DYNAMICAL ANALYSIS OF RADIO CLUSTERS

DARC

i.e. CLUSTERS WITH RADIO HALOS AND/OR RELICS

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see http://adlibitum.oat.ts.astro.it/girardi/darc

OBSERVATIONAL PHENOMENOLOGY OF RADIO HALOS AND RELICS

(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**.**

Large et al. 1959; confirmed by Wilson 1978 ; Gavazzi 1978; Hanish 1982.

Halos are placed around cluster centers. Relics are elongated and in peripheric position.

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^3 (origin: radiogals,qso, SF gals, merger shocks)

in a magnetic field about 0.1-1 microG.

Relics are polarized sources.

Frequency: about 50 clusters up to z=0.3

10% of clusters, 30% of clusters with high Lx (Giovannini et al. 99)

Correlations: RP –Tx, RP-Lx, Size-Tx, Size-Lx.

ORIGIN OF HALOS AND RELICS

Problem:

lifetime of relativistic electrons about 10^8ys+Alfven speed about 100km/s

→ **electrons do not cover a 1Mpc scale!!!!**

Primary electron reacceleration model: continuous in-situ reacceleration of the radiating electrons **(e.g., by CLUSTER MERGERS, Tribble 1993)**

OK with energetics: gravitational bindinding energies of 10^64 erg, 3 10^63 erg dissipated by hydrodynamical shocks.

ok with radio halos/relics as rare objects (transient phenomena).

Relics may be associated with shock waves (Ensslin et al. 1998; Roettiger et al. 1999; Ensslin & Gopal-Krishna 2001; Hoeft et al. 2004).

Halos may be associated with turbulence (Brunetti et al. 2001; Cassano et al. 2006).

Secondary electron model: electrons resulting from collisions between relativistic protons and thermal ions of ICM – ok with correlation radio-X properties (but not yet observed, non OK with halos/relic frequency)

Cluster mergers and radio halos/relics: Status of the art and our aims

Radio clusters are characterized by dynamical activity related to mergers
substructures in the X—ray distribution ; temperature gradients ; gas shocks;
absensence of cooling core (seeFeretti 01; Schuecker et al. 01; Markevitch et al. 03; Govoni et al. 04; Feretti 2006 for a review).
Correlation between radio power and the dipole power ratio of the gravitational potential (Buote 2001).
A spatial correlation between the radio spectral index and merger activity
(Feretti et al. 2004; Orru' et al. 2007).

Optical information coming from galaxies is complementary to X-ray information since galaxies and ICM react on different time scales !
Dynamical Analysis of Radio Clusters based on galaxies - AIMS
to check for a connection between halos/relics and cluster merger;
to study the correlation between radio and optical properties;
to determine the phase of merging correlated with radio halos;
to study the effect of likely strong mergers on galaxy properties.

DARC collaborators and observational program

W. Boschin (TNG), **R. Barrena** (IAC)+**M. Spolaor** **(**Swinburne Univ.)
+occasional coll. Radio: L. Feretti, A. Biviano, D. Fadda, M. Ramella

Pilot: A209, Mercurio et al. 2003, z=0.21, Tx=10keV, **NTTspectra+phot.**, Chandra arch
A2219, Boschin et al. 2004, z=0.22, Tx=10keV, **TNG**+CFHTarch. , Chandra arch.
A2744, Boschin et al. 2006, z=0.31, Tx=8keV, NTTarch.+lit. spectra
A697, Girardi et al. 2006, z=0.28, Tx=10keV, **TNGspec+INTphot.**,Chandra arch.
A773, Barrena et al. 2007, z=0.22, Tx=9keV, **TNGspec+INTphot**., Chandra arch.
A115, Barrena et al. 2007, z=0.19, Tx=8keV, **TNGspec.+INTphot.**
A610-A725-A796, in prep z=0.1, poor clusters, WYFOS@WHTspec+SDSS+**INTphot.**
A520, , **z=0.20, Tx=8keV, TNGspec.**+CNOCspec
A959, , z=0.28, Tx=6keV, **TNGspec.+**
A1240, , **z=0.19, Tx=4keV, TNGspec.+INTphot.**
A665, A786, EM0922+75, A2163, A2294 **INTphot (May 2007)**
TNG proposal (1night approved)
Clusters sample out to a radius of about >5' (about half R200 -R200)
with about **100 member galaxies,** sometime having spectral type determ.

A209 (z=0.21)

(Mercurio et al. 2003, A&A)

112 member galaxies,

σ_v **about 1300 kms-1**

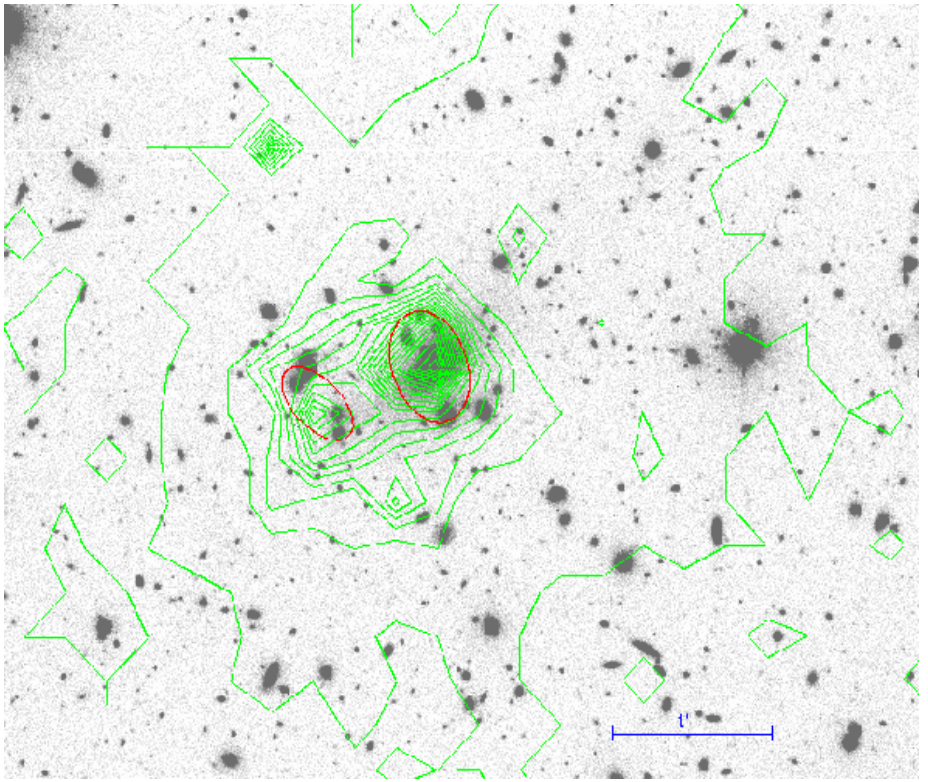
Preferential SE-NW direction

(velocity gradient, cD elongation,

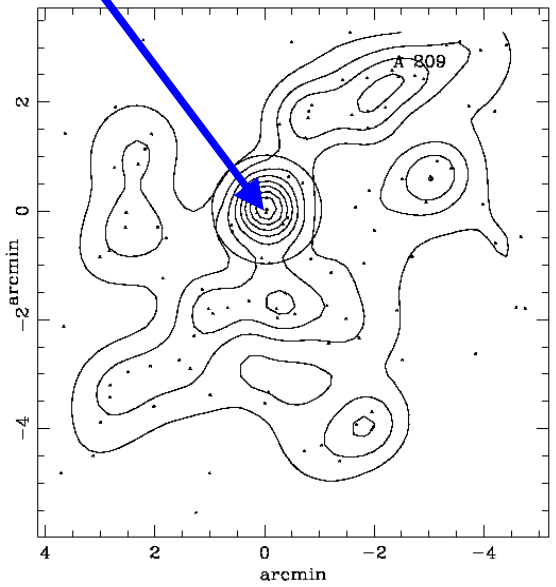
2D galaxy distribution,

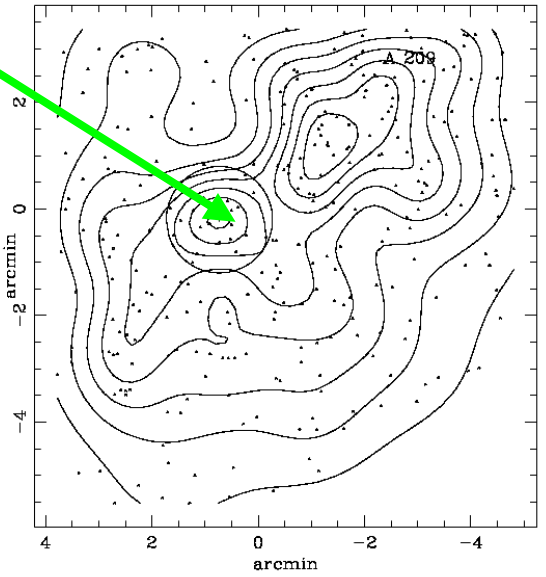
X-ray contours),

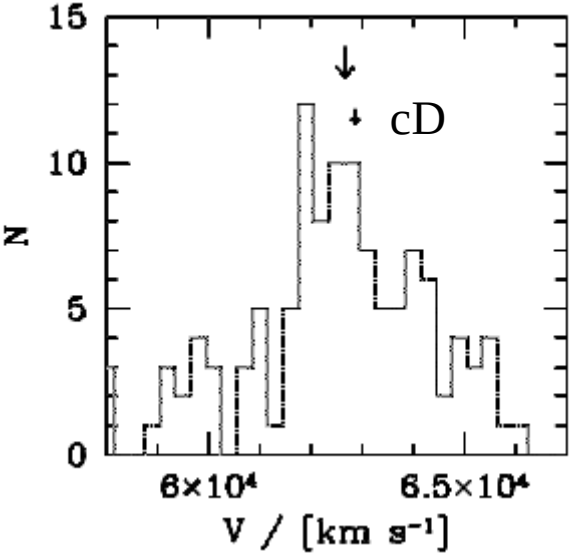
color segregation, substructure



R<19.5 (cD clump), R>19.5







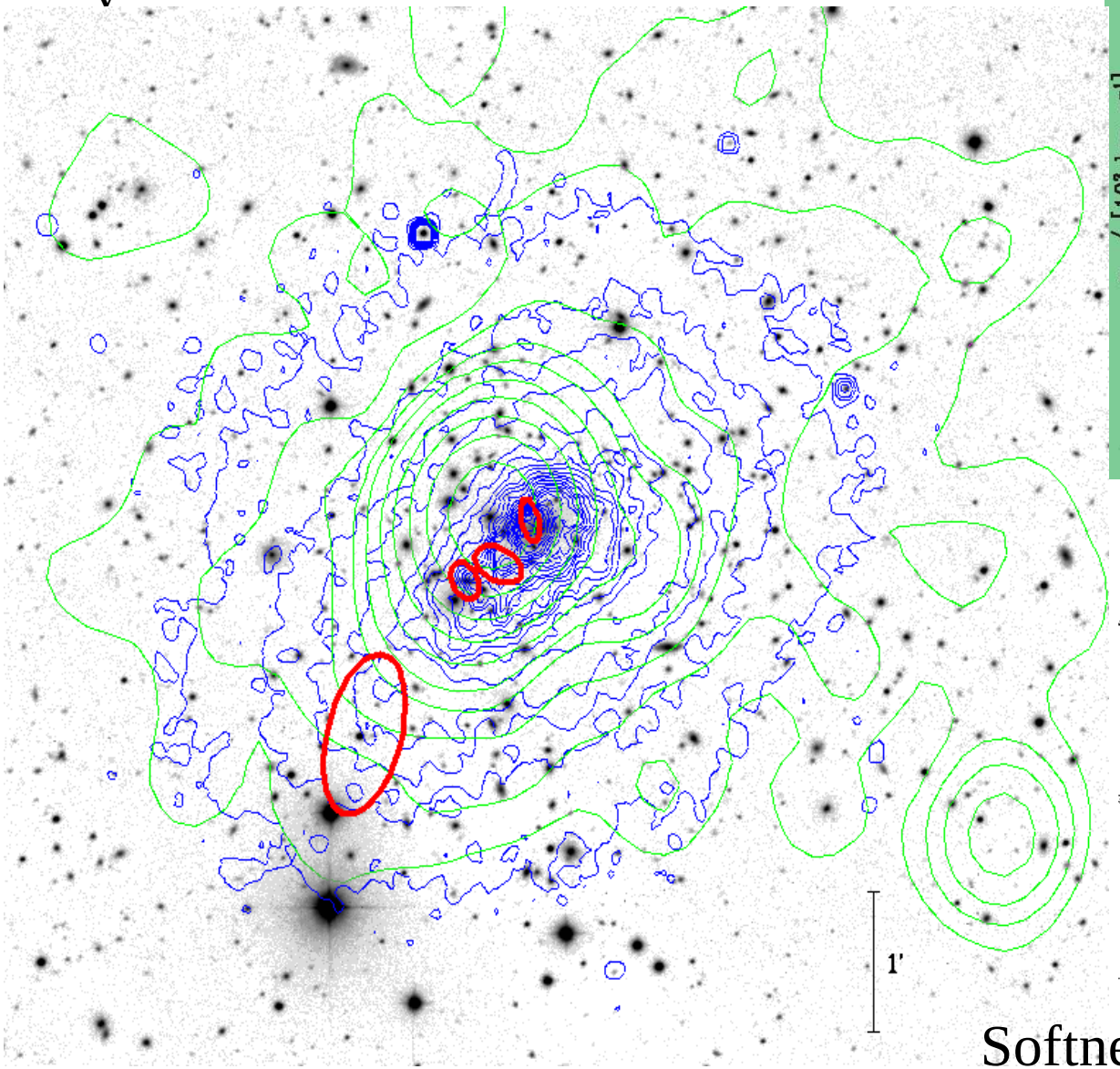
A2219, z~0.22

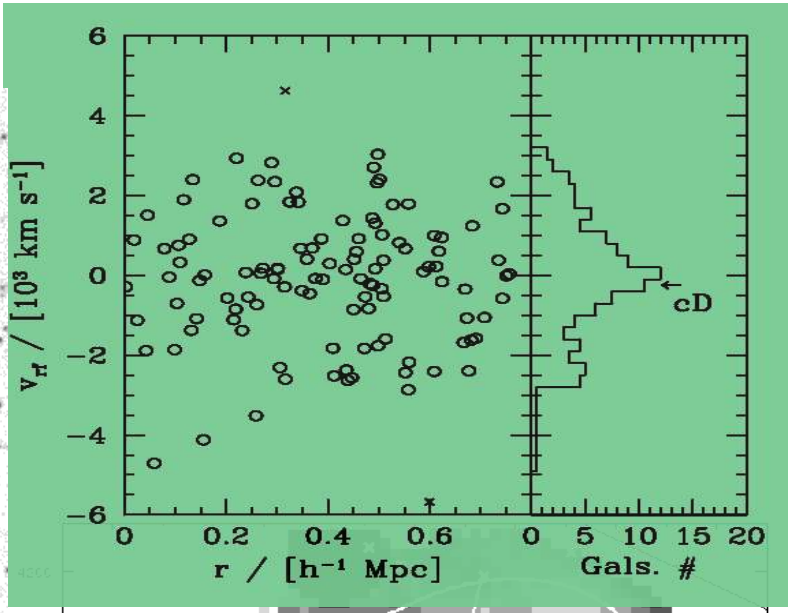
(Boschin, MG, Barrena, et al. 2004, AA, 416, 839)

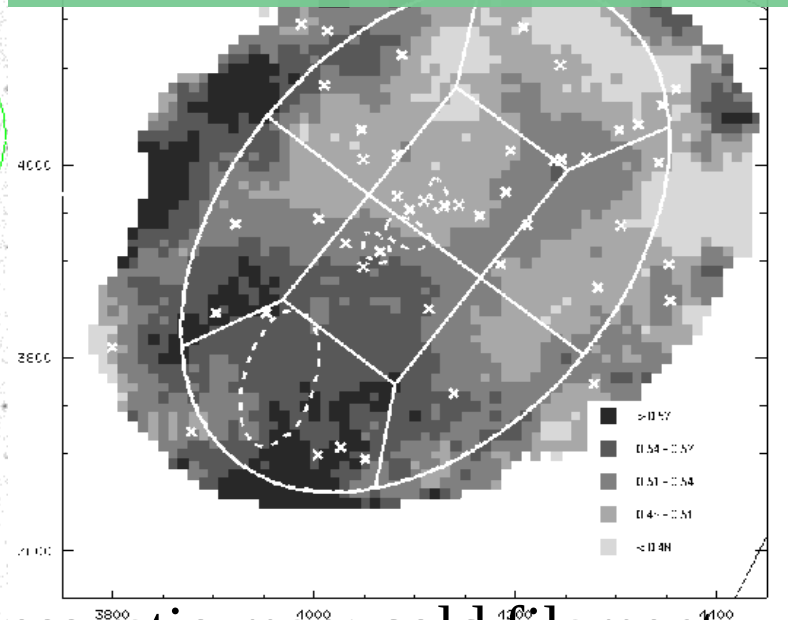
TNG/Dolores +CFHT multiobject spectroscopy

Preferential SE-NW direction, substructure

σ_v about 1400 kms-1





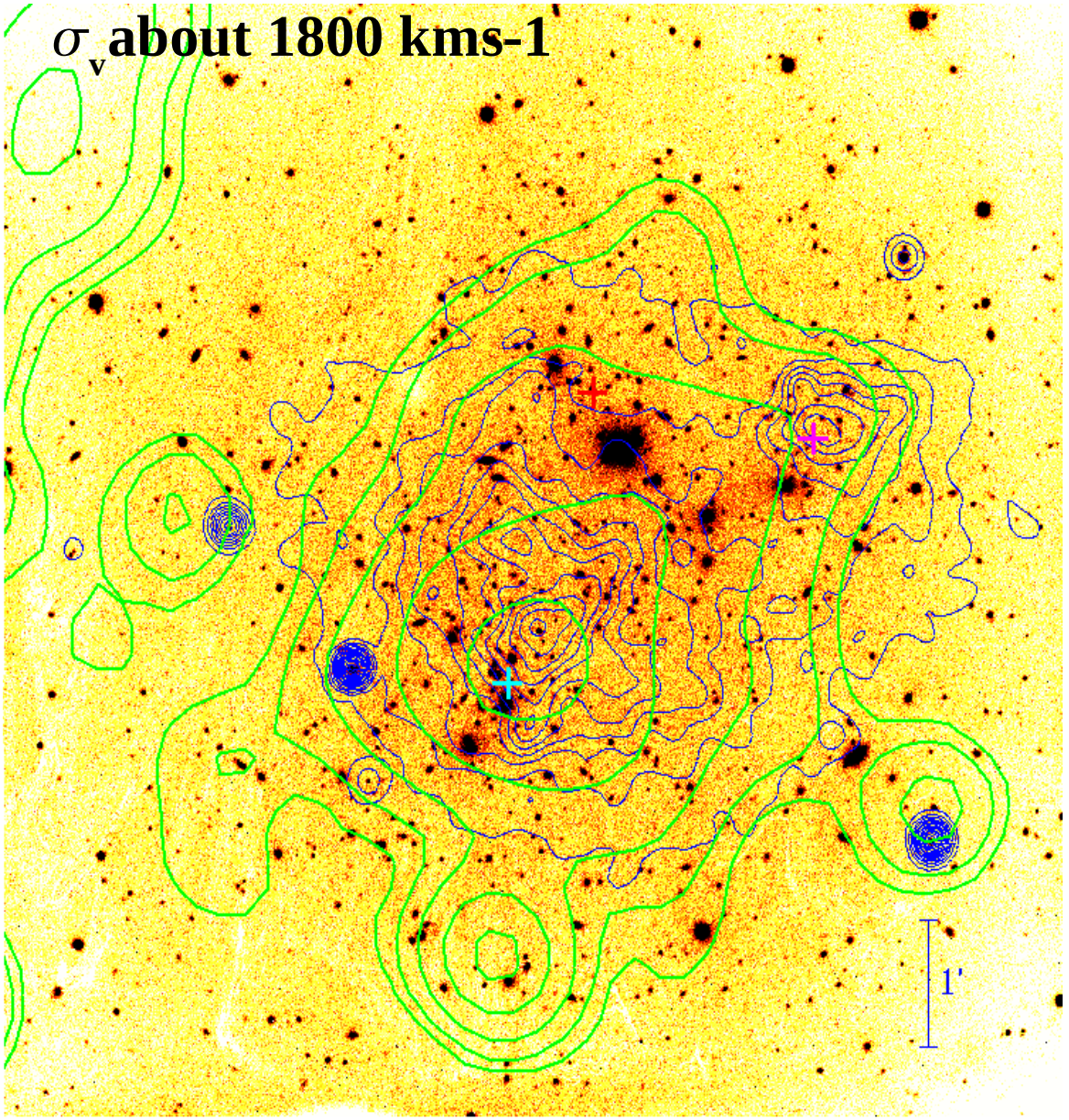


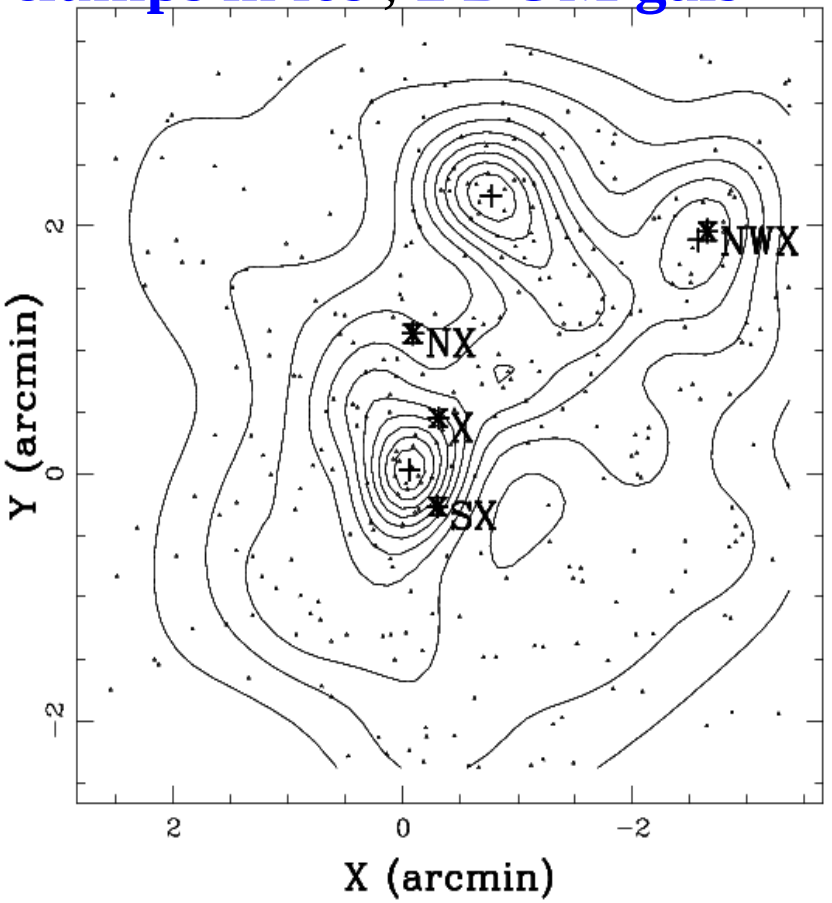
Softness ratio map: cold filament

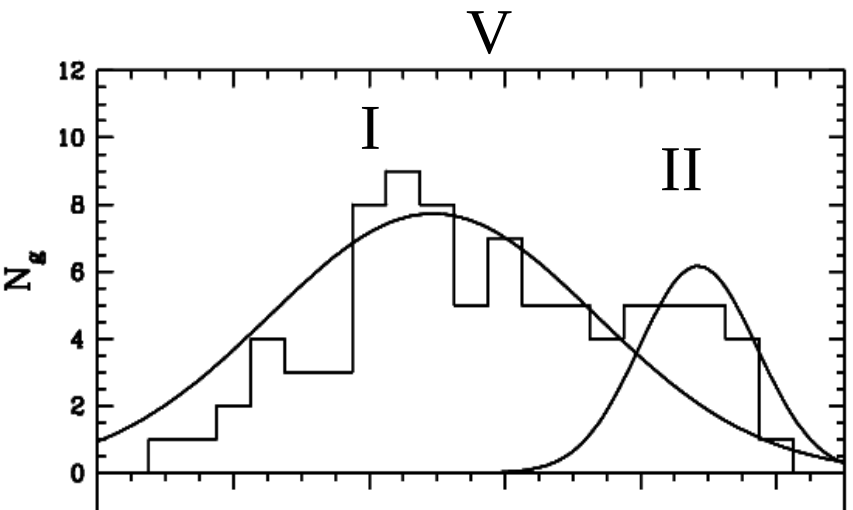
A2744, z~0.31

(Boschin, MG, Spolaor, and Barrena AA, 2006)

ungoing merger, **2 clumps in los** , **2 DOM gals**





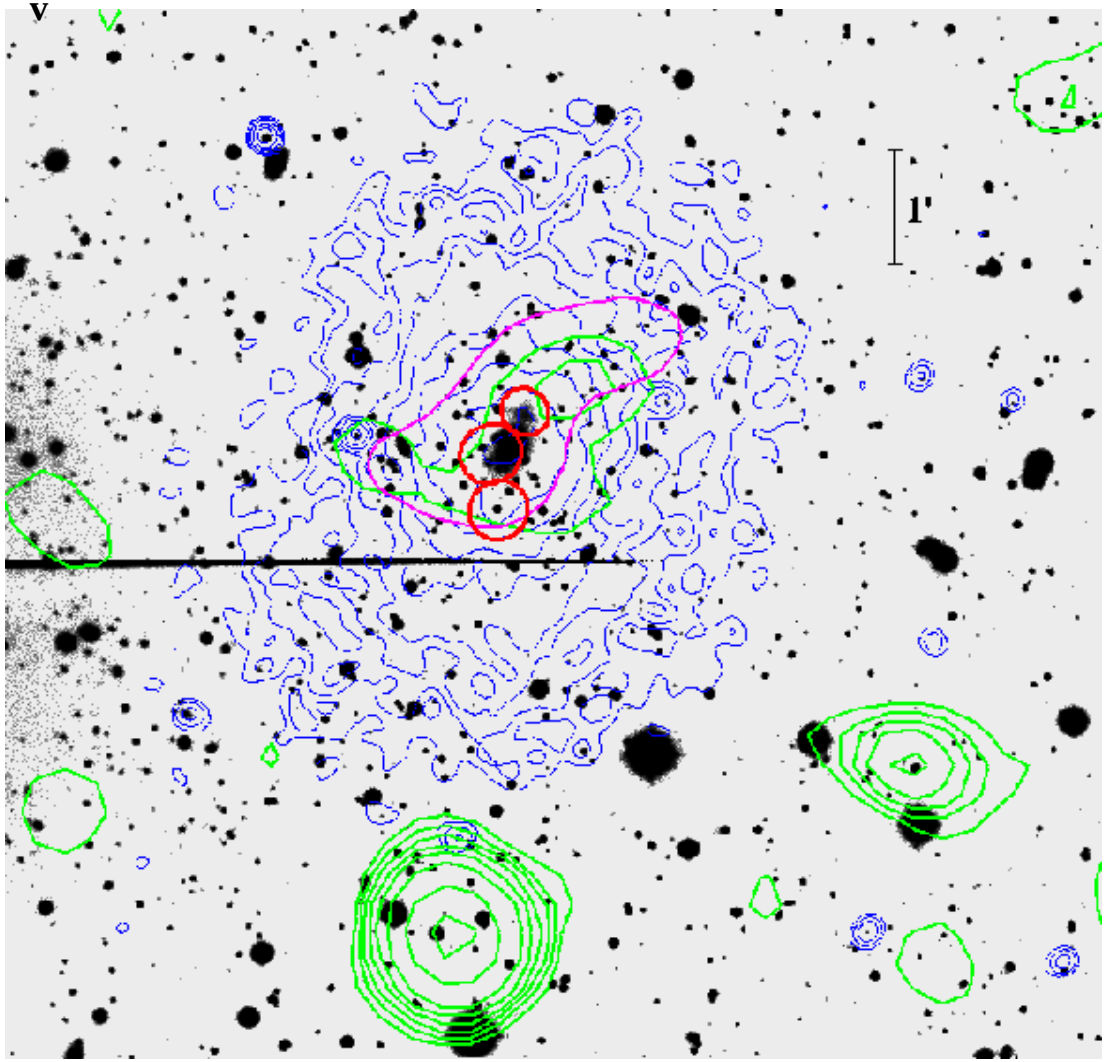


For radio spectral index, see Orru', Feretti...2007

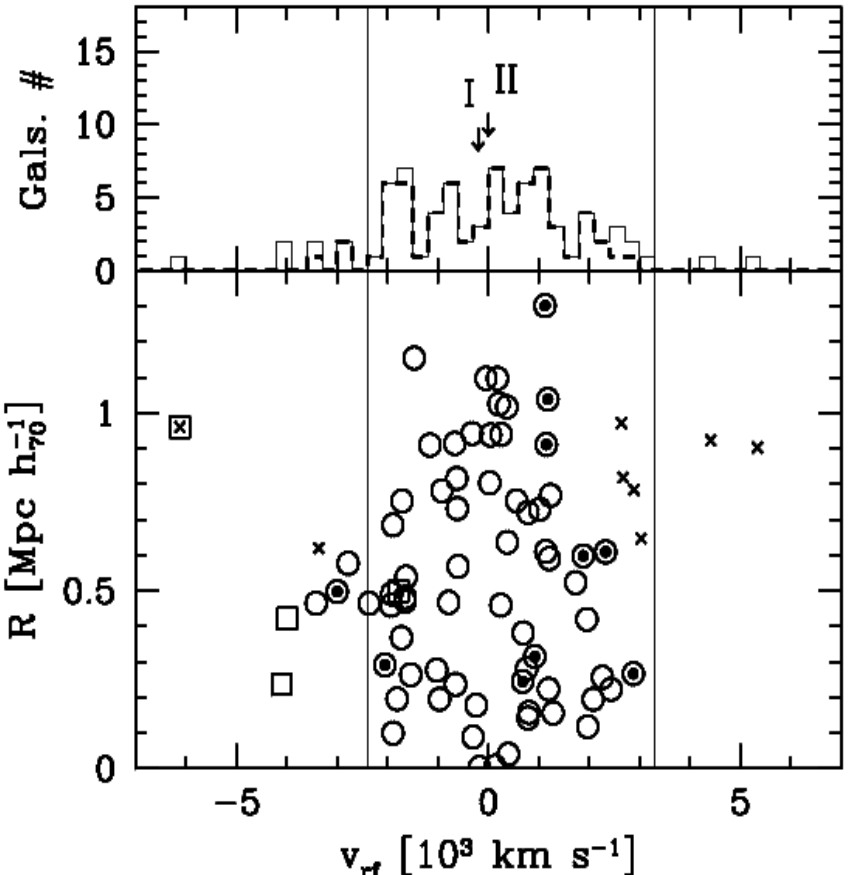
A697, z~0.28

(MG, Boschin, and Barrena, AA, 2006)
TNG-Dolores

σ_v about 1300 kms-1



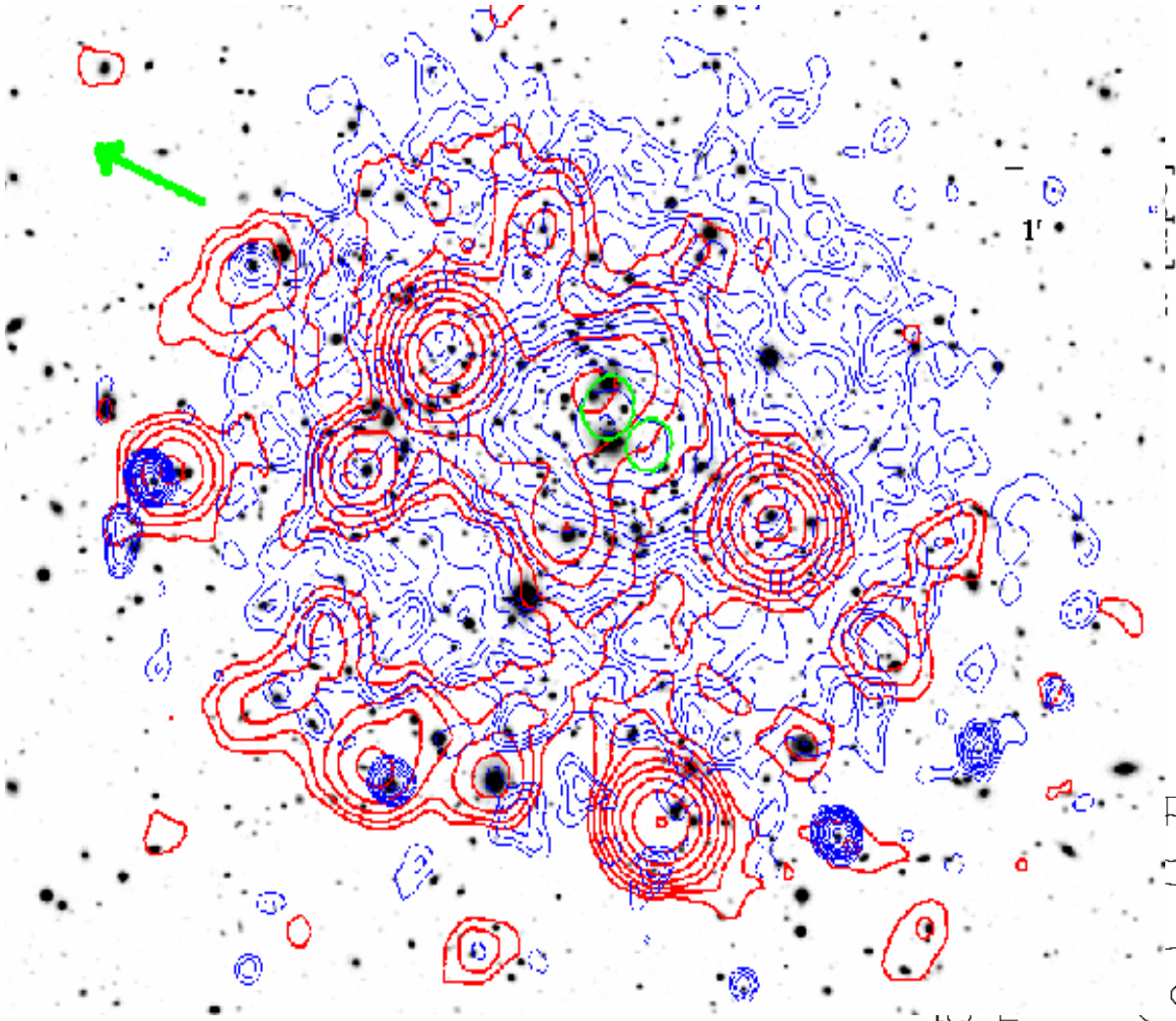
Past cluster merger?
3-4 clumps in Vlos?
Radio_ optical morphological similarity.

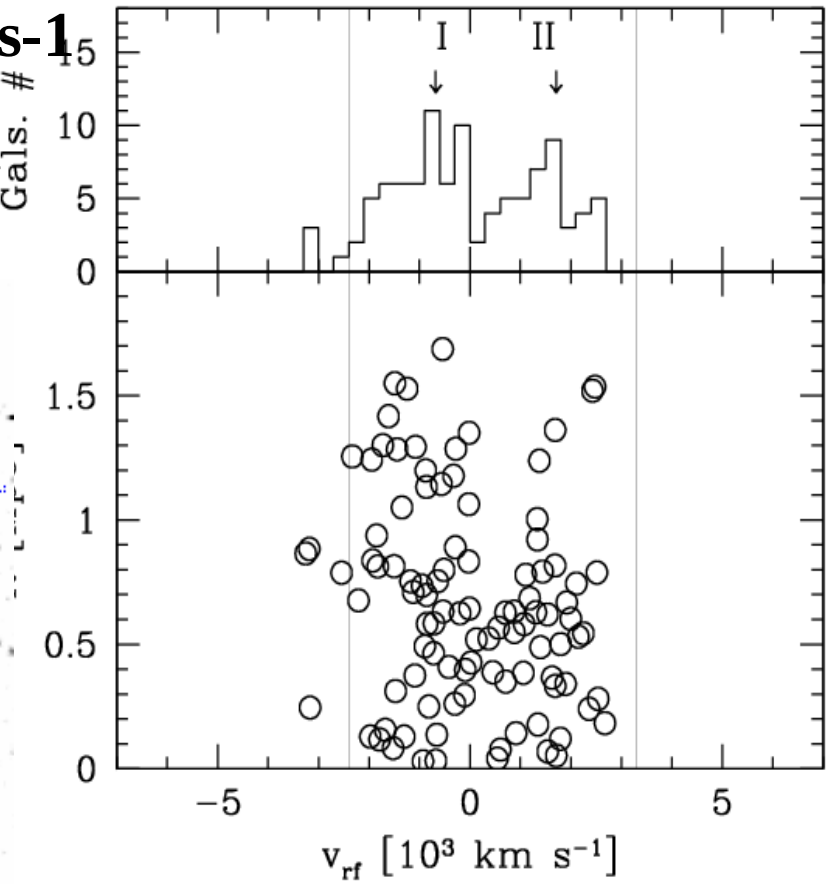


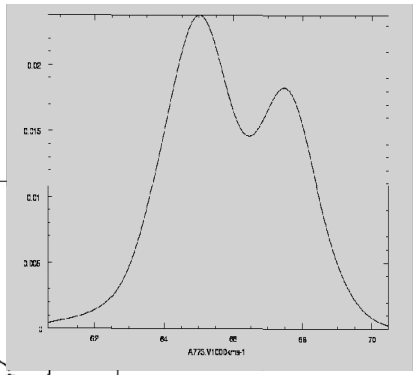
A773, z~0.22

σ_v about 1400 kms-1

Barrena, Boschin, MG, and Spolaor, AA 2007







2 clumps in los V, 2DOMs

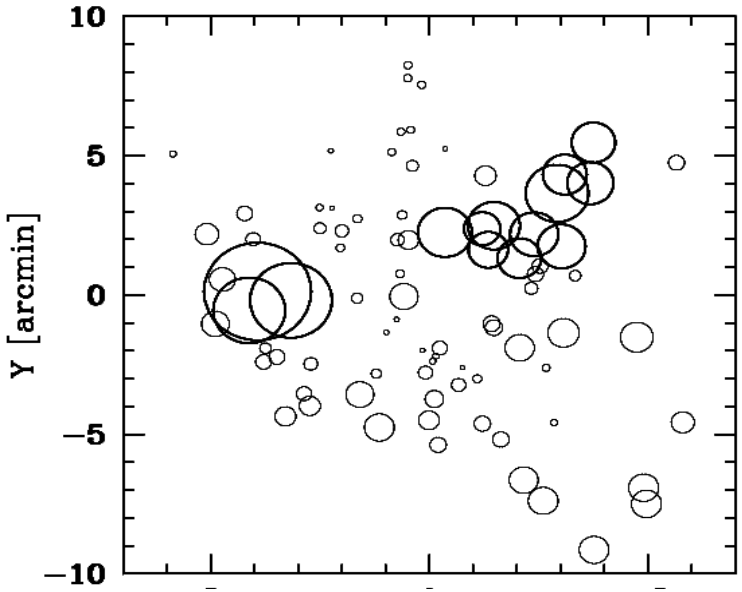
A115, z~0.19

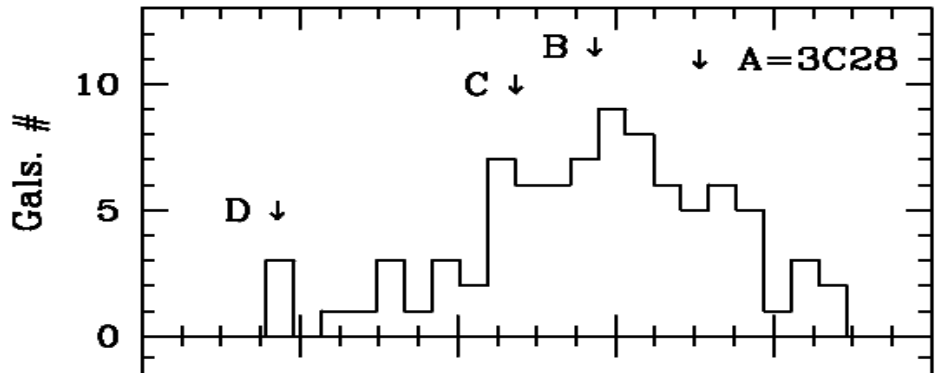
σ_v about 1400 kms-1

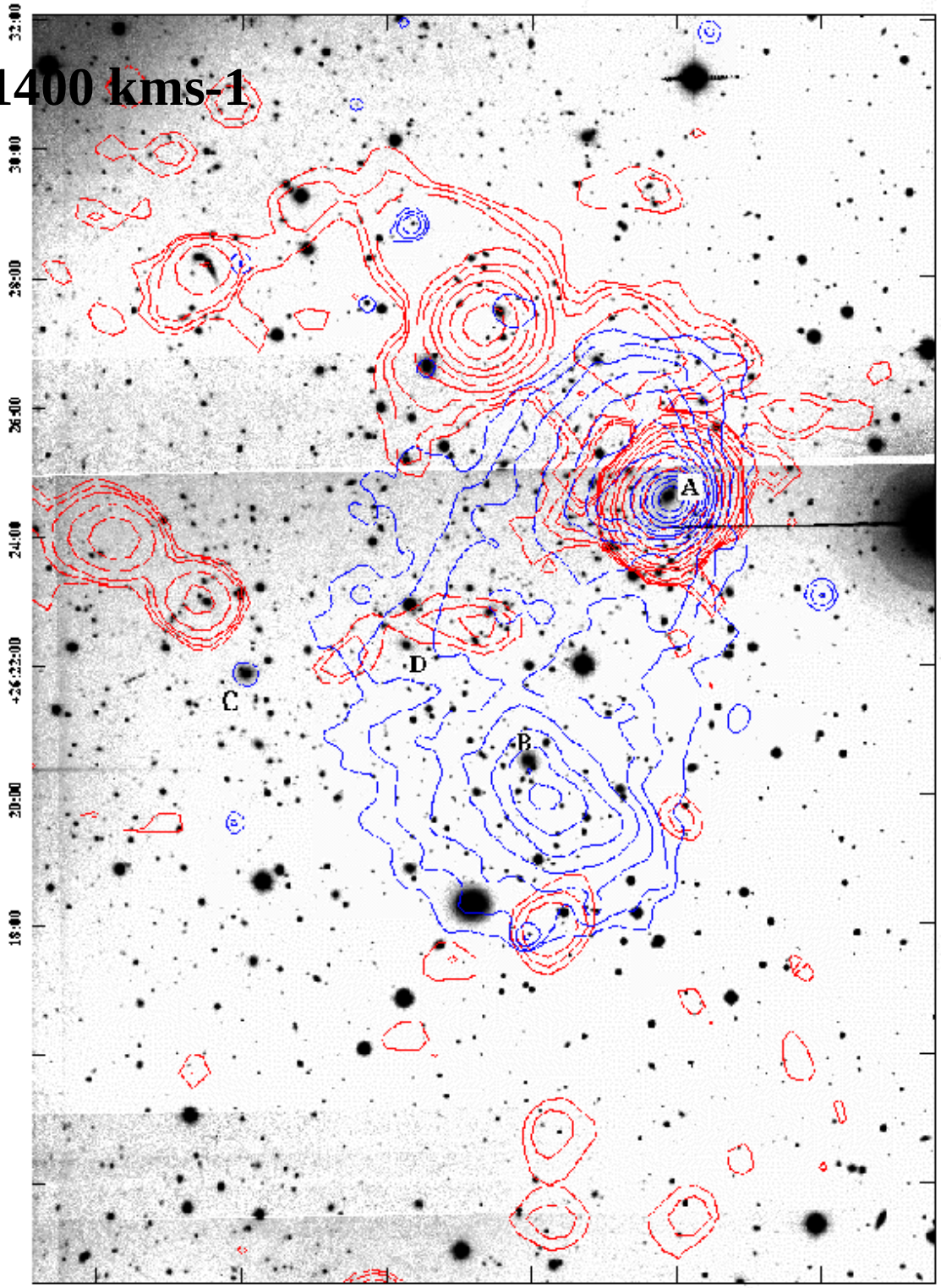
Barrena, Boschin, MG, & Spolaor 07

2 clusters (South is the main, radiogal lies in the northern)

+1-2 low-V groups (Beers et al.83)



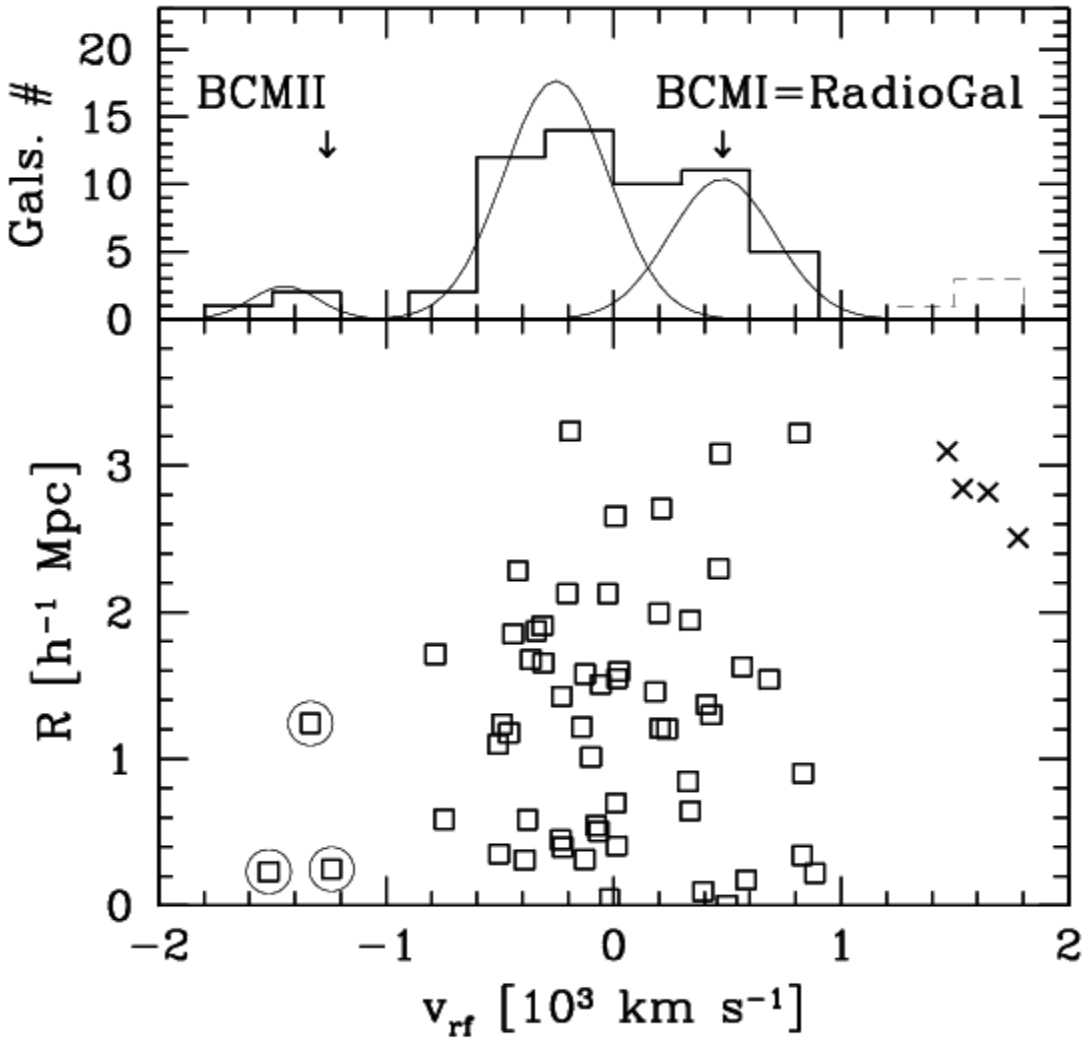


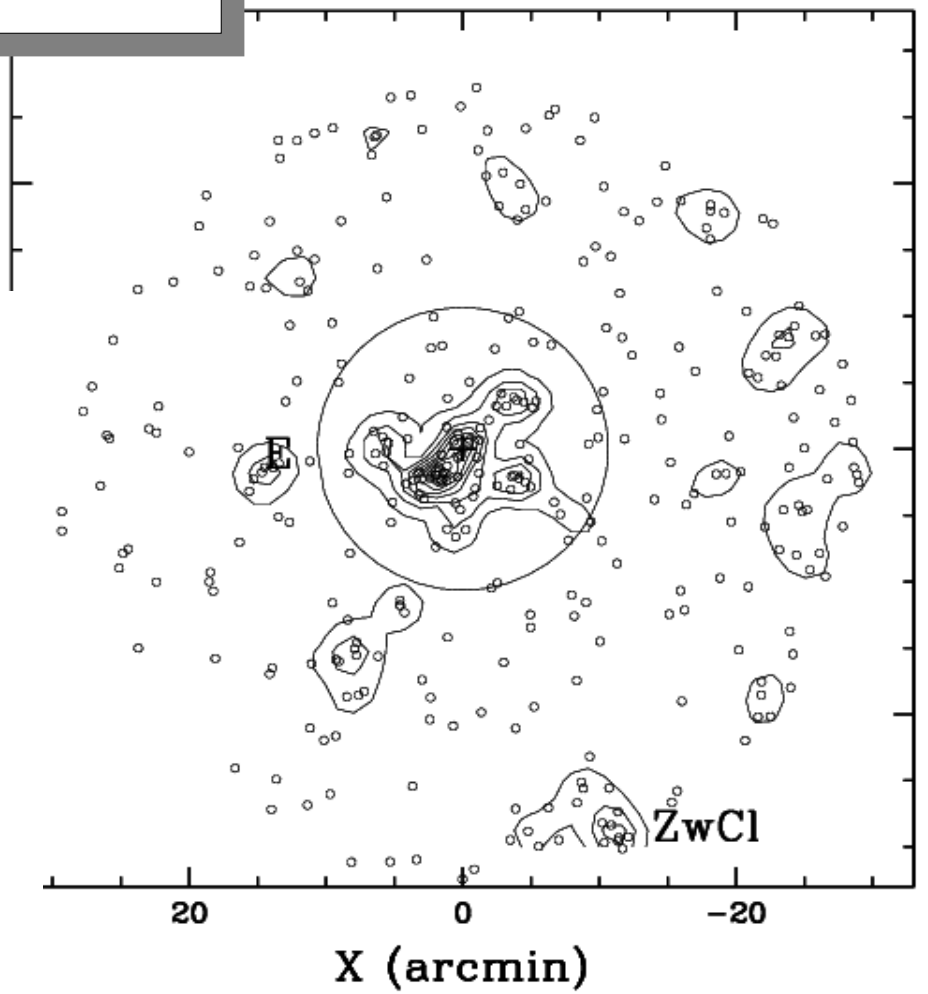


POOR CLUSTER A610, z~0.10

σ_v about 500 kms-1

Likely **2 clumps in losV**





RESULTS

RESULTS FROM DARC SAMPLE

presence of substructure; often two **clumps** in losV or 2D gals distribution;
often spatial correlation between radio emission and X/optical structure.

CONNECTION BETWEEN RADIO HALOS/RELICS & MERGERS

Possible evolutionary sequence:

2 separate systems (A115)

2 Vpeaks with 2 DOMs (A773,A2744)

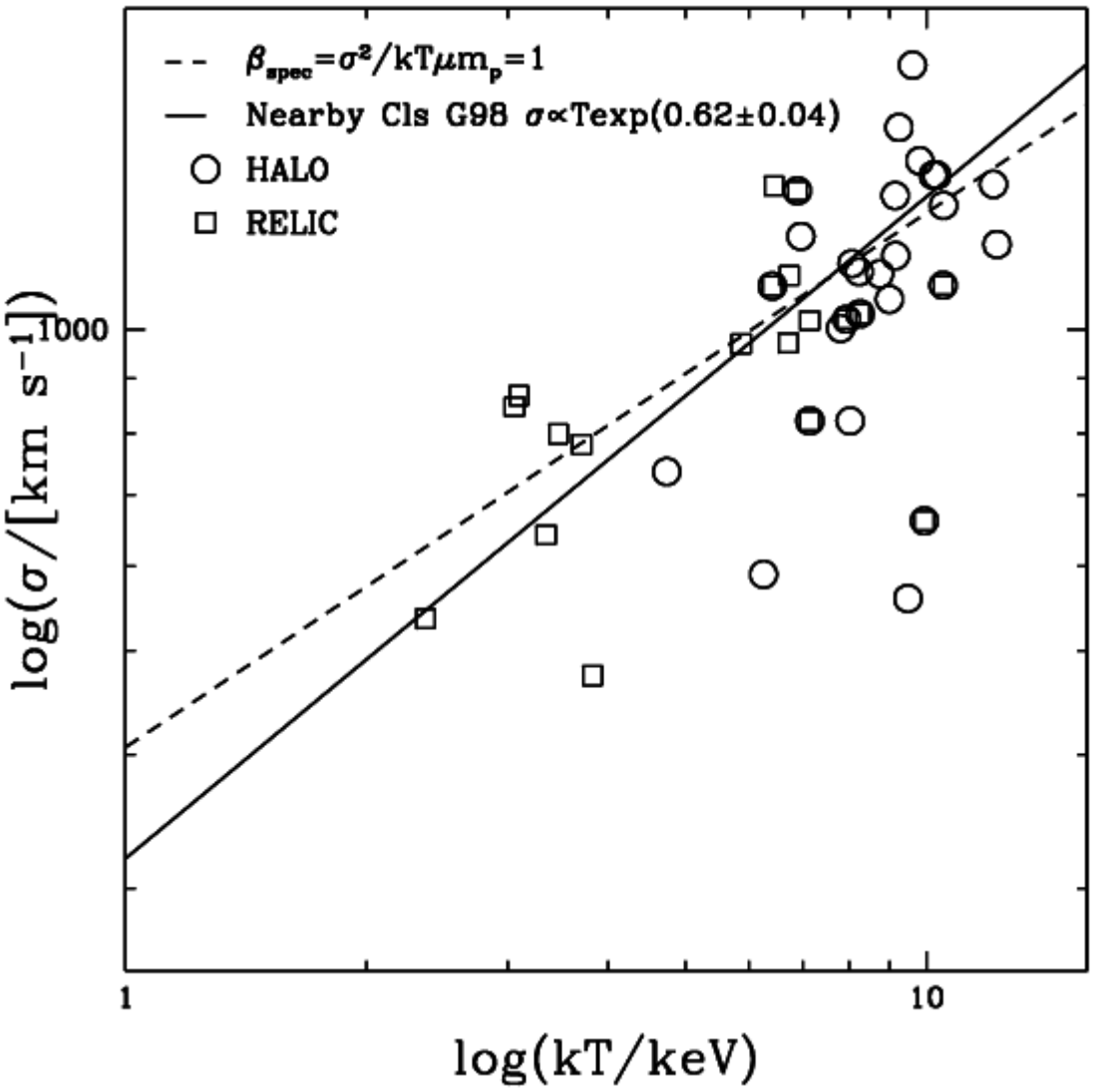
Substructured system with 2 DOMs with similar V (A697)

Substruc/Elongated system with (elongated) cD/DOM (A209,A2219)

Stastistical Analysis

51 CLUSTERS with radio halo/relic (40 having both sigma and Tx)

σ_v - Tx relation



OPTICAL DATA:
homogeneus analysis

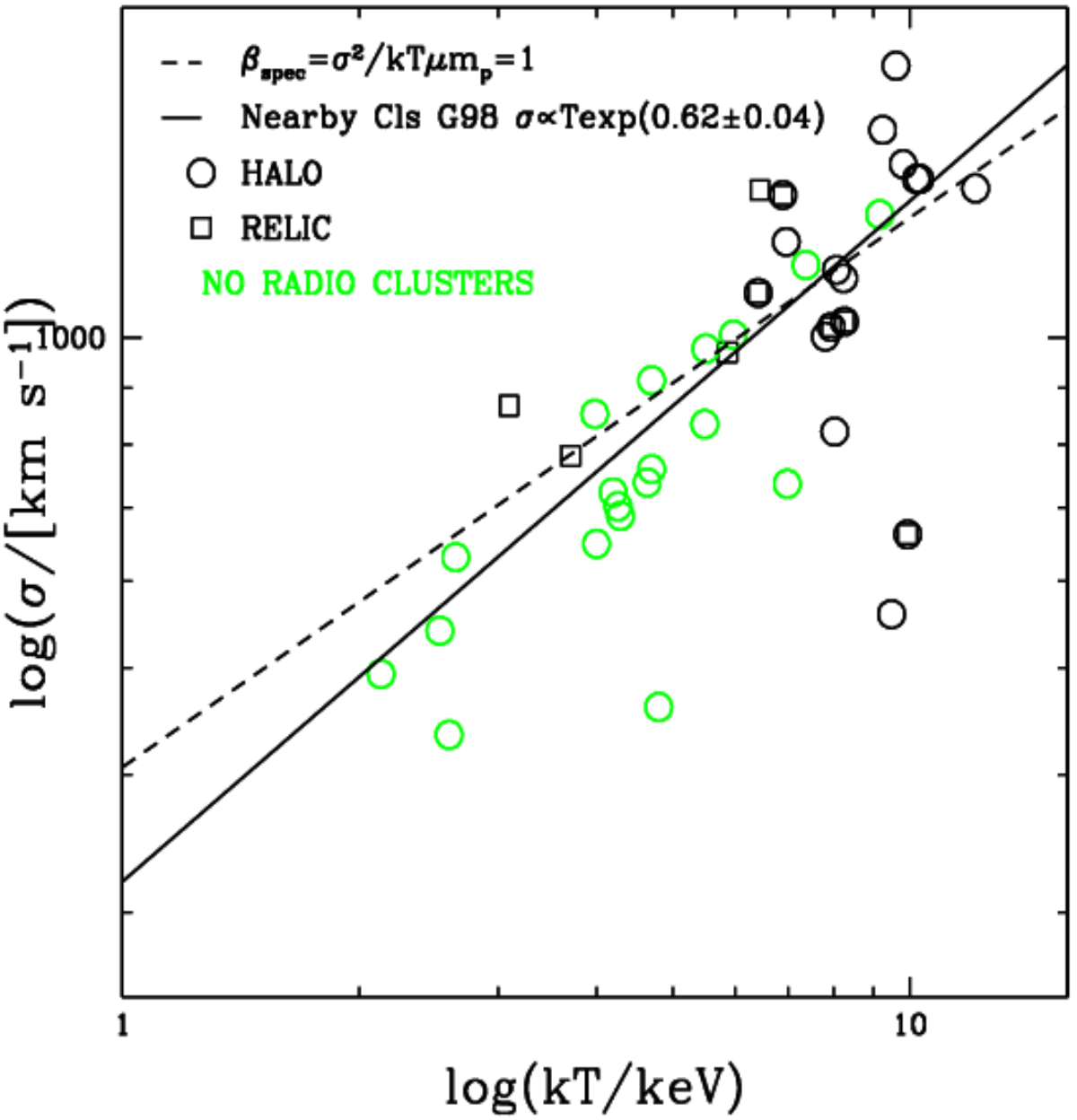
DARC+MG et al. works +analysis of data from SDSS and literature

Tx from the literature: ASCA (Horner ACC) +Chandra+XMM

σ_v - Tx relation

MG, Volker, Boschin, Mardirossian & Mezzetti 2007 in prep. -

σ_v-Tx relation

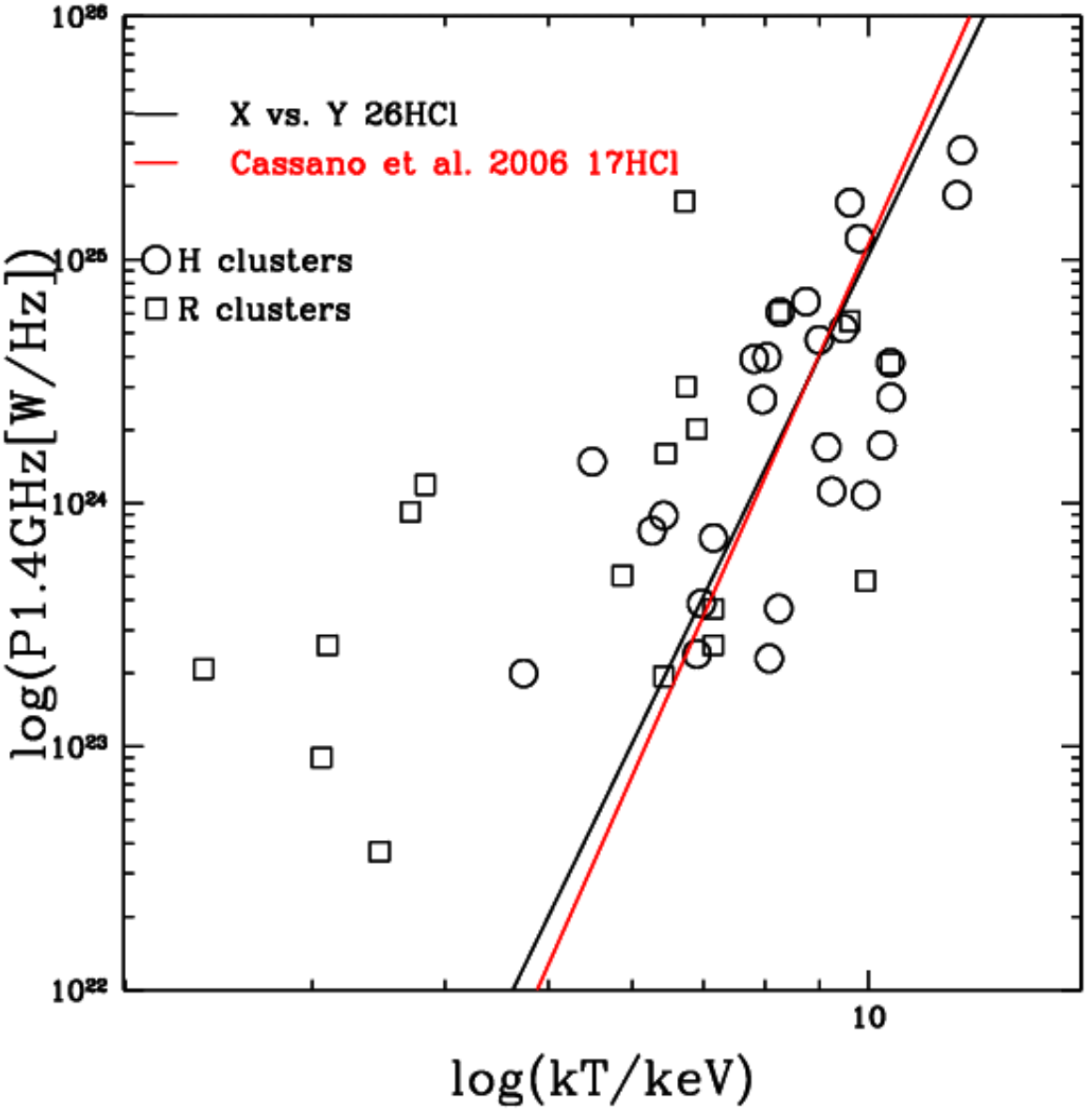


In the NRAO VLA Sky Survey (Giovannini et al. 1999).

No radio clusters are the subsample having homogeneus sigma determination (MG et al.)

Radio clusters have higher sigma and Tx than no radio clusters.

RadioPower-Tx relation



We confirm the old relations

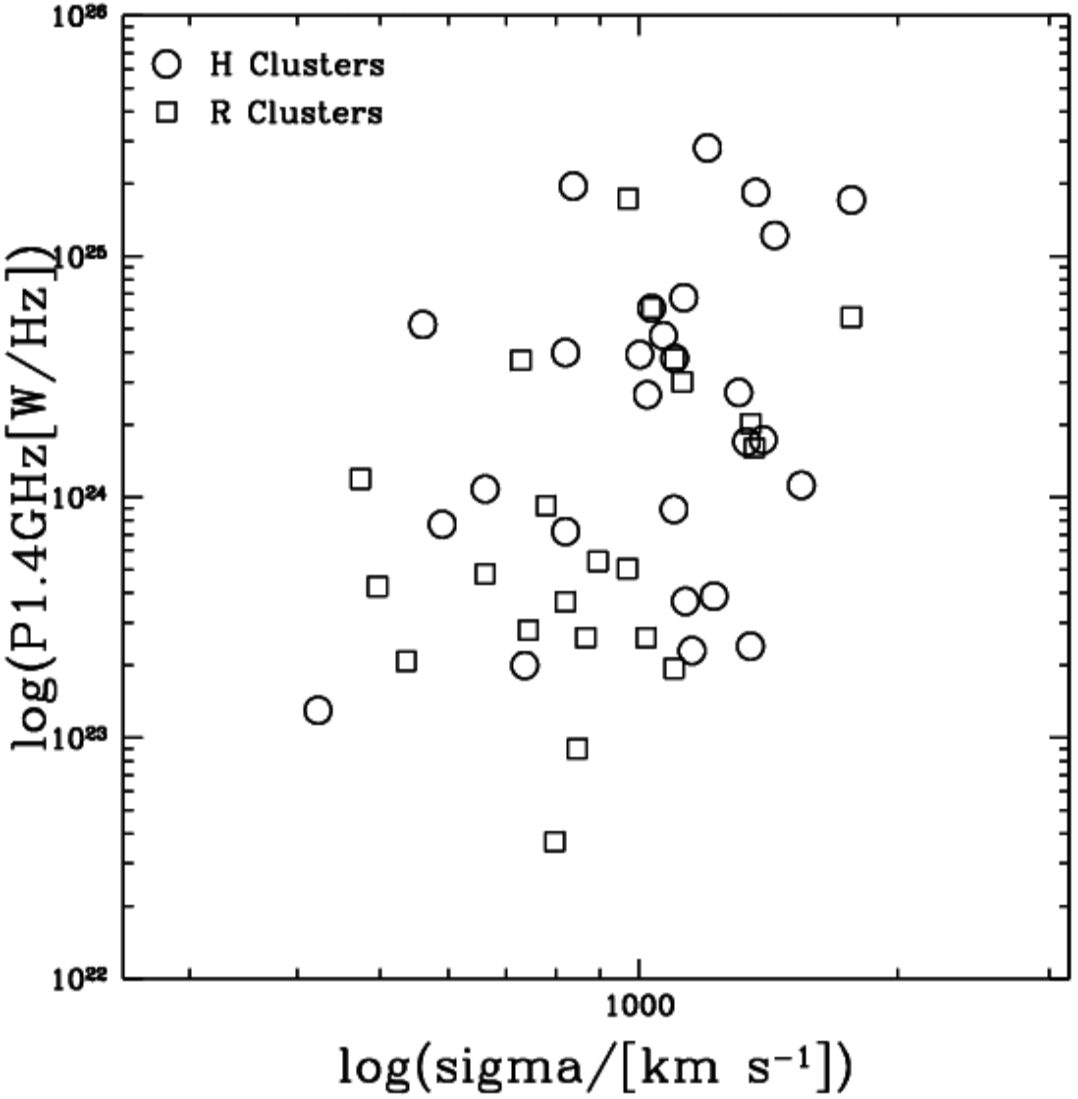
RP-Tx, Size-Tx

CORRELATIONS

	#Cls	Scoeff	Prob
RP-Tx H	26	0.65	99.98%
RP-Tx R	18	0.60	99.6%
RP-Tx H+R	44	0.63	>99.99%
LLS-Tx H	27	0.56	99.89%
LLS-Tx R	18	0.53	99%
LLS-Tx H+R	45	0.54	>99.99%

NEW, BUT LESS GOOD RELATIONS WITH σ_v

RadioPower- σ_v relation

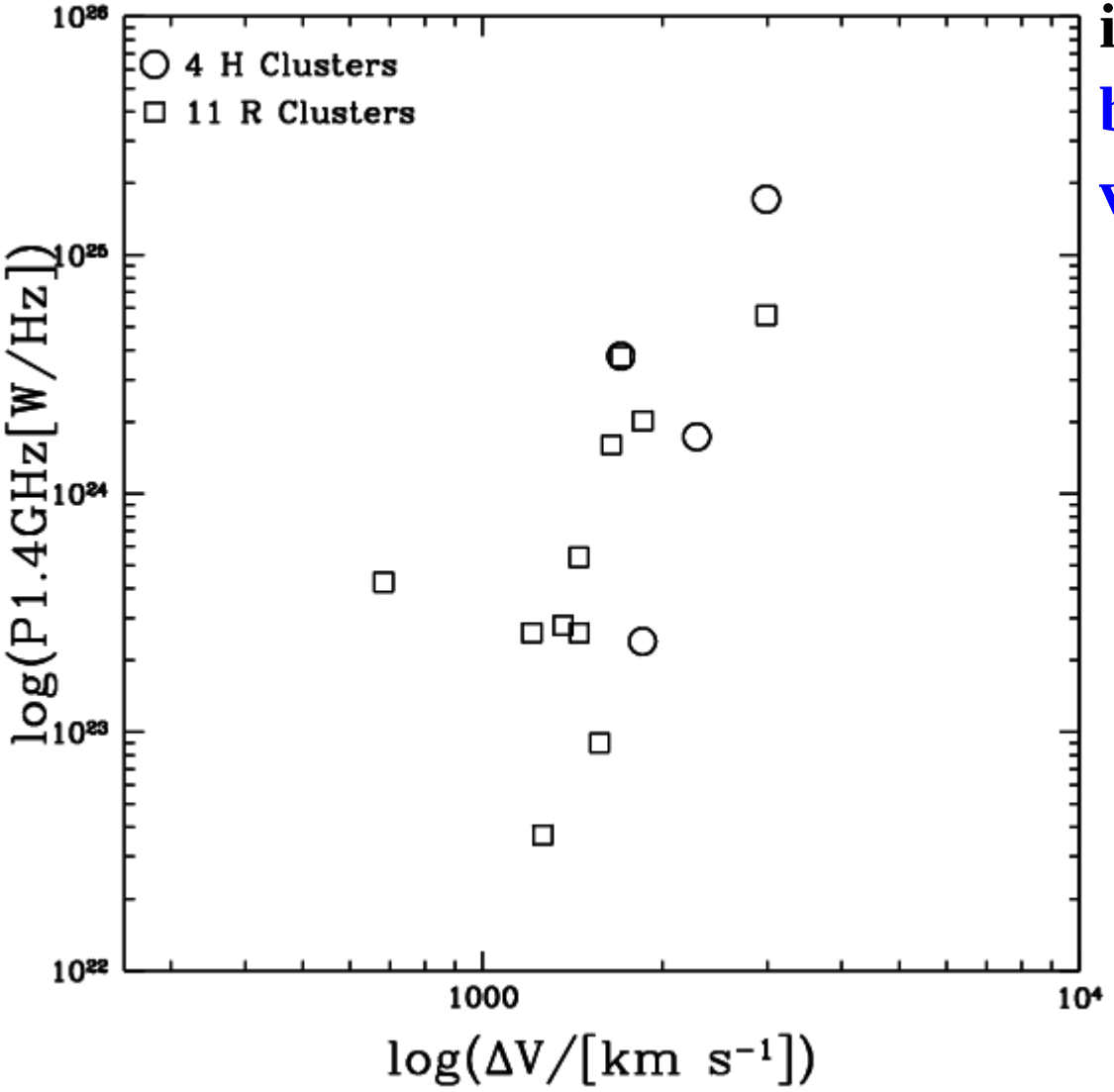


CORRELATIONS

		#Cls	Scoeff	Prob
RP-σ_v	H	27	0.23	no
RP-σ_v	R	22	0.41	97%
RP-σ_v	H+R	49	0.38	99.6%
LLS-σ_v	H	28	0.32	95%
LLS-σ_v	R	22	0.43	98%
LLS-σ_v	H+R	50	0.42	99.9%

NEW AND VERY GOOD RELATION WITH dV

RadioPower-dV relation

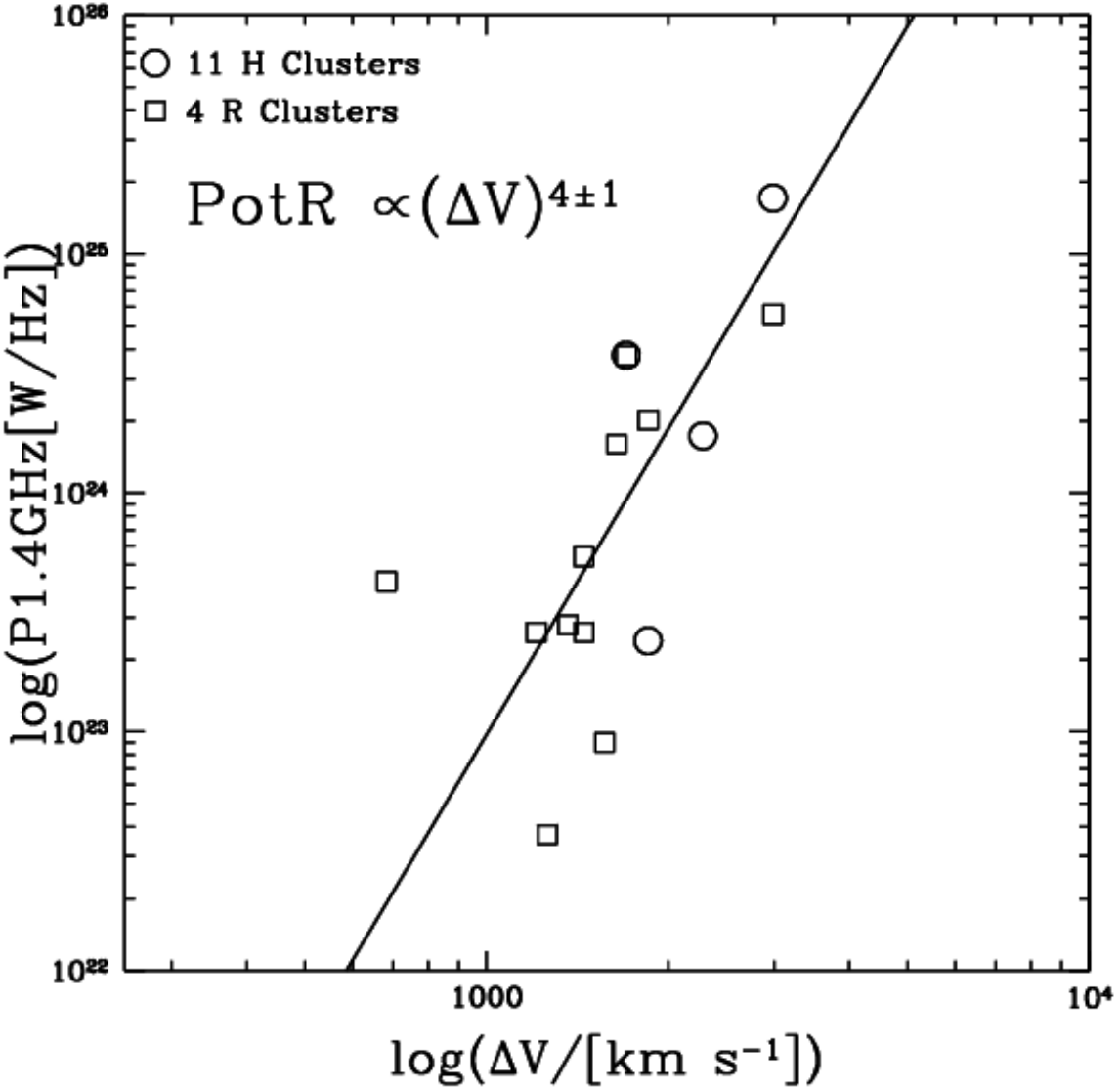


dV= line-of-sight velocity difference in the cluster rest-frame between the two peaks in the velocity distribution.

		#Cls	Scoeff	Prob
RP-dV	H+R	15	0.66	99.6%
LLS-dV	H+R	15	0.76	99.95%

RadioPower-dV relation

Radio Power depends on the dissipated energy, which depends on the amount of available energy, i.e. the merger kinetic energy K.

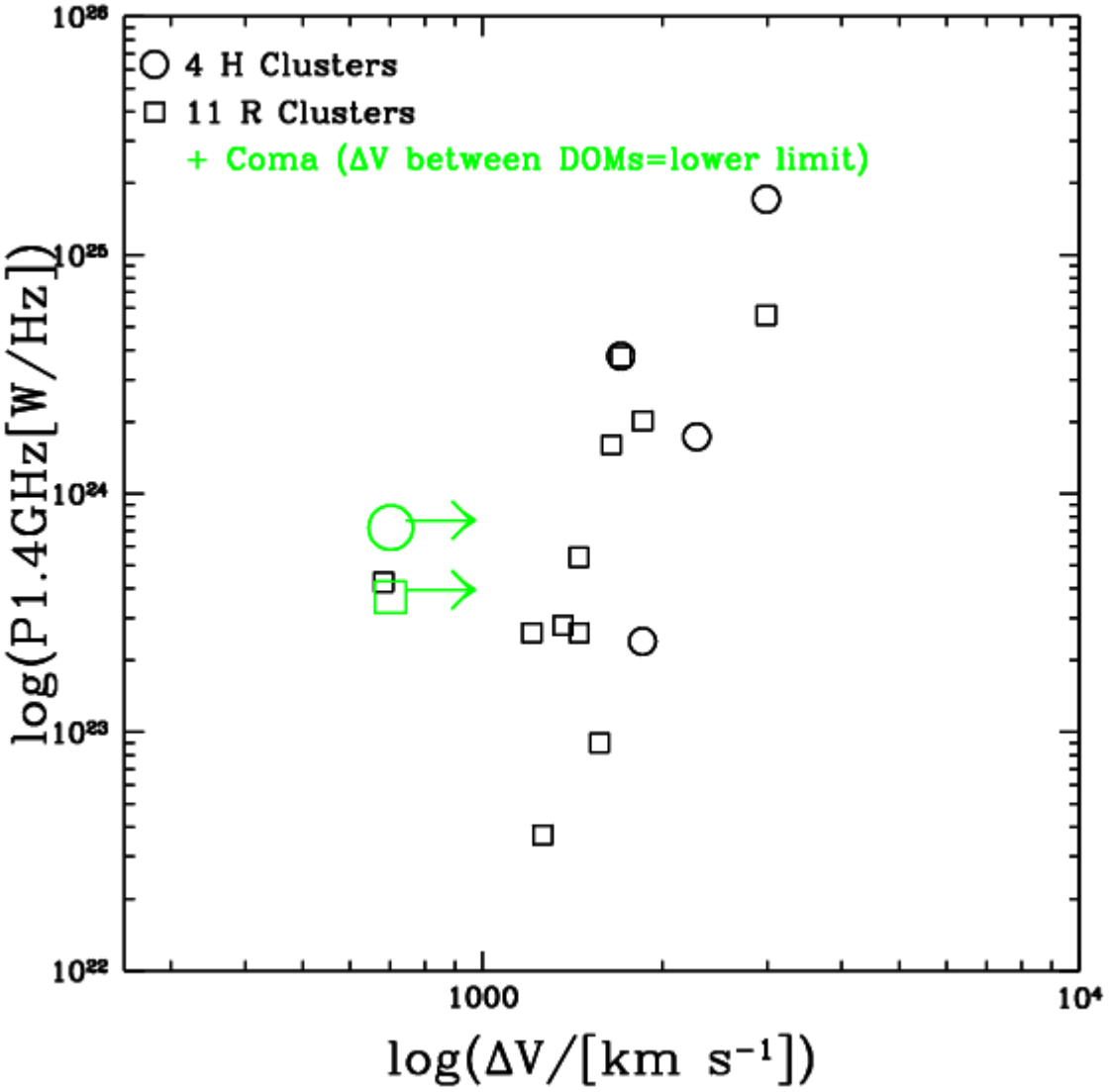


K proportional to M dV^2 but during the merger the infall velocity is expected to go as M^(1/2).

We expect and OBSERVE RP prop. dV^4.

RadioPower-dV relation

If BCMs trace the past merger, also when the 2 velocity peaks are not longer visible, BCMs dV is a lower limit for the measure of the energy involved in the past merger....



This scenario is possible for Coma, too (see Adami et al. 2005 and other previous works and review by A. Biviano).

We plot the dV between the 2 Dominant galaxies NGC4874 and NGC4889.

SUMMARY I

RESULTS FROM DARC SAMPLE

presence of substructure; often two **clumps** in los V or 2D gals distribution;
often spatial correlation between radio emission and X/optical structure.

CONNECTION BETWEEN RADIO HALOS/RELICS & MERGERS

Possible evolutive sequence: **2 separate systems (A115)**

2 Vpeaks with 2 DOMs (A773,A2744)

Substructured system with 2 DOMs with similar V (A697)

Substruc/Elongated system with (elongated) cD/BCM (A209,A2219)

SUMMARY II

RESULTS FROM DARC SAMPLE +OTHER CLUSTERS

RP-LLS-sigma correlations

RP-LLS-dV correlations **MERGERS-HALOS/RELICS CONNECTION**