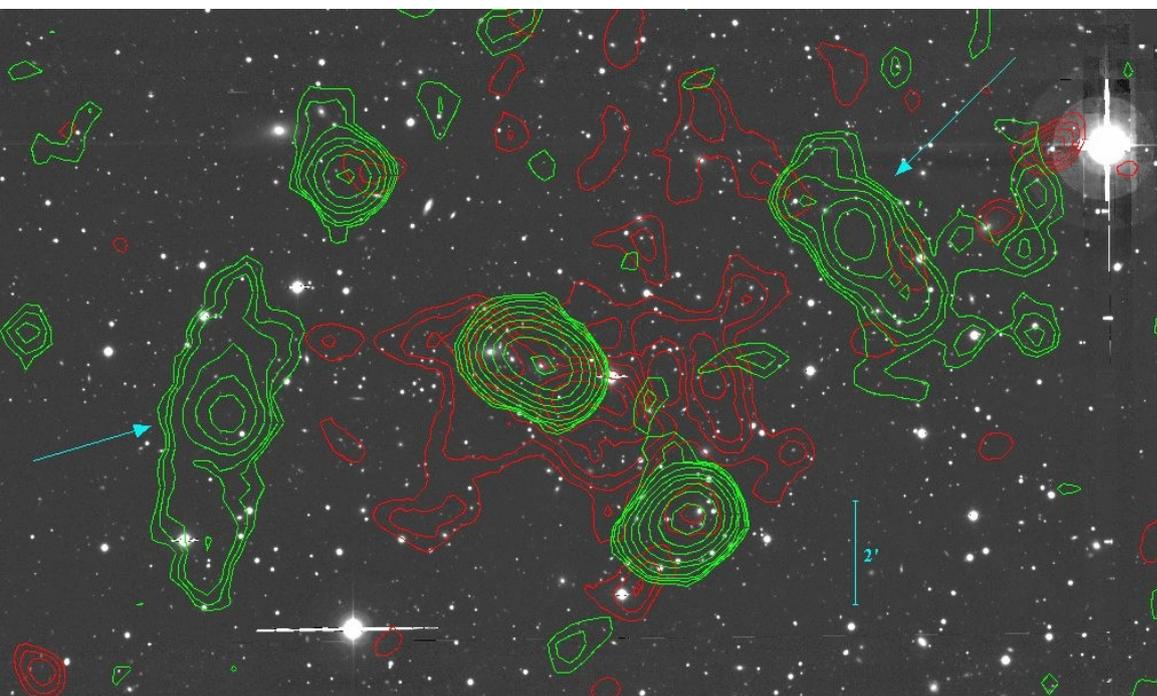
**We strongly support the
outgoing merger shocks
model to explain the relics.**

CANDIDATE FOR CONSTRAINING THE SELF-INTERACTING DM

A2345 with two non symmetric relics (Boschin et al. 10)

(Boschin et al. 2010, A&A just accepted)

Merging of three subclusters.



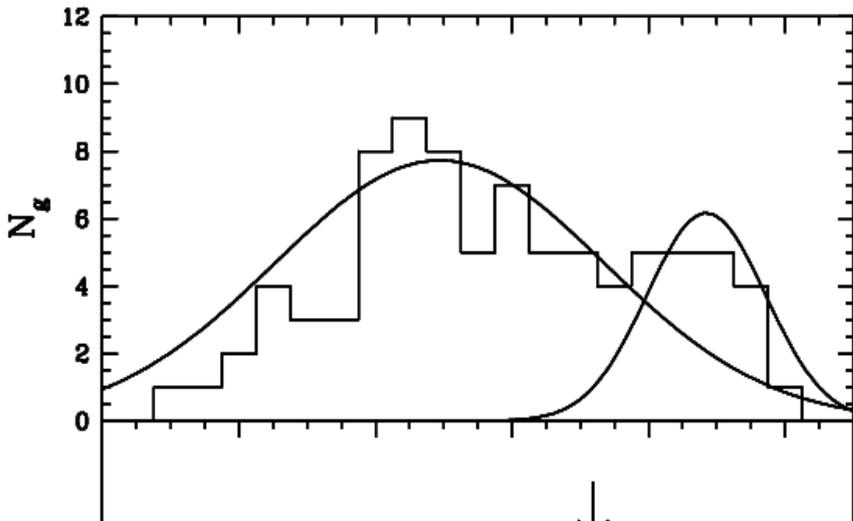
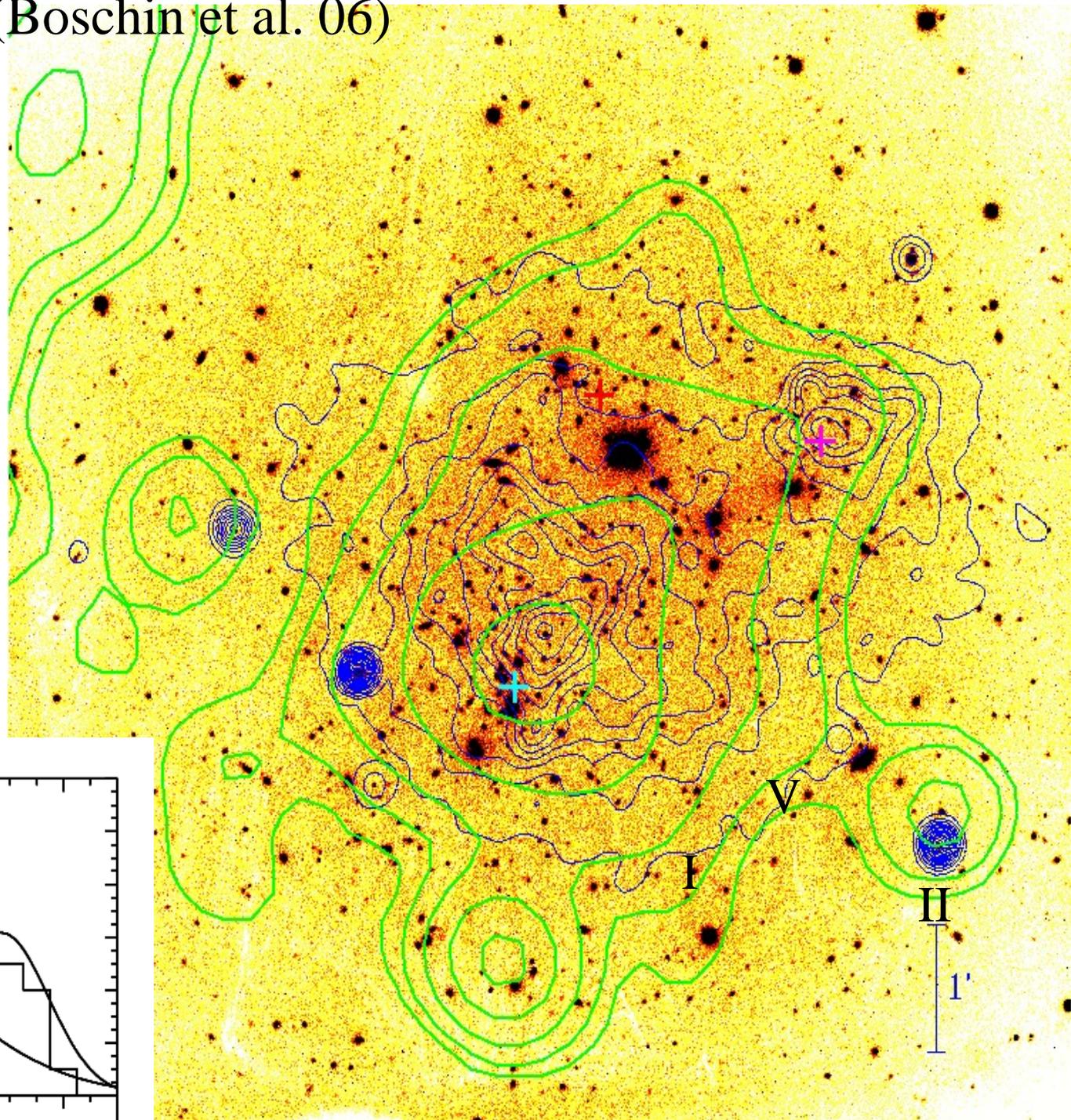
A2744, $z \sim 0.31$ Radio halo

2 cool blobs
(Kempner & David 04).

Ongoing merger
of 2 clumps (2BCGs)
with $\Delta V \sim 3000$ km/s
A LOS merger.

Velocity distribution.

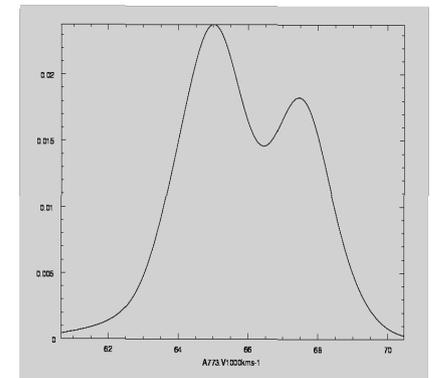
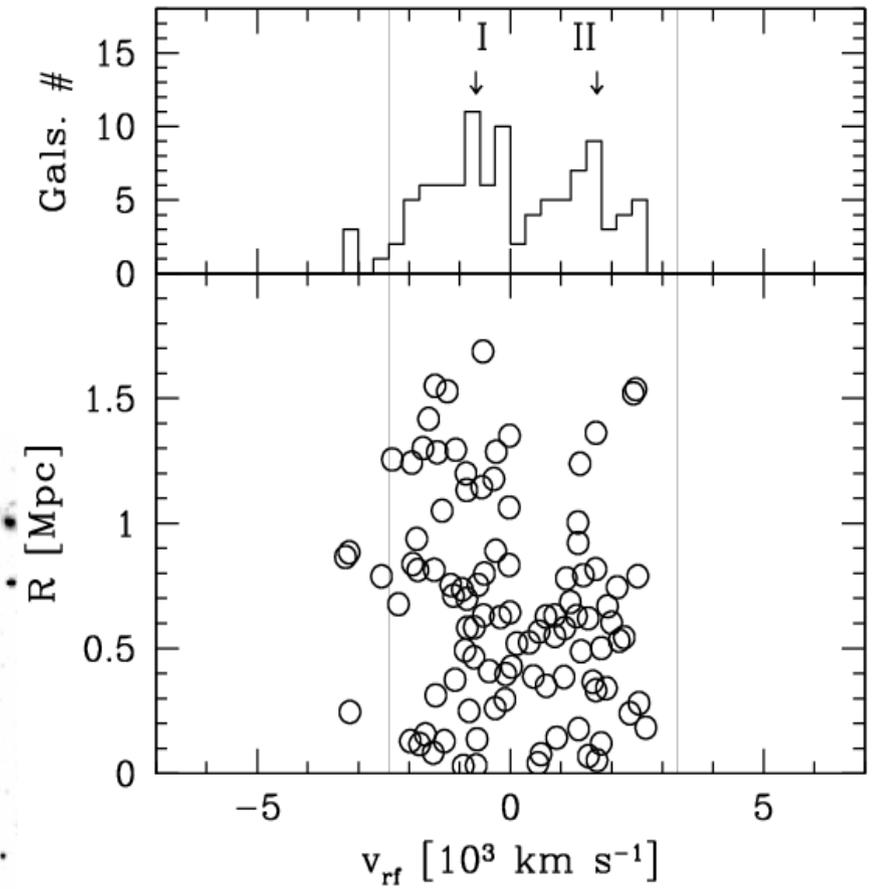
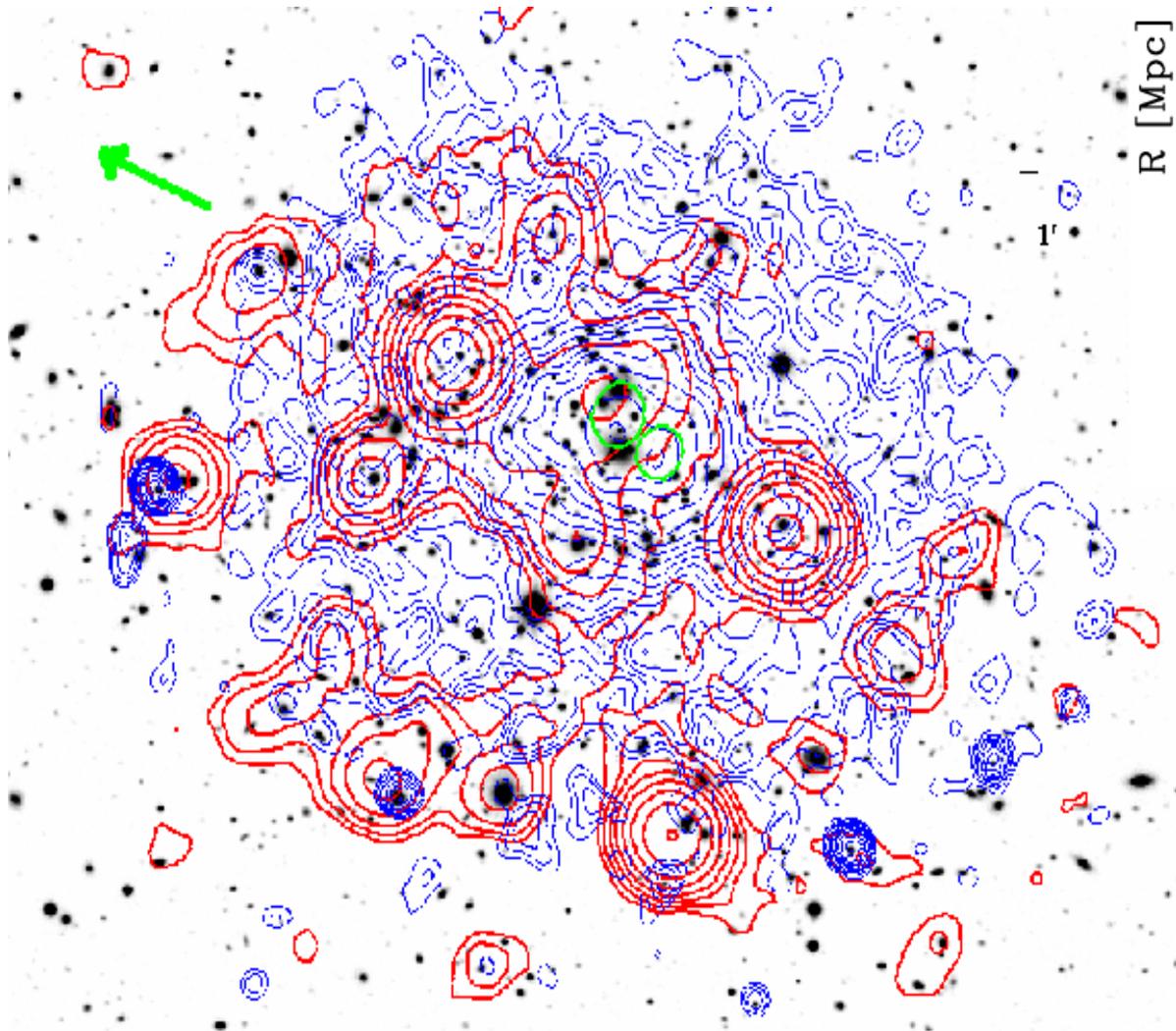
(Boschin et al. 06)



A773, $z \sim 0.22$ (Barrena et al. 07)

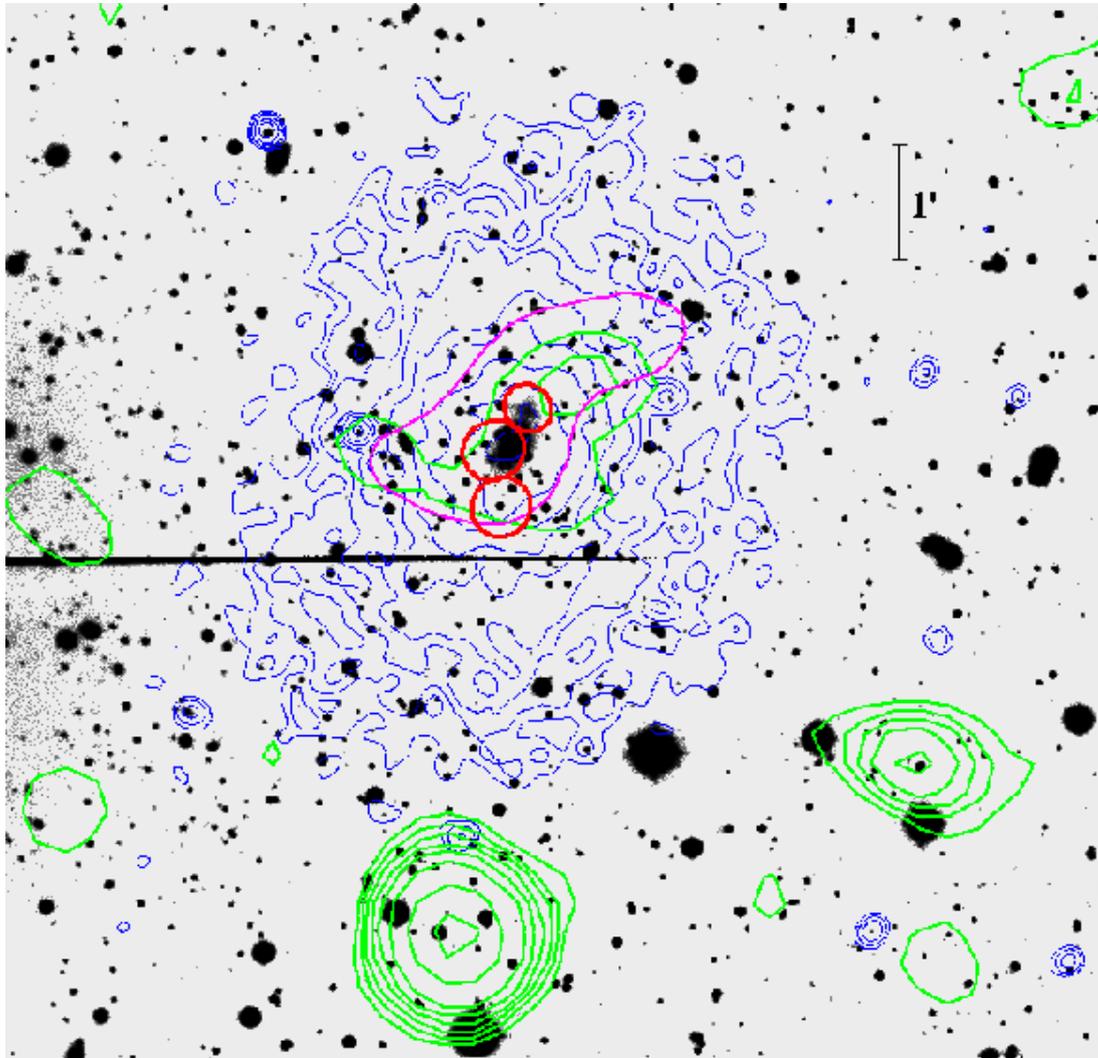
Radio halo

LOS merger between two clumps
with $\Delta V \sim 2300$ km/s, 2 BCGs.



A697, radio halo (MG et al. 06)

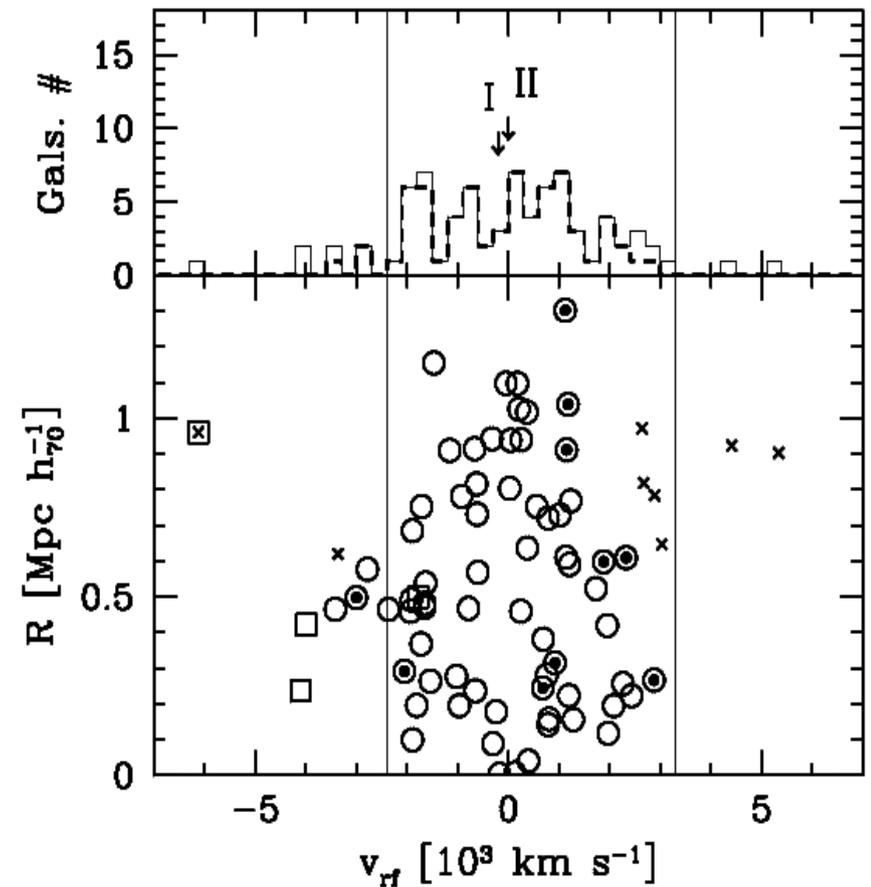
Cluster merger, but in
an advanced phase ? 2 close BCGs!



Radio_optical
morphological similarity.

Substructured:

3-4 Velocity peaks confirmed
by new data.



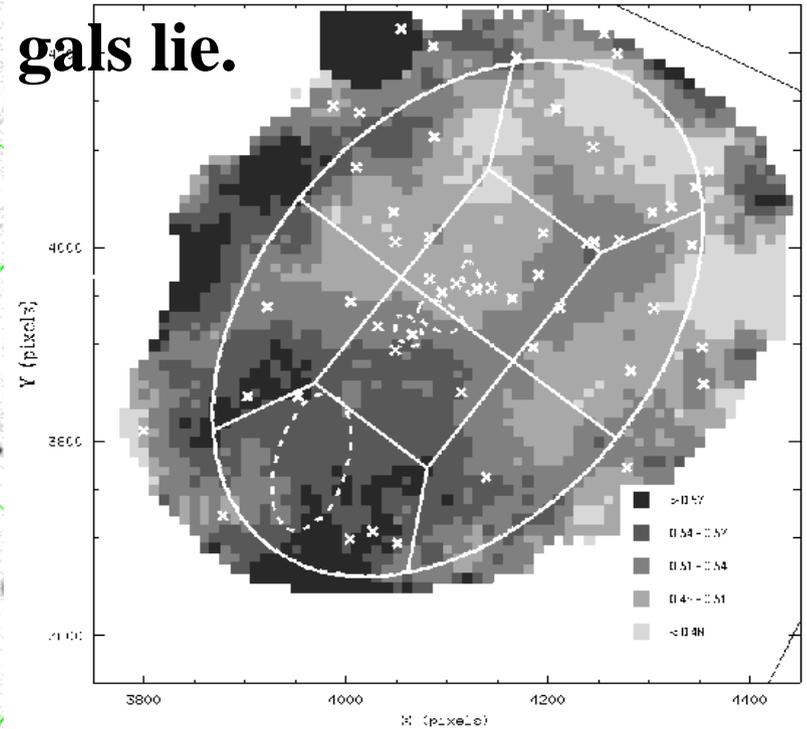
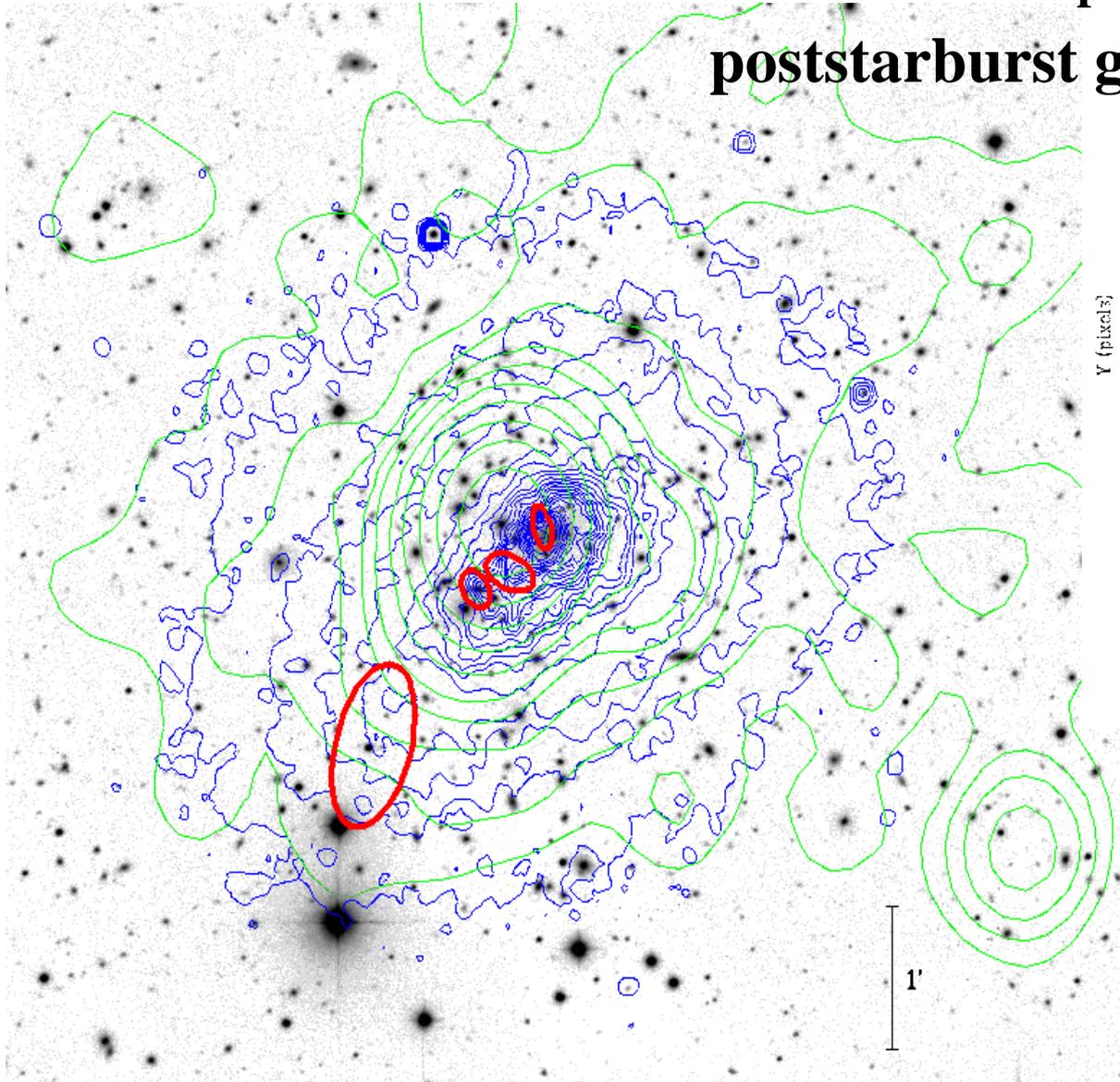
A2219, $z \sim 0.22$

Radio halo

(Boschin et al. 04)

SE-NW cluster and BCG elongation. X-ray elongation.

**Softness ratio map: cold filament where
poststarburst gals lie.**



**Recent discover of
a shock wave
(Million & Allen et al. 09).**

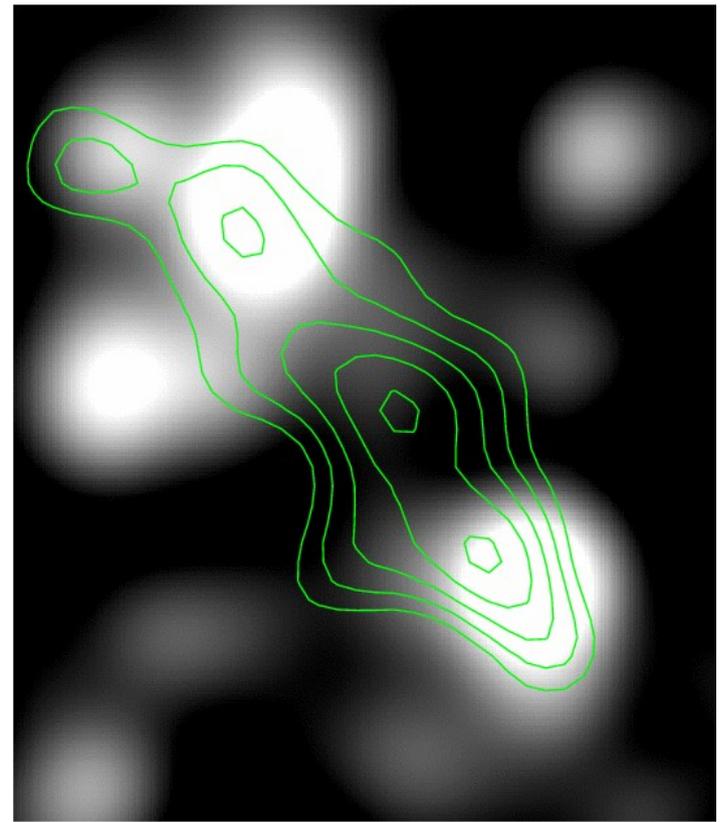
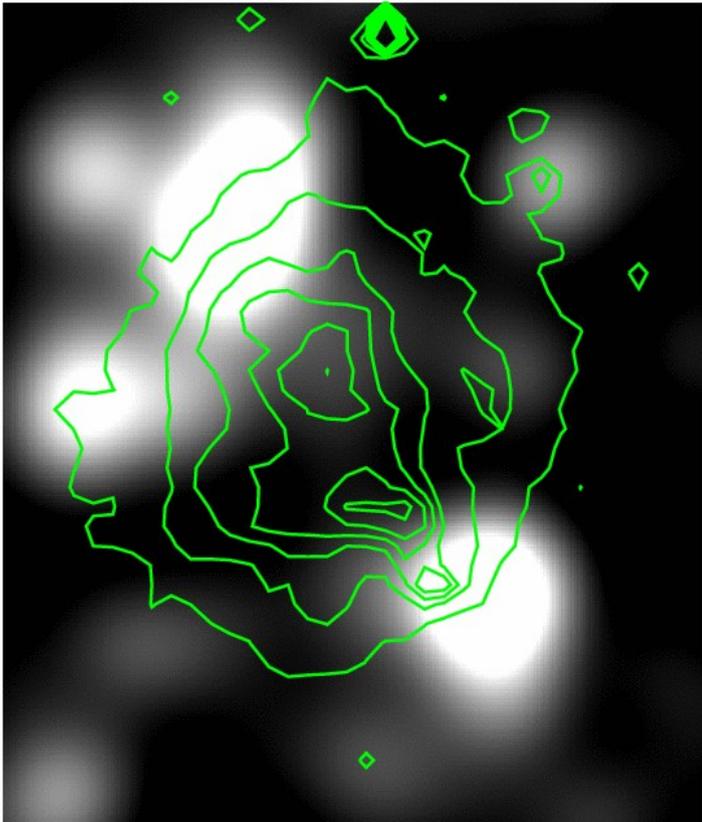
A520 THE CLUSTER WITH A DARK CORE?

A520 shows a shock due to a merger (X-ray data) + radio halo
2D mass distribution from gravitational lensing (Mahdavi et al. 2007).

Mass does not perfectly coincide with gal. distribution!
A problem for current CDM paradigm?

Red light distribution + X-ray contours

+ Mass(~DM) contours



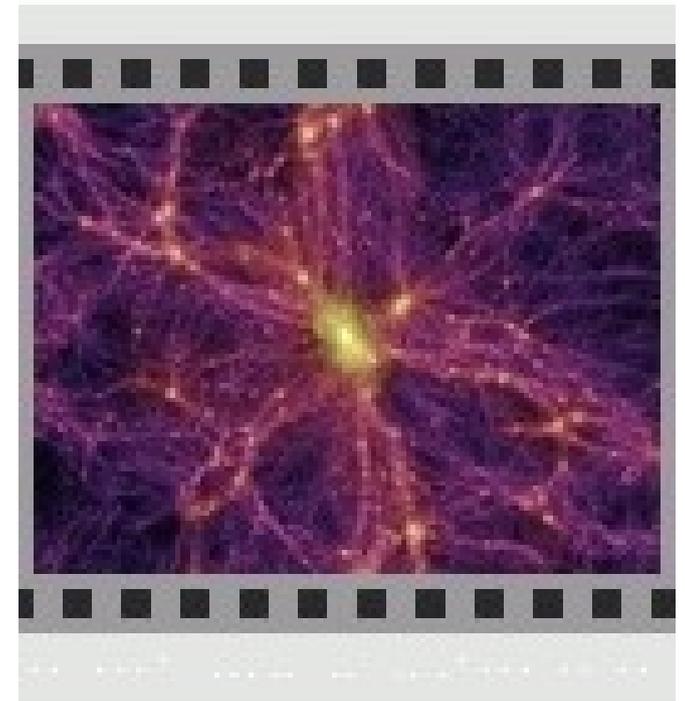
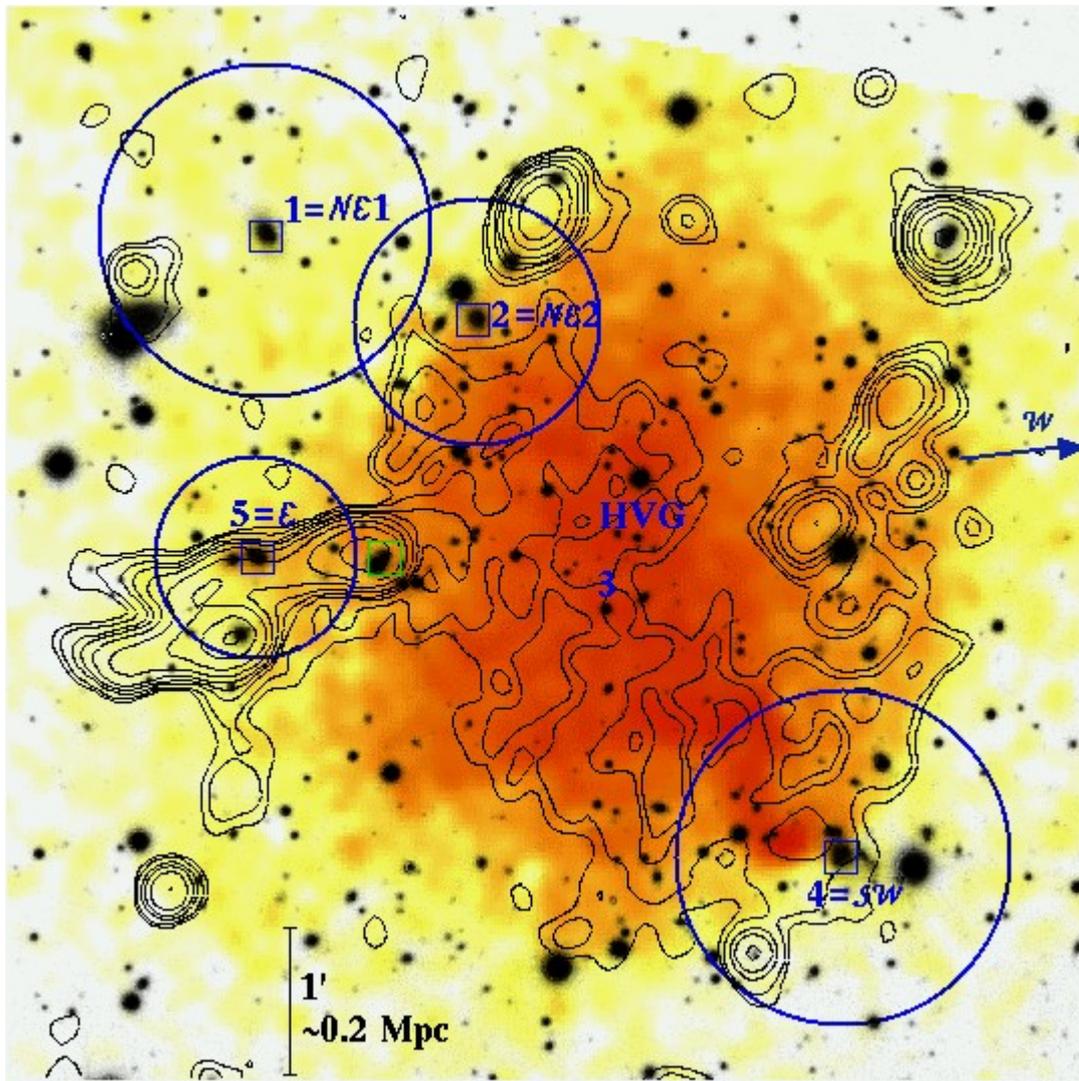
A520 radio halo (167 gals MG, Barrena, Boschin & Ellingson 2008)

A520 at the crossing of 3 LSS filaments:

1. Main system: two main clumps NE-SW with los $\Delta V=1100$ km/s;
2. A small clump at E + premerging clump at W;
3. 1-2 High Velocity Groups projected in the center:

the projection of a LOS filament is the likely cause of the DM core

(suggested by GL analysis of Mahdavi et al. 07).



Millennium simulations

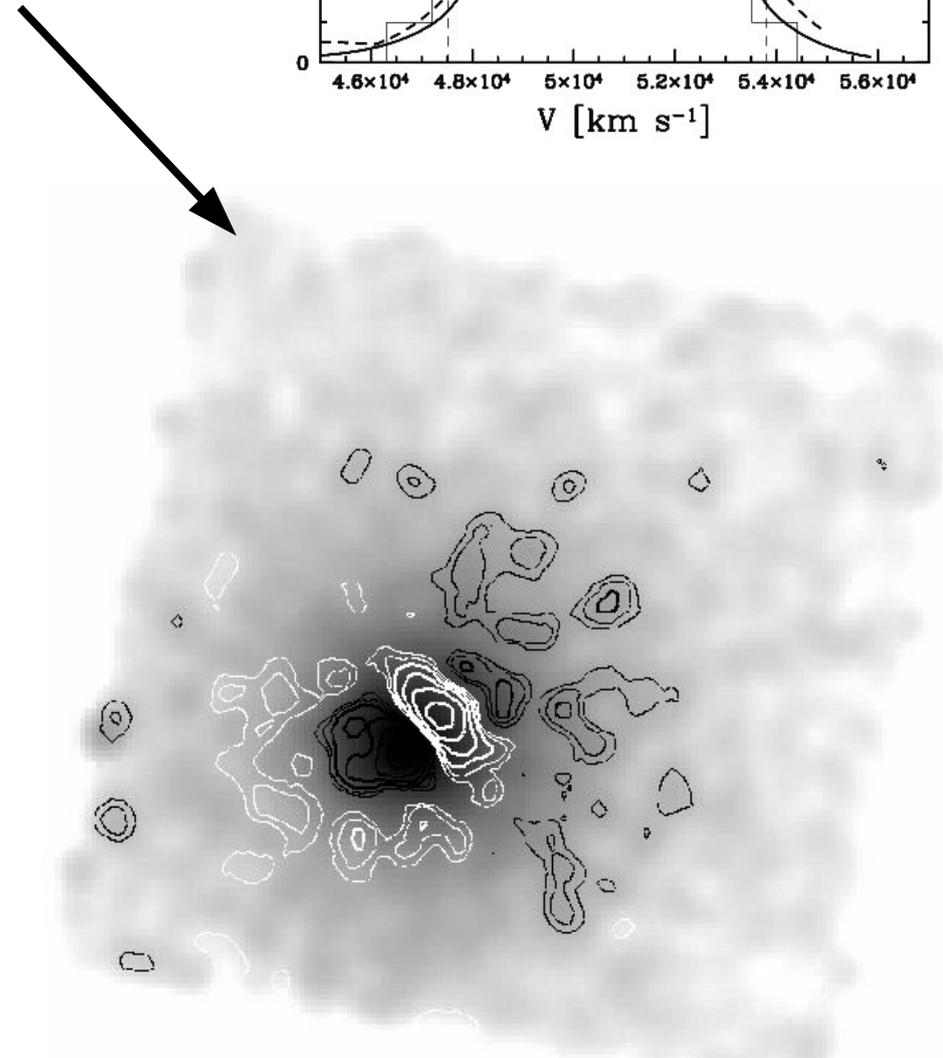
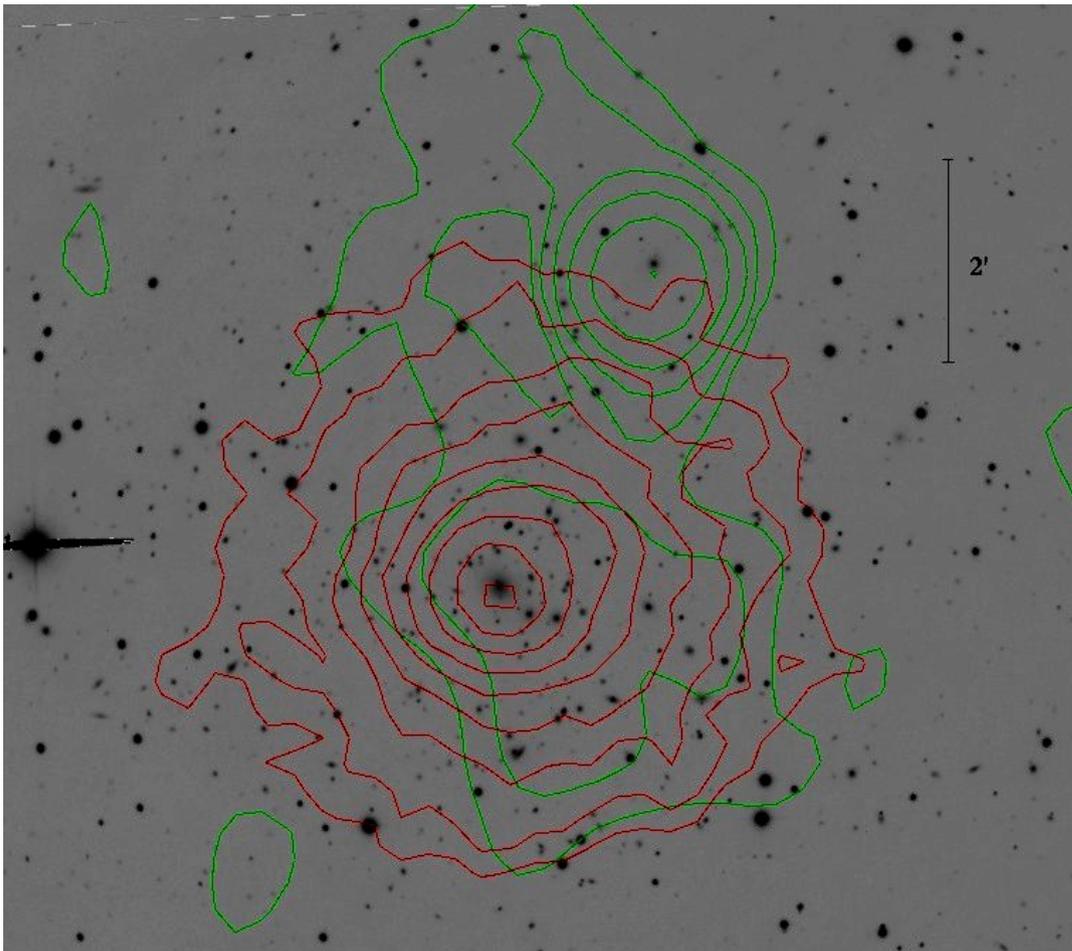
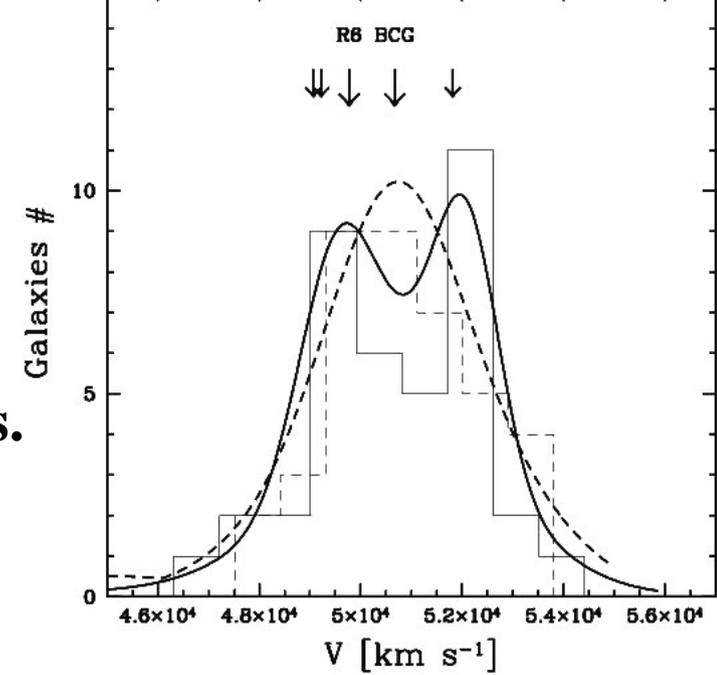
A2294 with radio halo (MG et al. 10)

It seems very regular in X-ray!

MG et al. 2010, A&A in press.

Two peaks in the V-distribution of luminous galaxies.

It shows 2 clumps in the residual image.



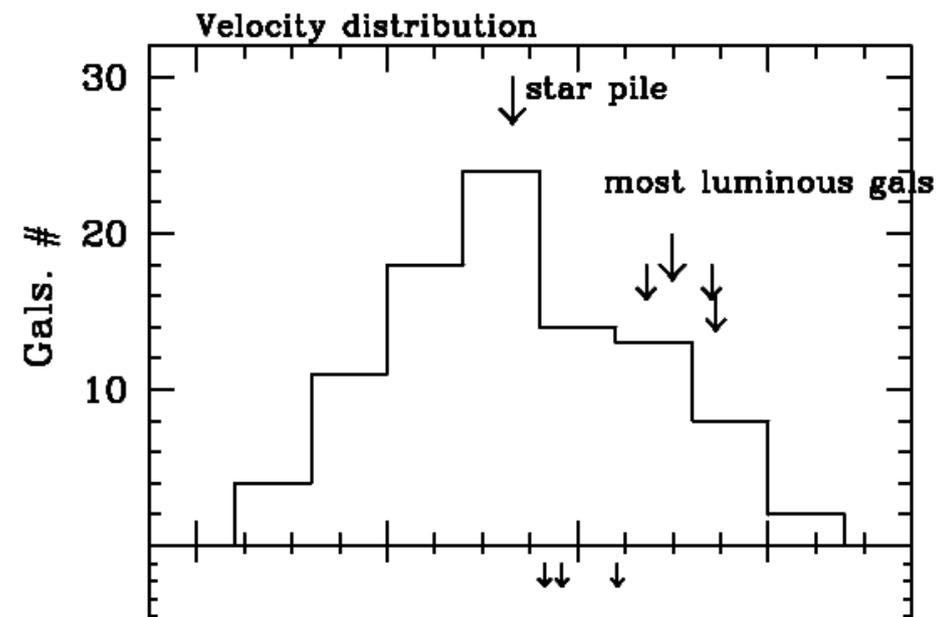
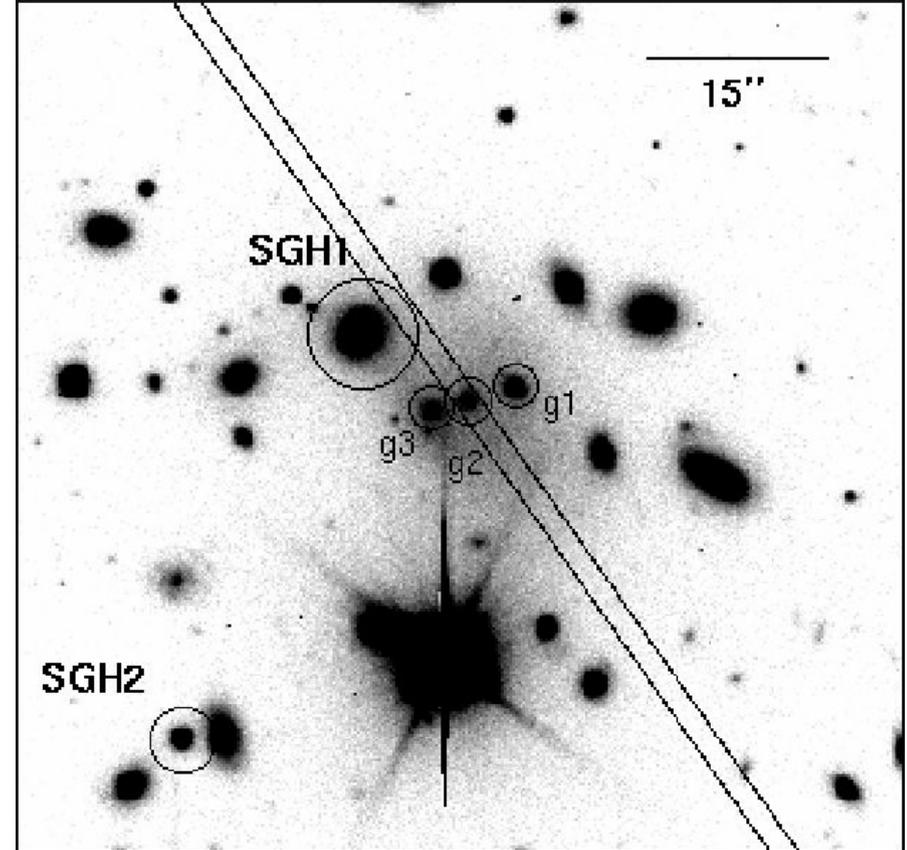
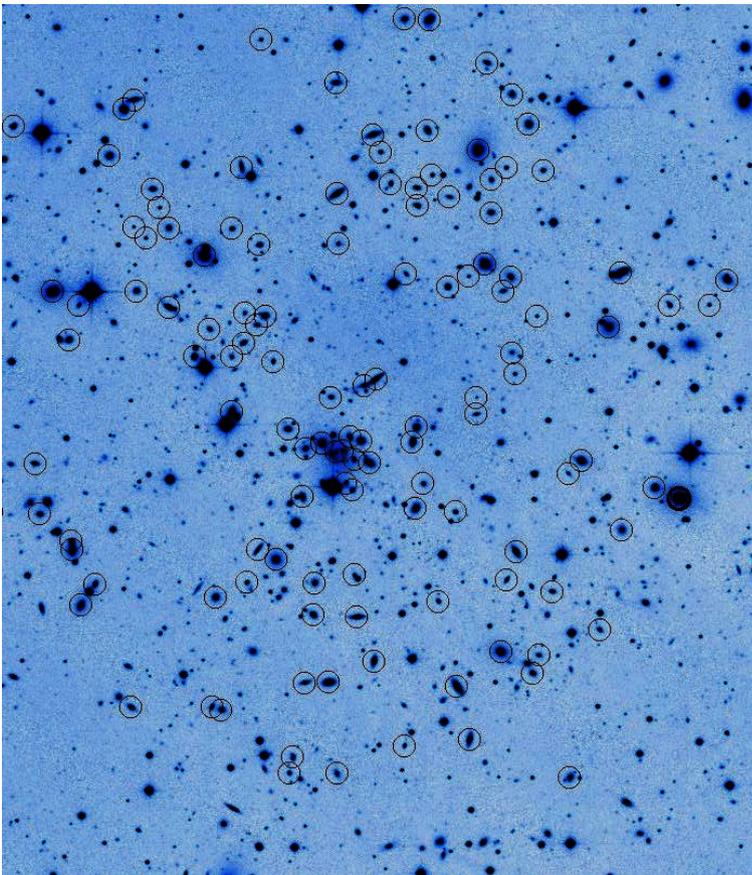
A545 WITH A “STAR PILE” INSTEAD OF A BCG

Radio halo, $z=0.15$.

(Red) star pile (Strouble 88, Salinas et al. 08).

Three 2D subclusters, star pile lies at the center of the main one (=X-ray center) and is at rest in the cluster (in progress).

XMM data (De Grandi analysis in progress).

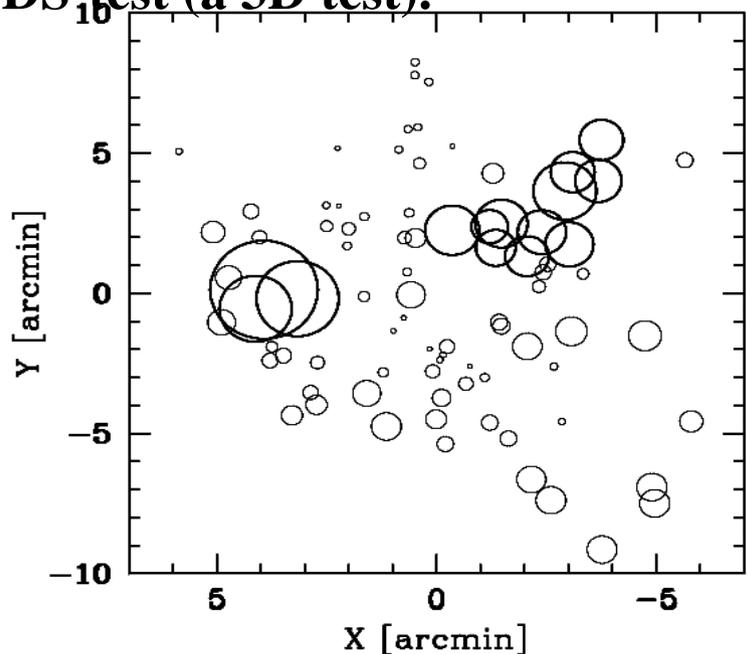


A115, $z \sim 0.19$ Radio relic?

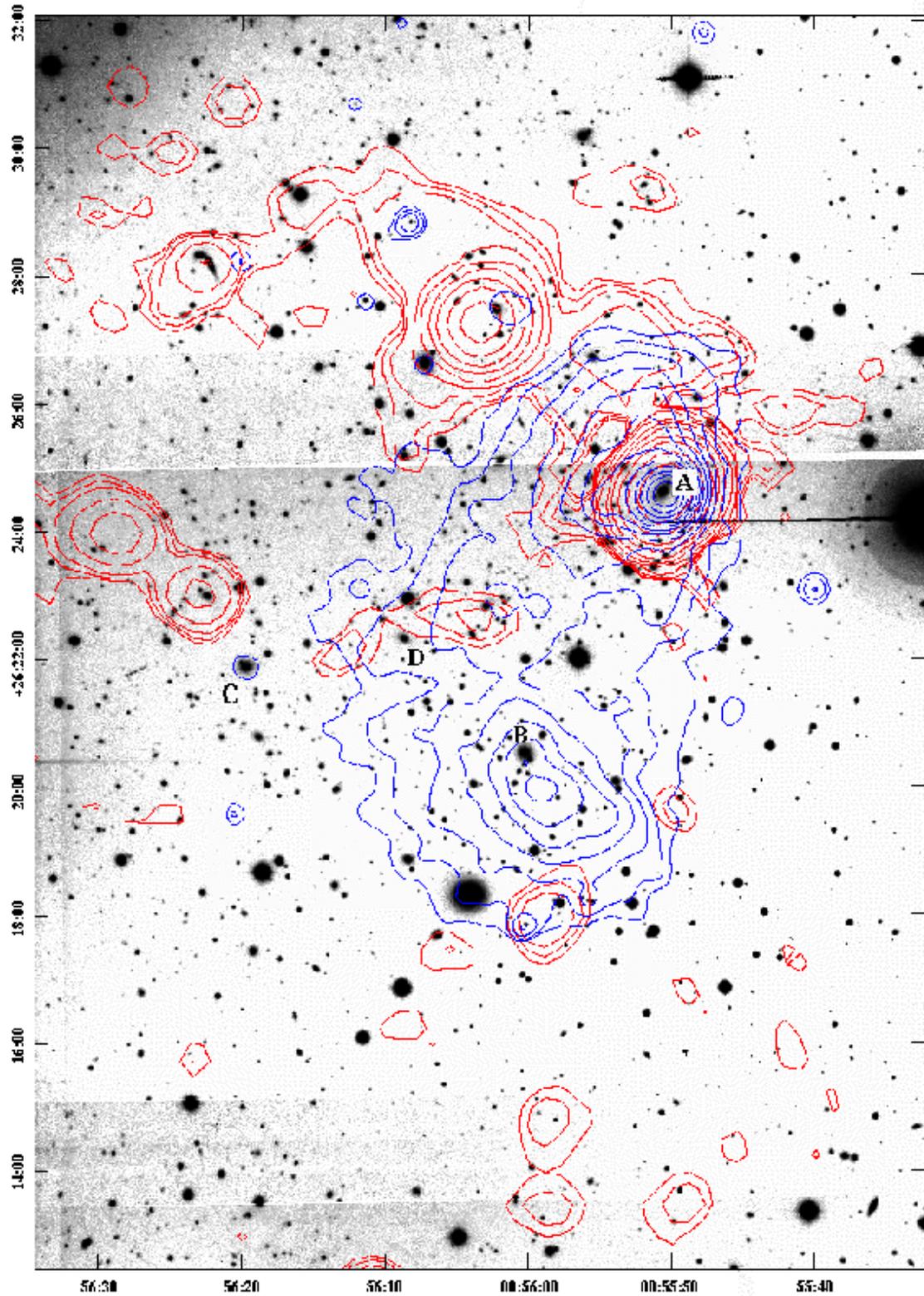
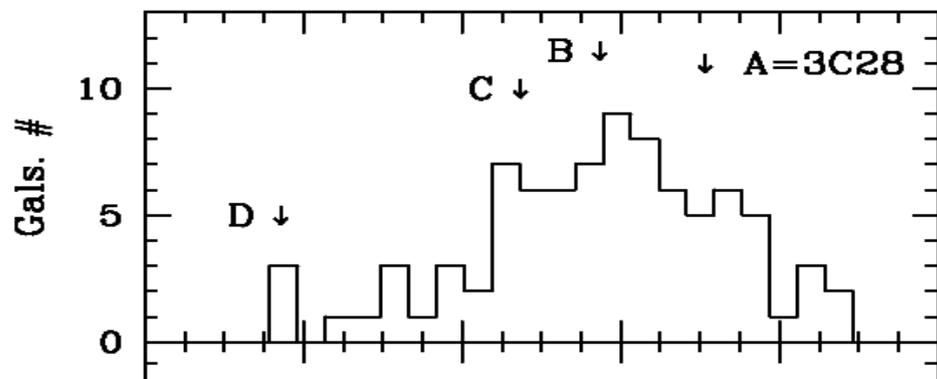
2 main subclusters with 2 main BCGs.

LIKELY A PRE-MERGER!!!

DS₁₆ test (a 3D test).



Velocity Distribution.



POOR CLUSTER A610, $z \sim 0.10$

σ_v about 500 kms-1

Likely 2 clumps in $\log V$

