

# RADIO HALOS AND RELICS IN GALAXY CLUSTERS

(see book of Feretti, Gioia, Giovannini 2002 )

**EXTENDED** diffuse radio emission in clusters (halos and relics):  
size up to about **~1Mpc**, observed at e.g. 300,800, 1400 MHz.

Radio power of  $10^{24-25}$  W/Hz at 1.4GHz,

Steep radio spectrum due to **synchrotron emission** from

**relativistic electrons** (Lorentz factor likely  $10^4$ ) and

energy density of  $10^{14-13}$  erg/cm<sup>3</sup> (origin: radiogals, QSO, SF gals, merger shocks)  
in a **magnetic field** about 0.1-1 microG.

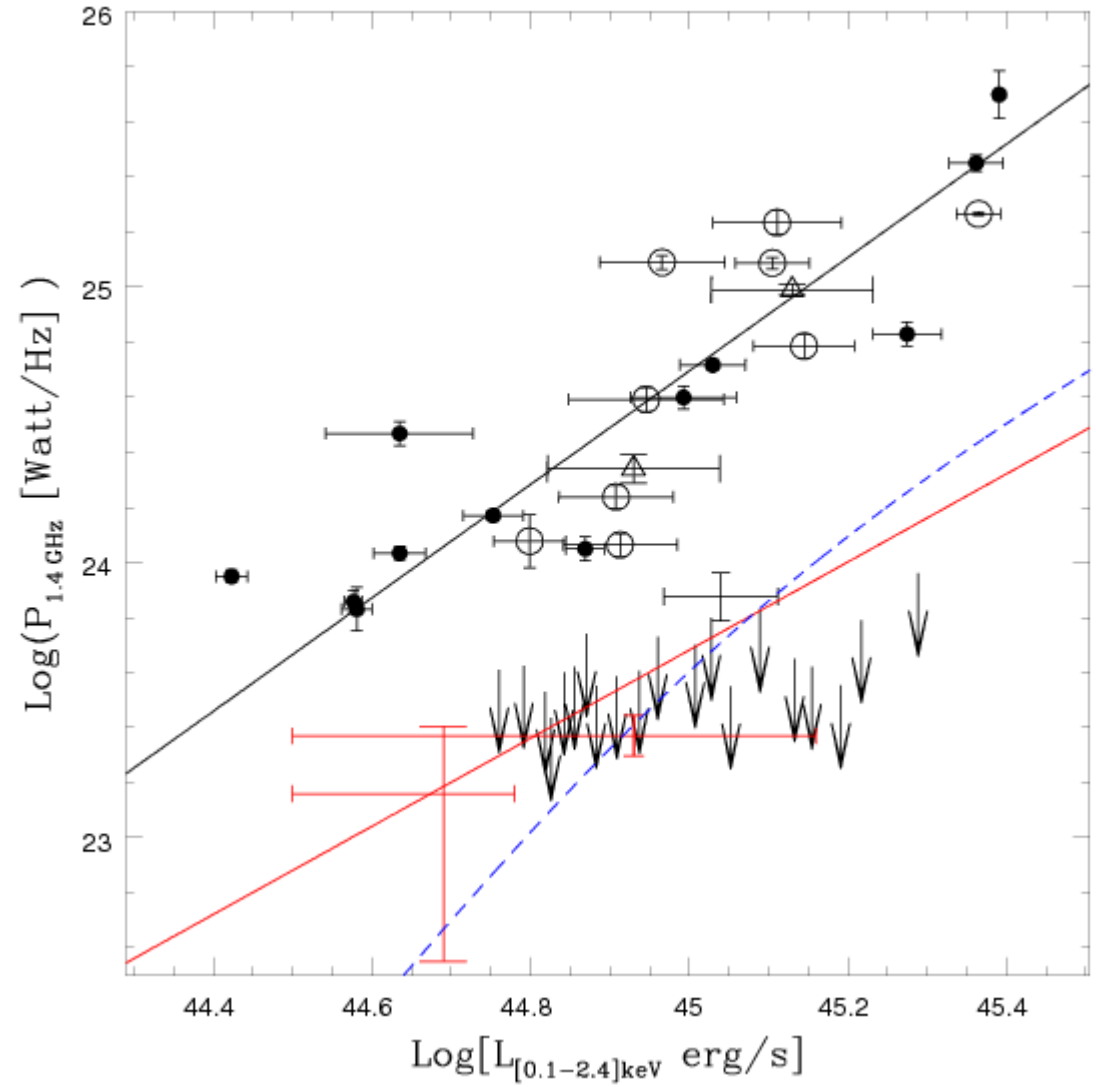
Relics are polarized sources.

**RARE PHENOMENA:** about 50 clusters up to  $z=0.3$

**Correlations with X-ray prop.:** RadioPower –Lx, RP-Tx, Size-Tx, Size-Lx.

Venturi et al. 2008 A&A

# RADIO HALO BIMODALITY



# ORIGIN OF HALOS AND RELICS: CONNECTION WITH CLUSTER MERGERS the most energetic events of the Universe

**Problem:** lifetime of relativistic electrons  $10^8$ yr+Alfven speed ( $\sim 100$ km/s)  
**electrons do not cover a 1Mpc scale!!!!**

**Primary electron reacceleration model:**

continuous in-situ reacceleration of the radiating electrons

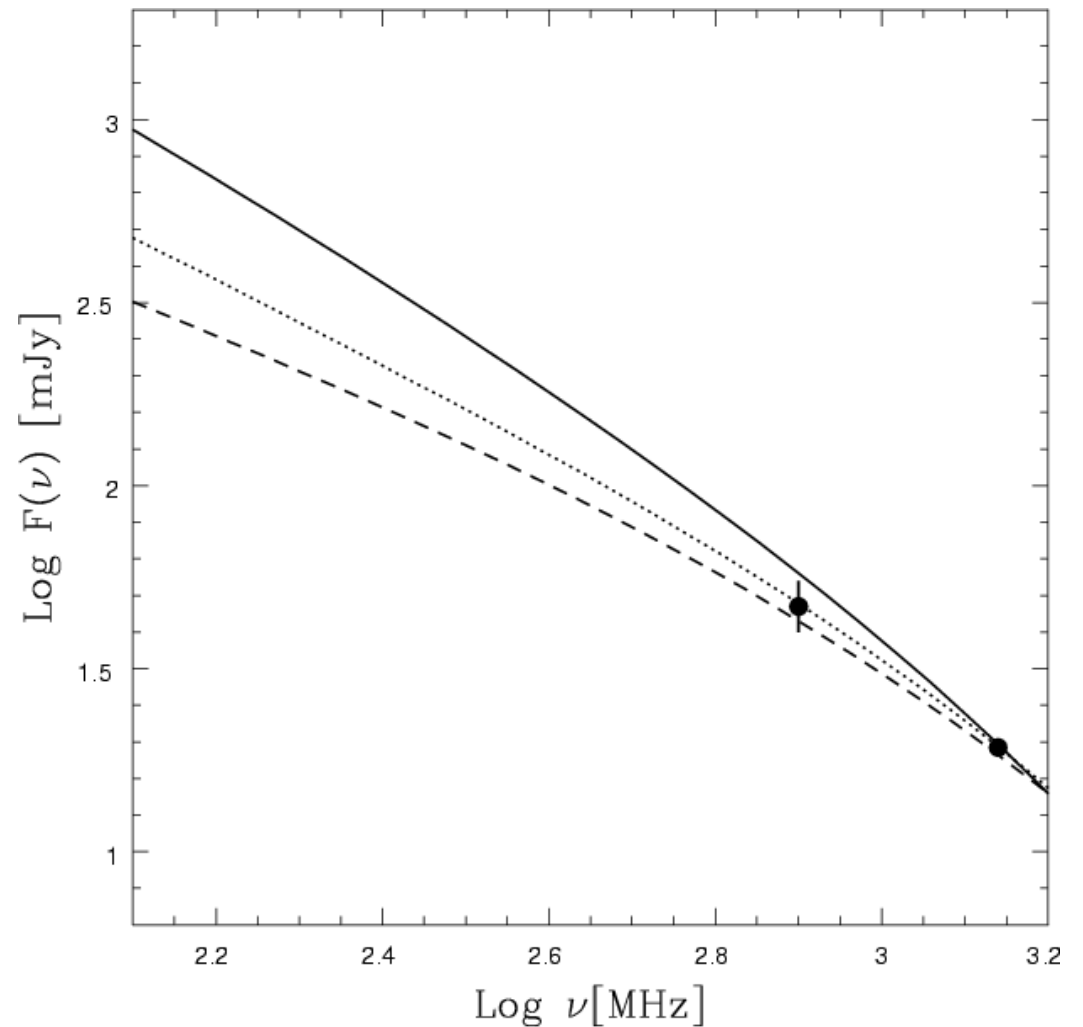
**CLUSTER MERGERS ipothesis (Tribble 1993)**

**energetics:** gravitational binding energies of  $10^{64}$  erg,  
 $3 \times 10^{63}$  erg dissipated by hydrodynamical shocks.

**Frequency:** transient phenomena

**Mergers: shock waves(RR)+turbulence(RH)**

Venturi et al. 2003 A&A



Synchrotron halo spectra from a reaccelerated electron population are superimposed on the radio data (filled circles) for A3562 at 1.4 GHz and 843 MHz (this paper). The models are performed (assuming  $G$ ) to match the 1.4 GHz flux and to reproduce the observed halo radial extension. **The solid line corresponds to a reacceleration time of 0.1 Gyr, the dashed line to 0.4 Gyr and the dotted line to an intermediate value.**

# DARC program

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

## Dynamical Analysis of Radio Clusters

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

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



**To date:**

**DATA FOR >20 CLUSTERS**

SPECTRA at the **TNG** +WHT

IMAGING at the INT

MULTIWALENGTH ANALYSIS

+**Chandra X-ray Data Archive**

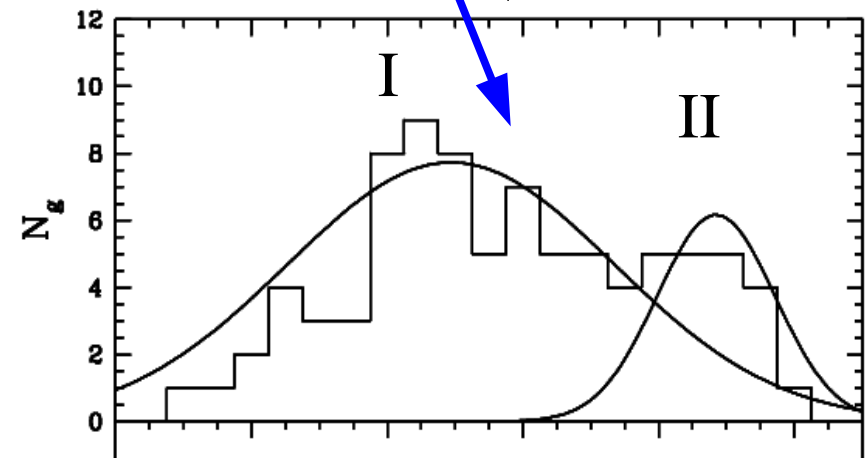
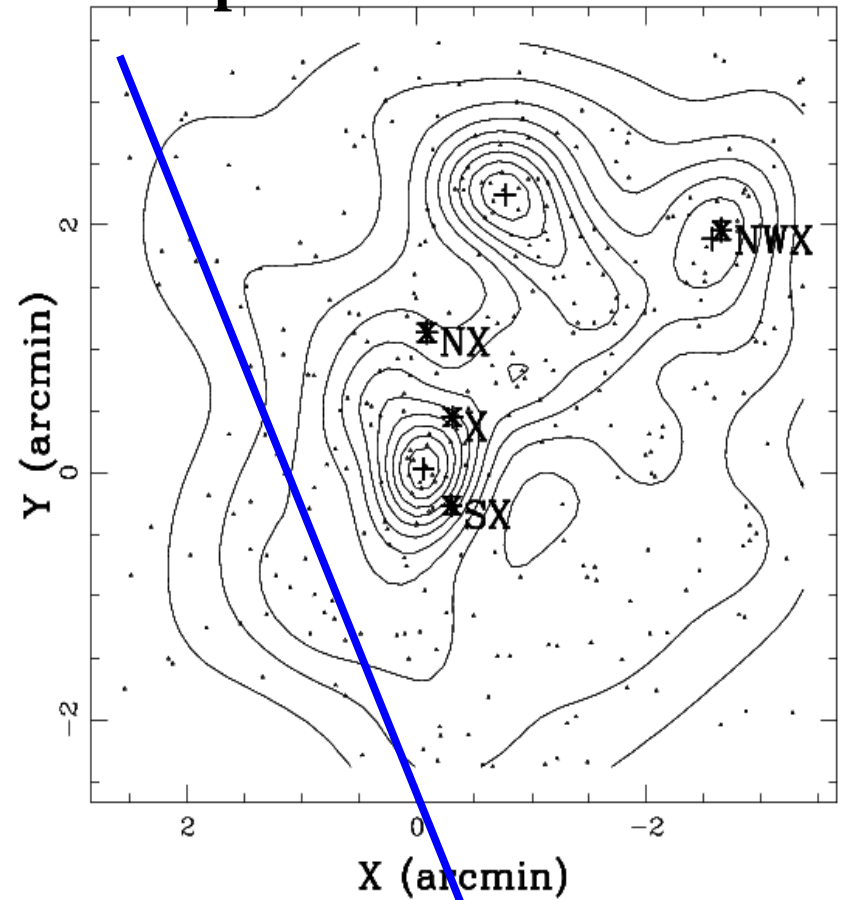
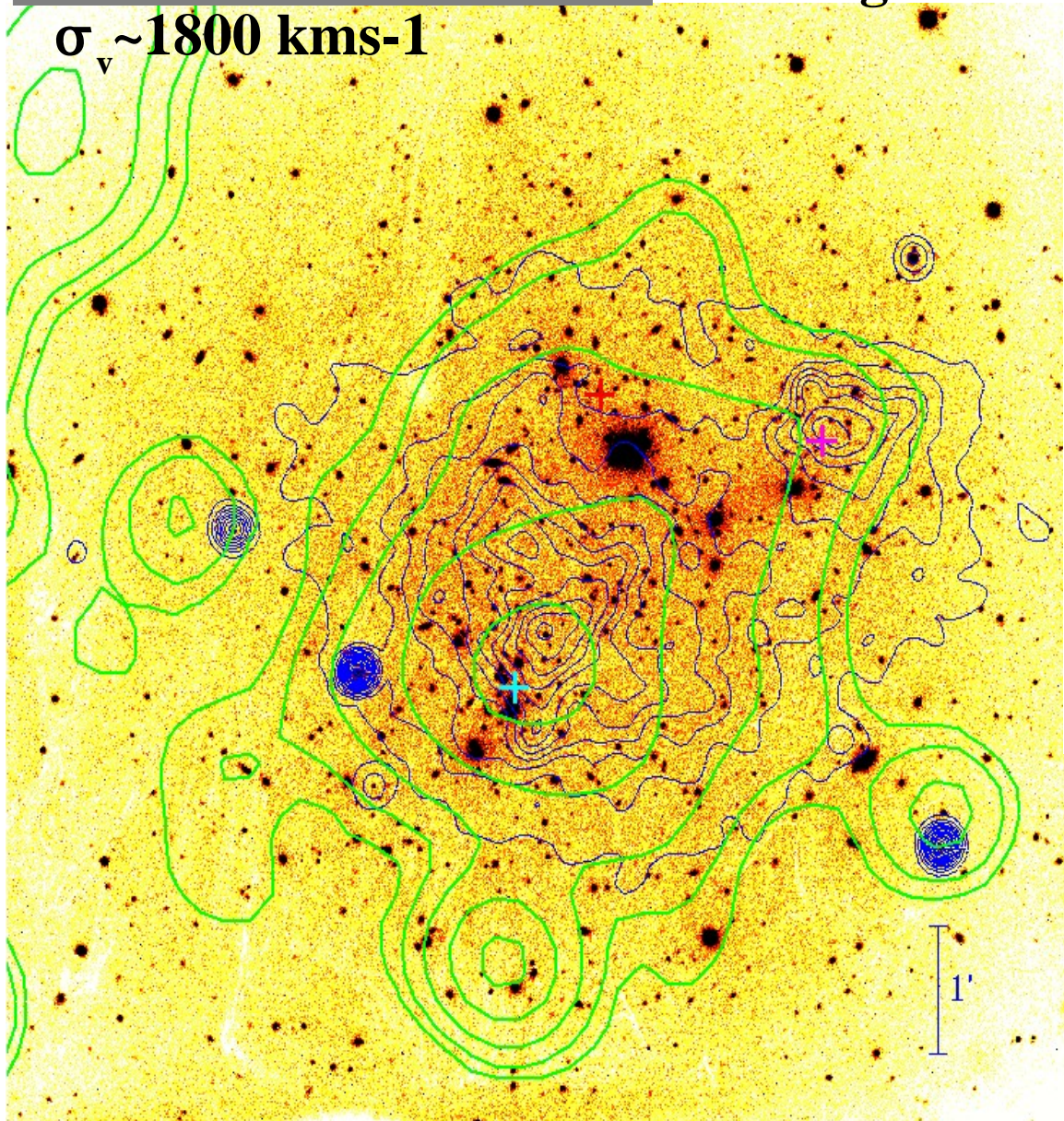
+use of X-ray, GL, Radio results

**A2744,  $z \sim 0.31$**

**Radio halo**

(Boschin, MG, Spolaor, and Barrena AA, 2006)  
ongoing merger of **2 clumps** with  $V \sim 3000$  km/s  
**2 DOM gals**

$\sigma_v \sim 1800$  kms-1



# A1240, $z \sim 0.19$ Two Symmetric Radio relics

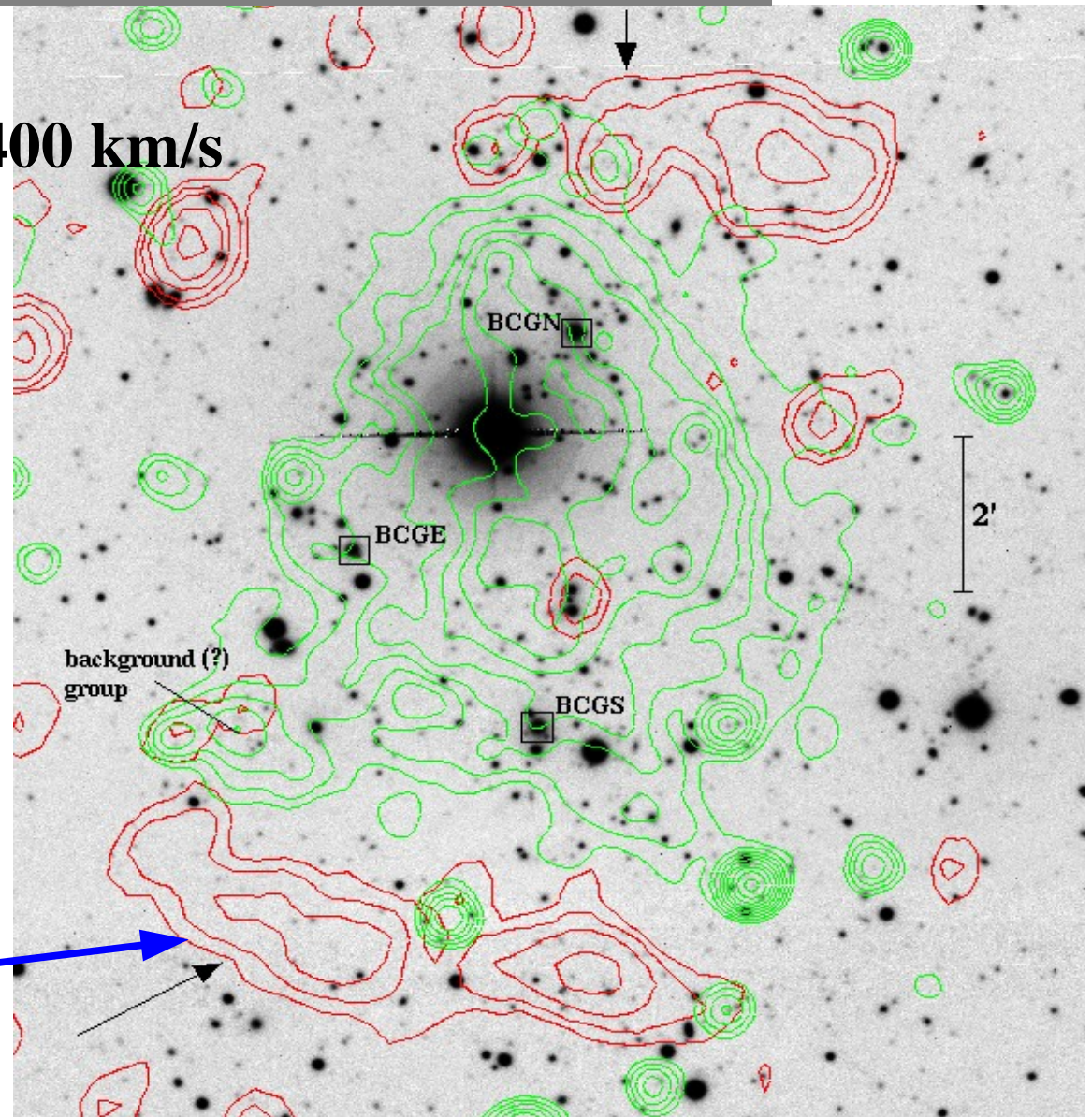
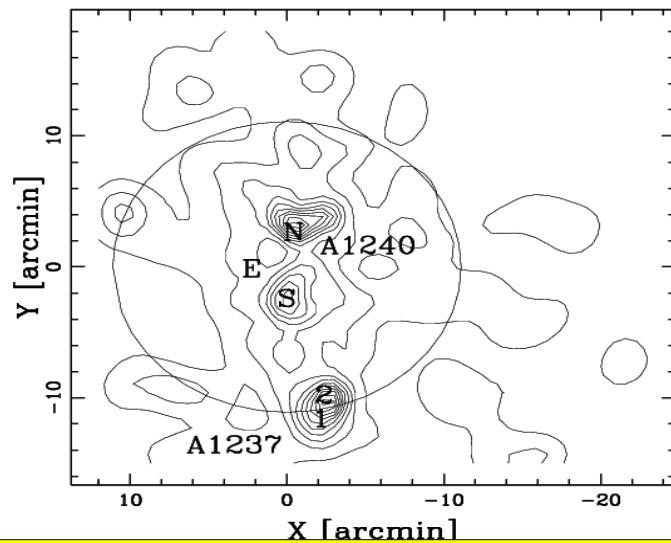
Barrena, Boschin, MG and Dasi 2009

$\sigma_v \sim 900$  kms-1,  $T_x = 6$  keV

2 clumps with DOMs,  $\text{los } V \sim 400$  km/s

merging in the plane of sky

with  $V \sim 2000$  km/s



We strongly support the **outgoing merger shocks** model to explain the relics. Shock precedes the subcluster, It is not slowed down by gravity.

# THE CASE OF A520 at $z \sim 0.2$

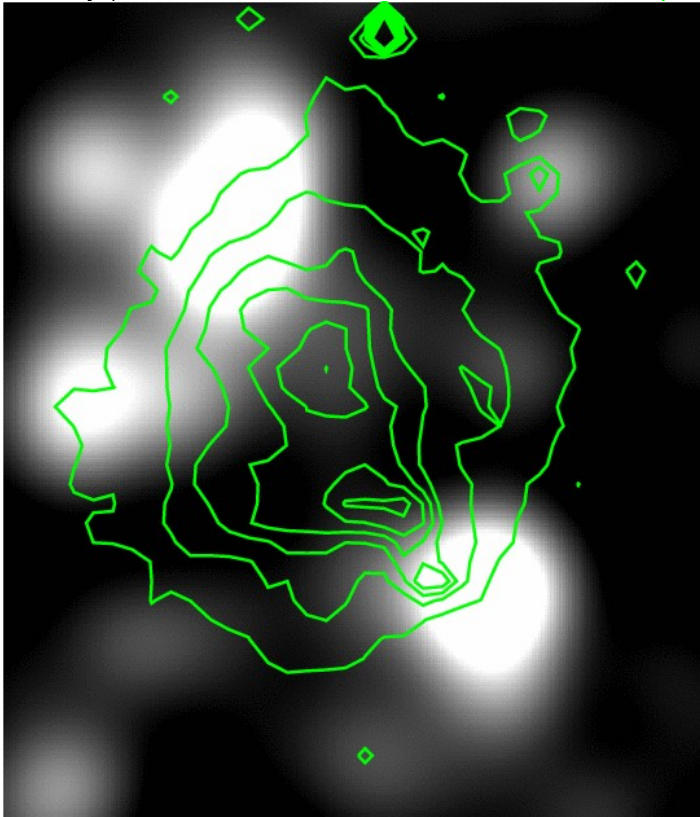
A520 shows a shock due to a merger (X-ray data) + radio halo  
2D mass distribution from gravitational lensing (Mahdavi et al. 2007,  
but see Okabe & Umetsu 2008)

**Mass does not perfectly coincide with gal. distribution:**

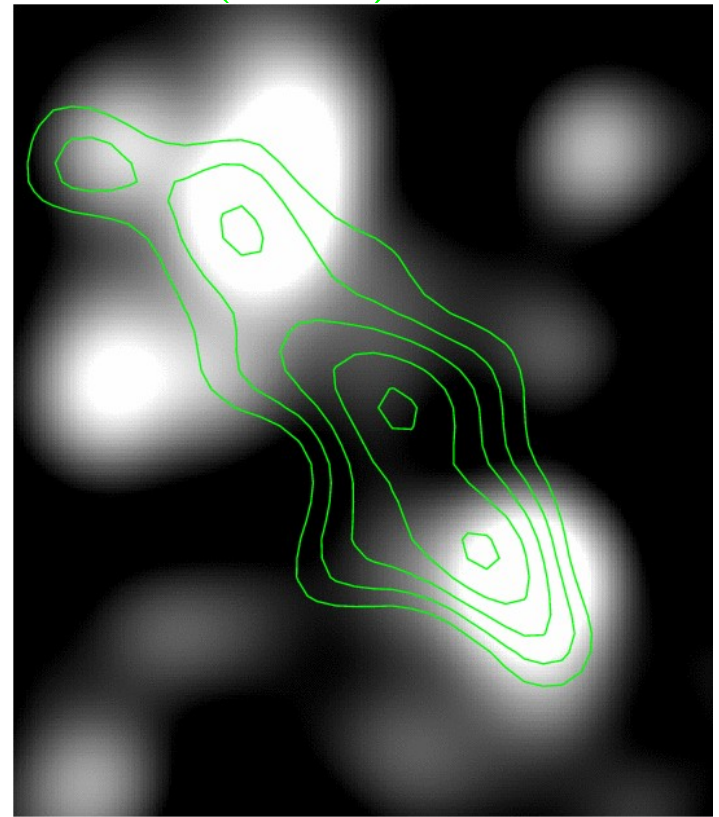
**a massive DM core!** But both DM and gals are collisionless components...

**A problem for current CDM paradigm?**

Red light distribution + X-ray contours



+ Mass (~DM) contours



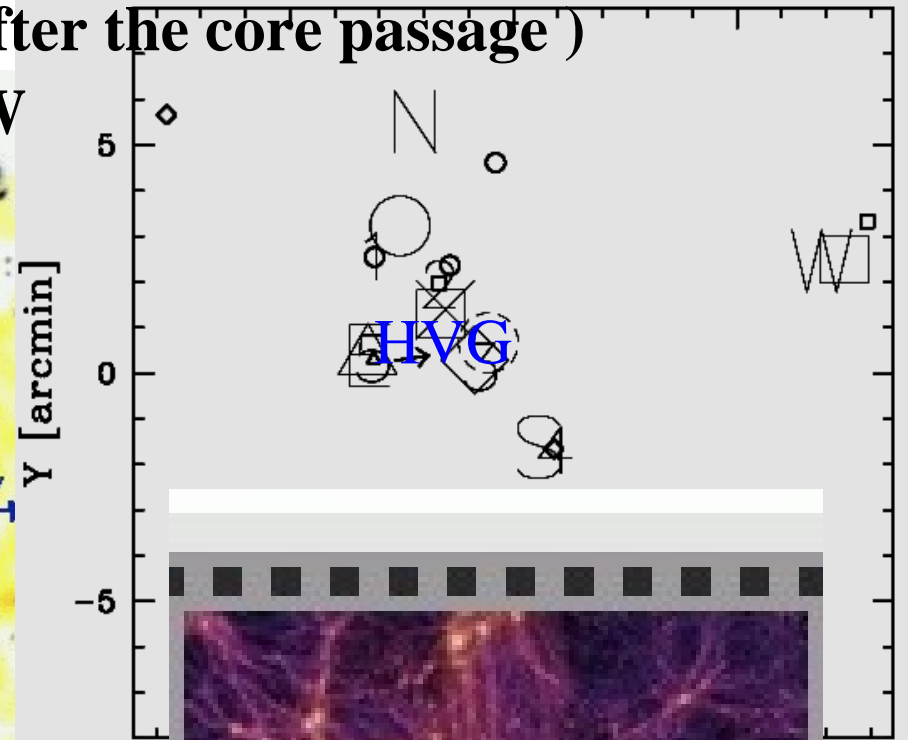
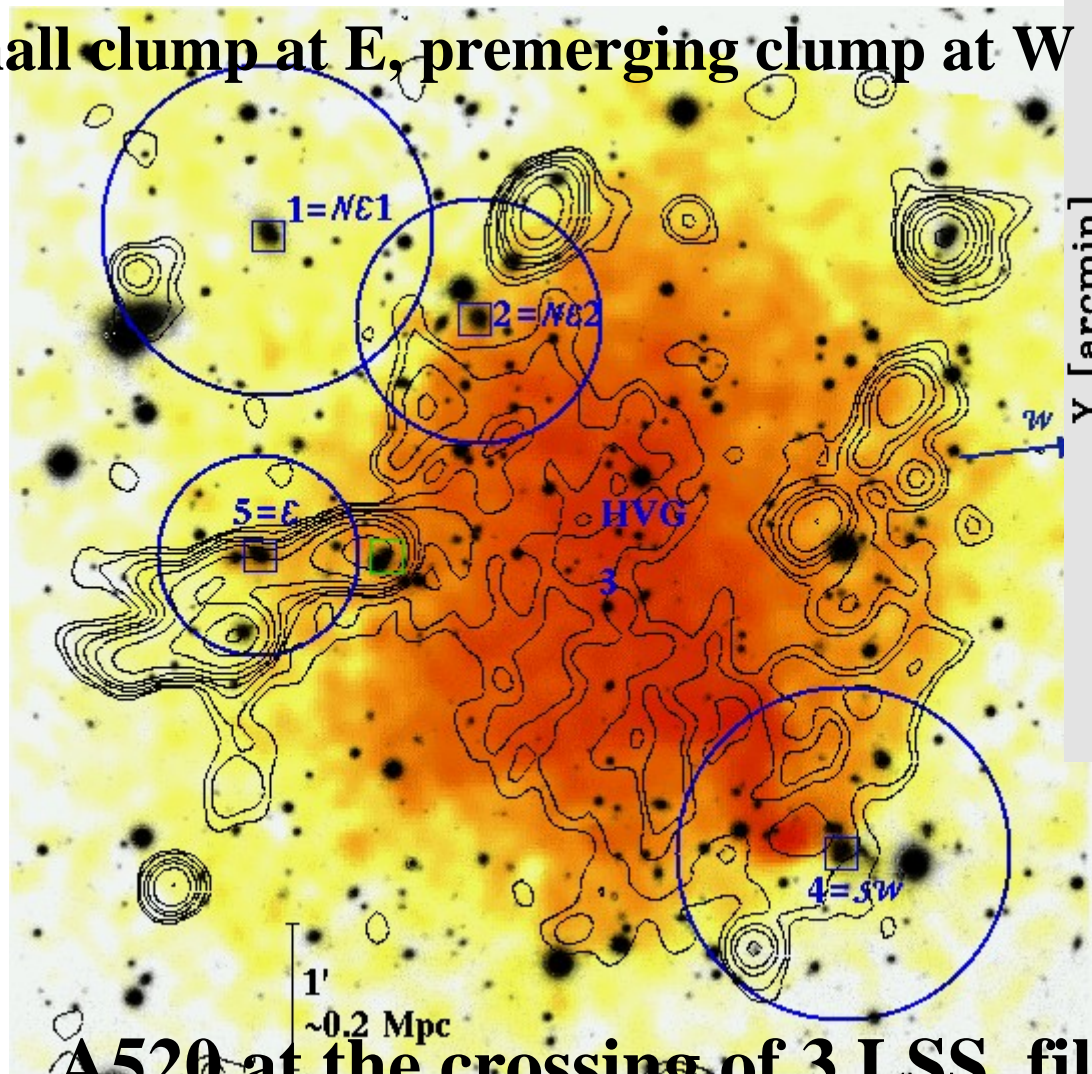


# A520 radio halo (167 gals MG, Barrena, Boschin & Ellingson 2008)

High Velocity Group projected onto the “dark core” position

Main system: two main clumps NE-SW with  $\text{los } V=1100 \text{ km/s}$ ,  
(likely with  $V=2000 \text{ km/s}$ , 0.2-0.3 Gyrs after the core passage)

small clump at E, premerging clump at W



Millennium  
simulations

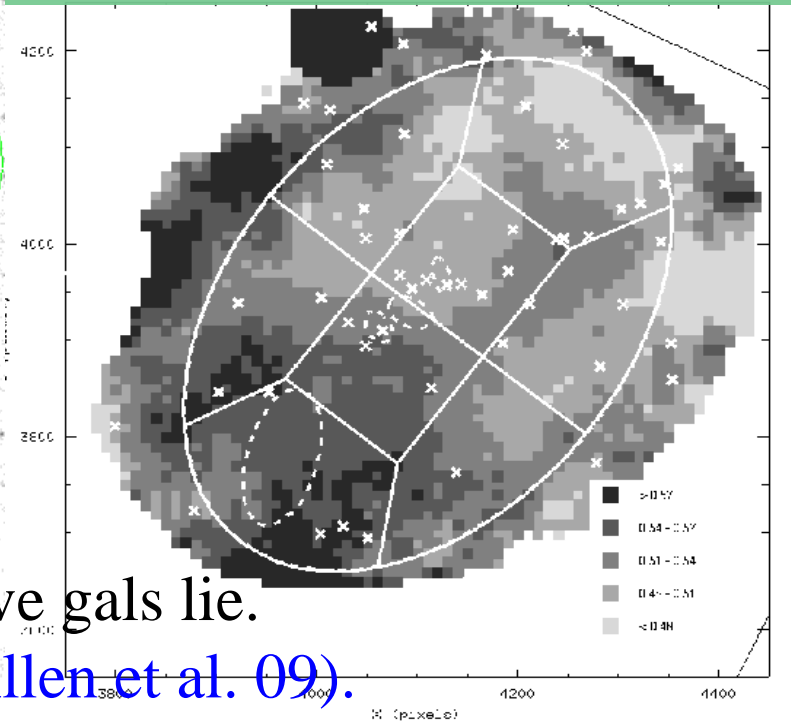
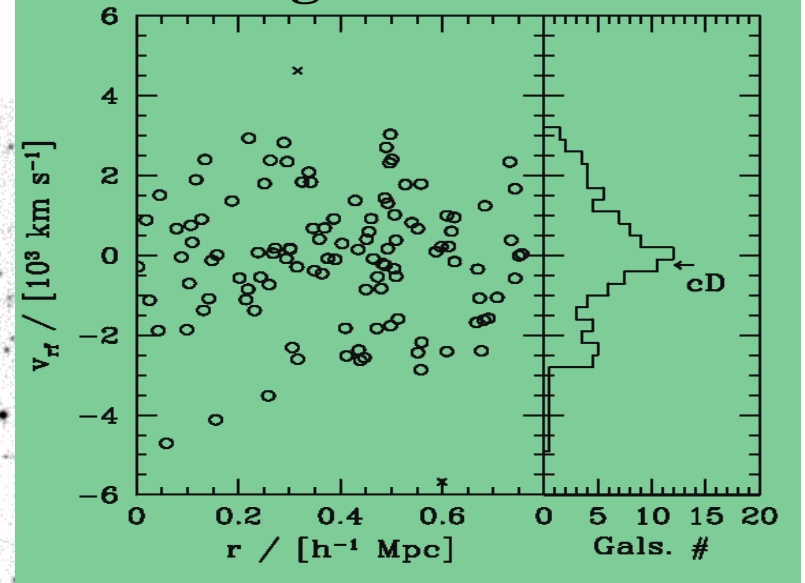
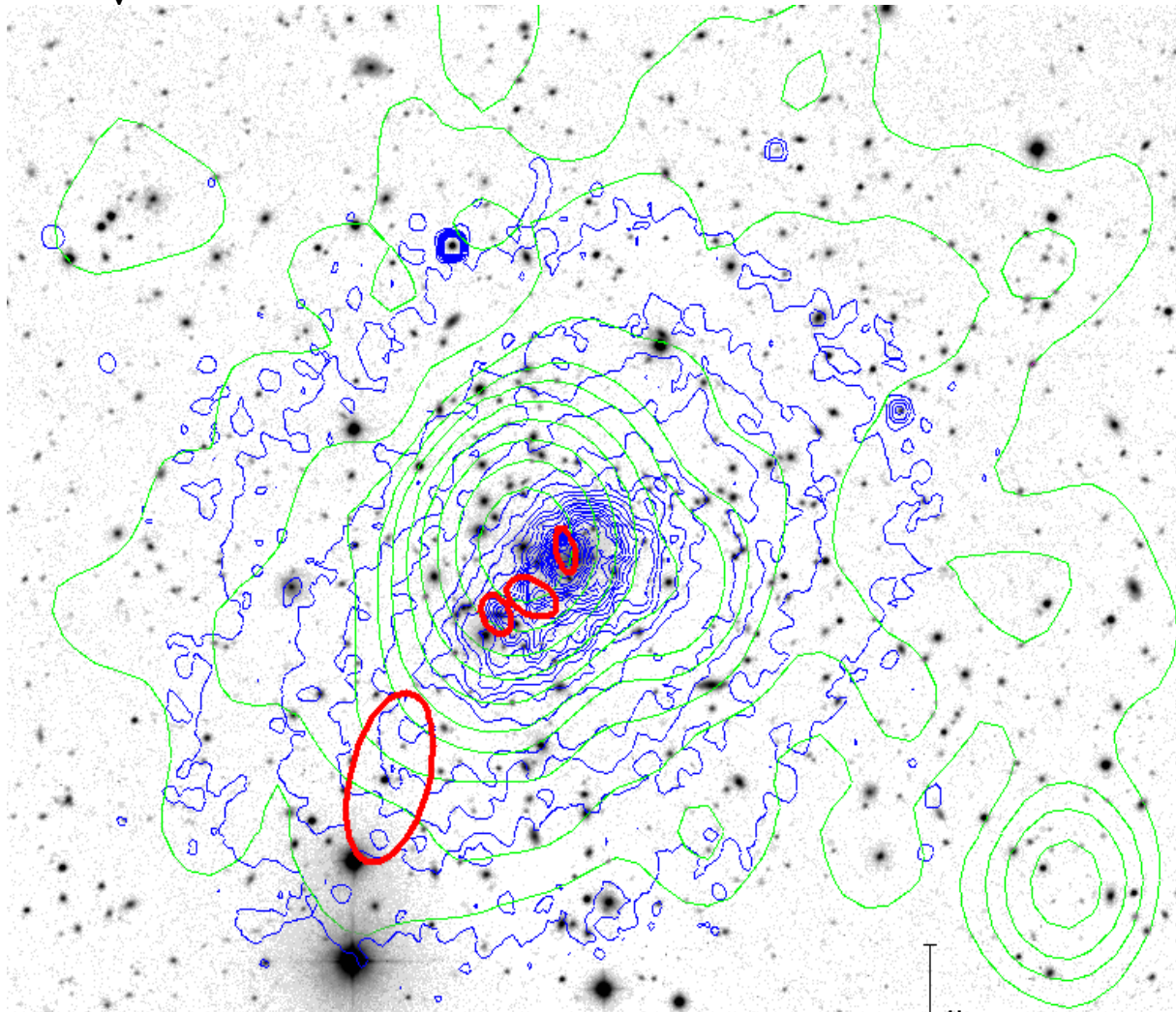
A520 at the crossing of 3 LSS filaments, the projection  
of the LOS filament is the likely cause of the DM core

# A2219, $z \sim 0.22$

## Radio halo

(Boschin, MG, Barrena, et al. 2004, AA, 416, 839)  
TNG/Dolores + CFHT multiobject spectroscopy  
**SE-NW cluster and cD elongation**

$\sigma_v \sim 1400 \text{ kms}^{-1}$



Softness ratio map: cold filament where active gals lie.

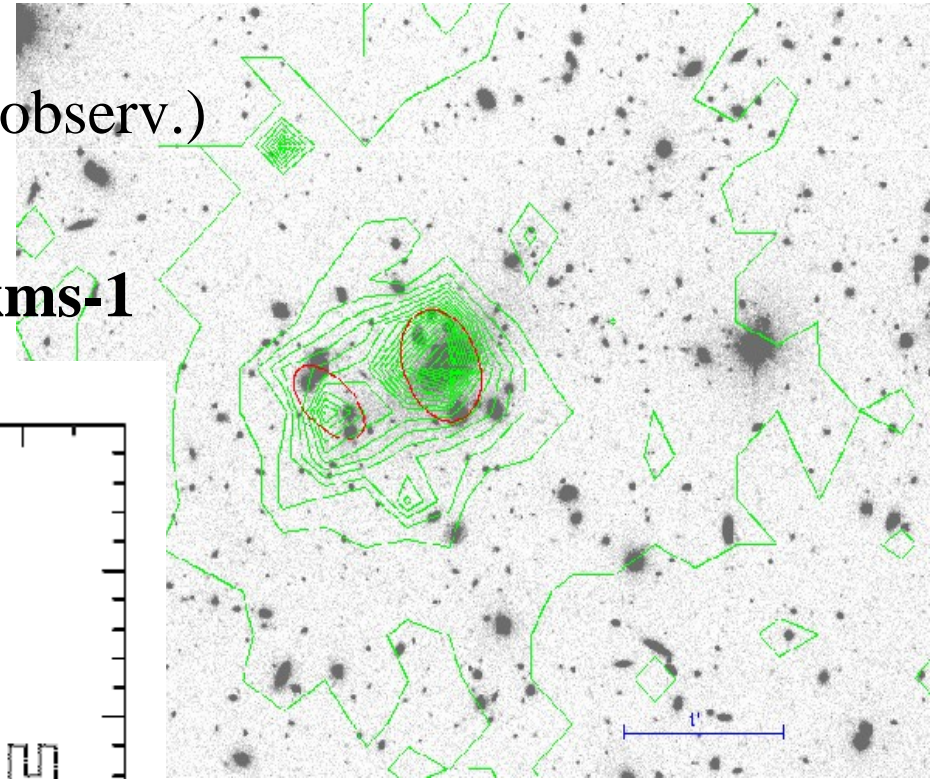
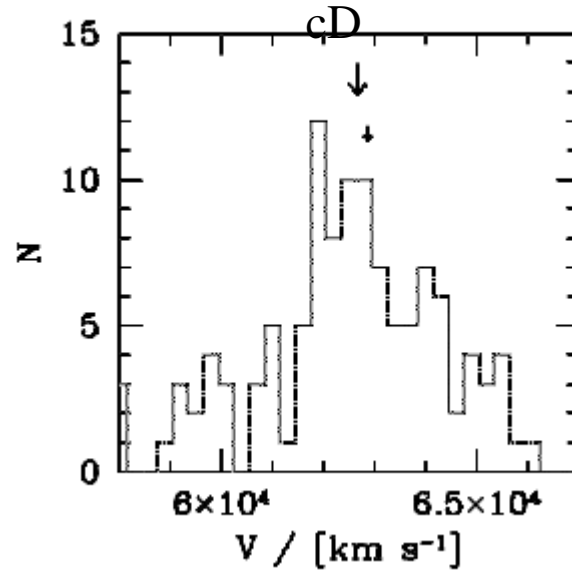
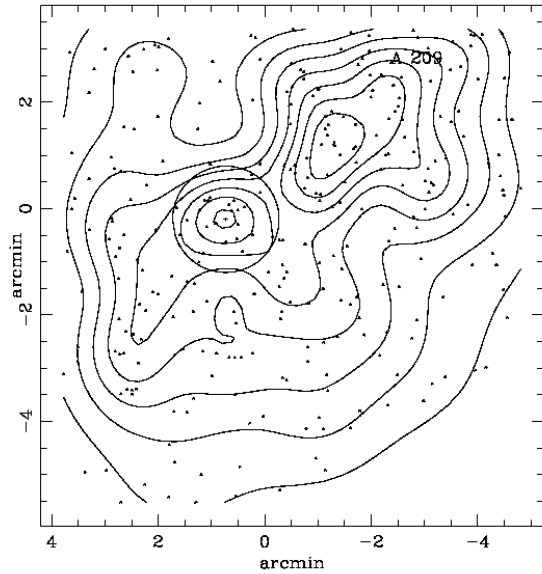
Recent discover of a cold front (Million & Allen et al. 09).

# A209 ( $z=0.21$ )

(Mercurio et al. 2003, A&A .NTT-ESO observ.)

Part of her PhD thesis.

112 member galaxies,  $\sigma_v$  about 1300  $\text{km s}^{-1}$



Radio halo confirmed by Venturi et al. 2007 !!!!!

2015 NEW DATA FROM CLASH-VLT!!!!!!!

>1000 redshift

A523, MG et al. MNRAS accepted  
A peculiar radio halo.  
perpendicular to the  
cluster merger axis and polarization

