RESULTS ABOUT GALAXIES FROM INTERNAL DYNAMICS OF GROUPS AND CLUSTERS

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TRIESTE

+contribution of Andrea Biviano (OATS-INAF)

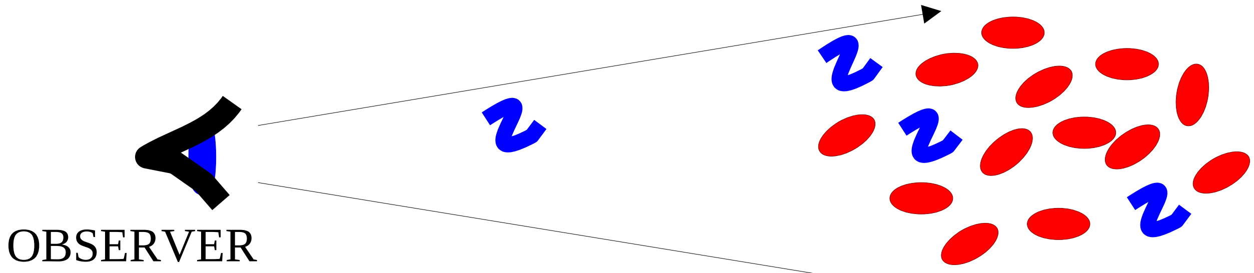
GALAXIES ⇒ CLUSTER/GROUP MASS &
(TEST PARTICLES) INTERNAL DYNAMYCS

STUDYING CLUSTER/GROUP DYNAMICS⇒
PROPERTIES OF MEMBER GALAXIES

RESULTS & OPEN PROBLEMS

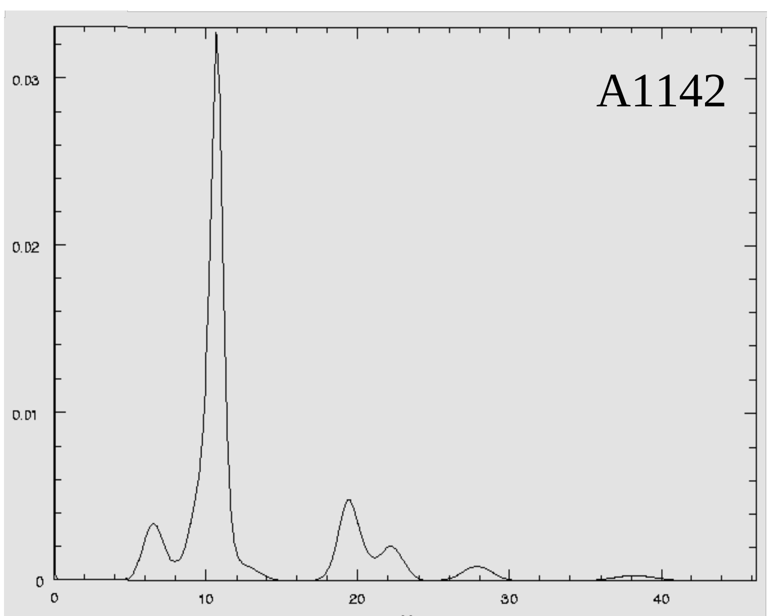
- General results on galaxy systems (MG; Biviano & co.).
- First results on very unrelaxed clusters (MG, Barrena & Boschin)-

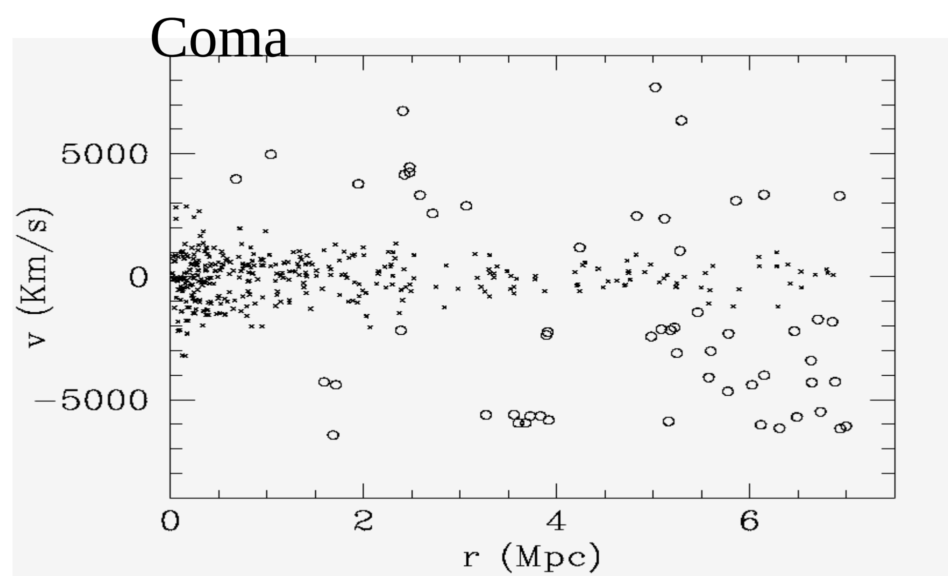
Selection of Cluster Members



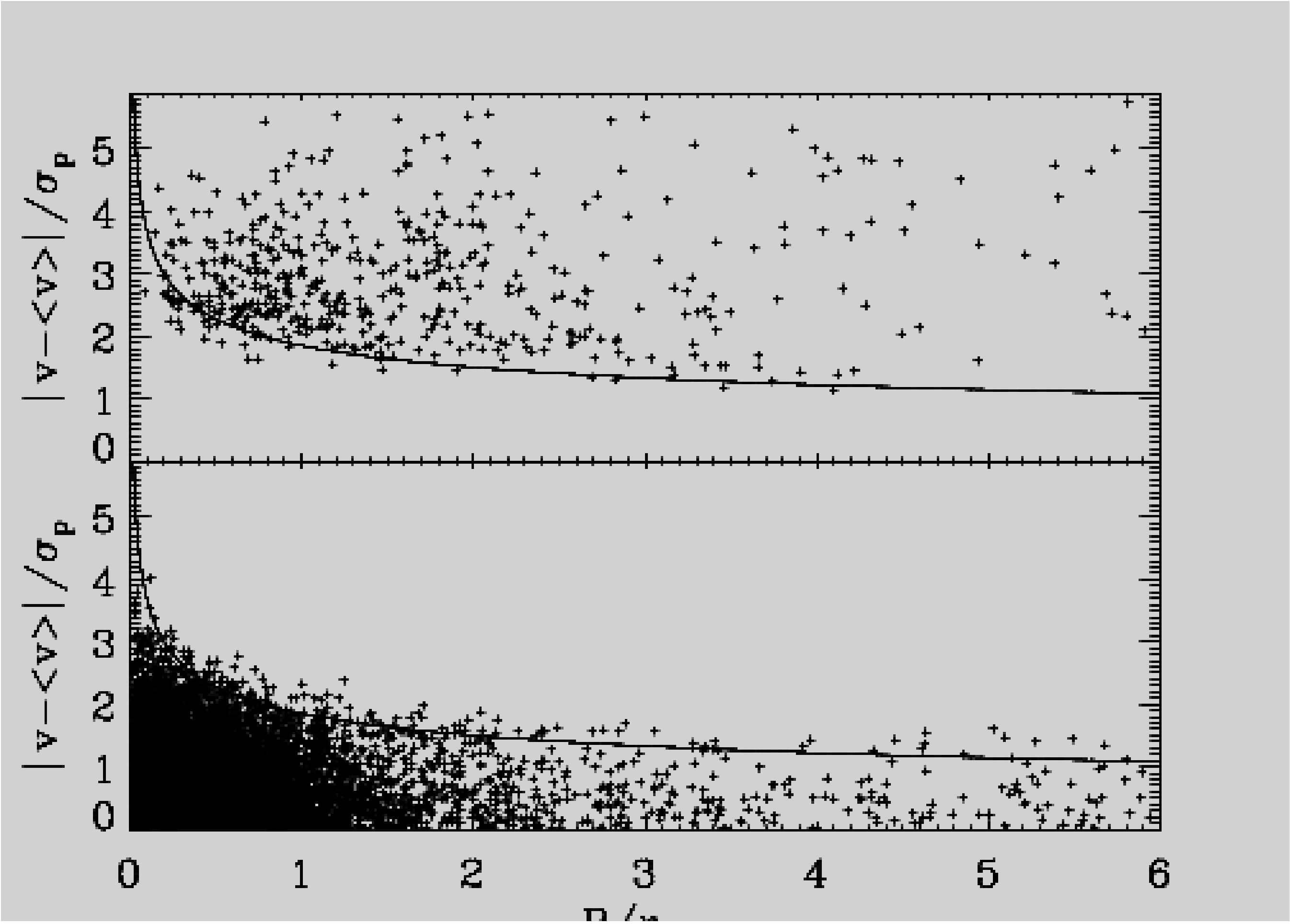
Density peaks in the LOS **velocity distribution** (Pisani 1993).

Velocity+position information (shifting gapper method; Fadda, MG et al. 1996).

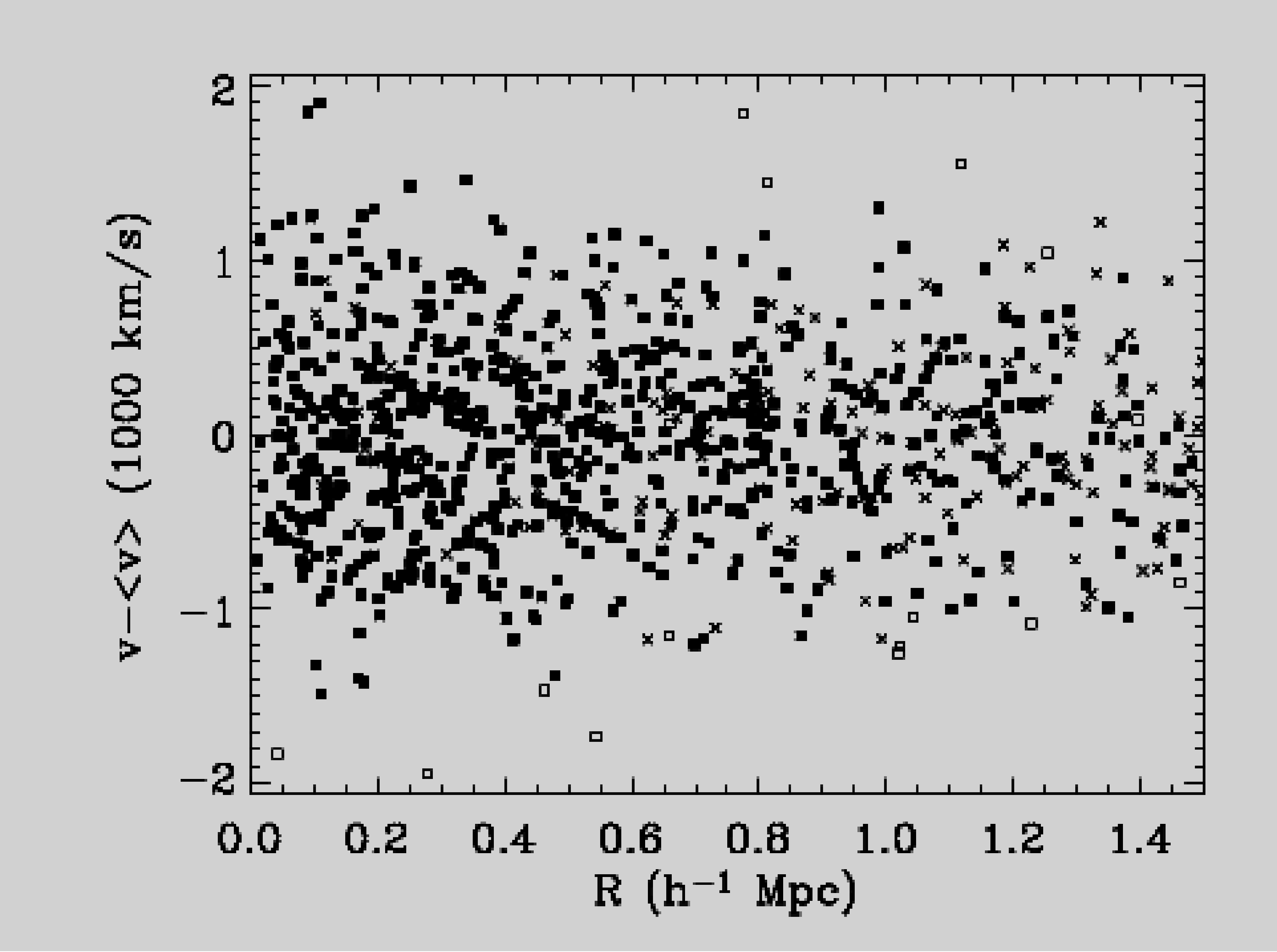




Other methods in the projected phase-space V vs.R
(e.g. based an iterative mass profile, Hartog & Katgert 96).
Result ENACS clusters (ensemble cluster of 3000 gals)
(Katgert, Biviano e& Mazure 04):



Member selection checked through N-body simulations (Biviano et al. 06). Good selection ------------------->**Less good**



CLUSTER MASS FROM THE VIRIAL THEOREM: THE OLD VISION (having poor data!)

BASED ON GALAXY POSITIONS AND VELOCITIES

ASSUMPTIONS: SPHERICAL SYSTEM+DYNAMICAL EQUILIBRIUM

$$M_{V,old} = 3\pi/2 \cdot \sigma_{proj}^2 2R_H/G$$

$\sigma_{proj} = \sqrt{(\Sigma_i(v_i - <v>)^2/(N-1))}$, velocity dispersion

$2R_H = N(N-1)/(\Sigma_{i\neq j} R_{ij}^{-1})$, R_H harmonic radius

MODER,N CORRECT VISION:

JEANS EQUATION ⇒ VIRIAL THEOREM

⇓

$$M_J(<r) = -\frac{r\sigma_r(r)^2}{G}\left(\frac{d\,ln(\rho(r))}{d\,ln(r)} + \frac{d\,ln(\sigma_r(r))^2}{d\,ln(r)} + 2\beta(r)\right)$$

$$\sigma^2_{proj}(R)\Sigma(R) = 2\int_R^\infty \rho(r)\sigma_r^2(r)\left(1 - \beta\frac{R^2}{r^2}\right)\frac{r}{\sqrt{r^2 - R^2}}dr$$

$\Sigma(R)$ projected spatial number density of gals

$\rho(r)$ spatial number density of gals recovered from $\Sigma(R)$

$\sigma_{proj}(R)$ projected (l.o.s.) velocity dispersion

$\sigma_r(r)$ radial component of the velocity dispersion

$\beta(r) = 1 - \sigma_\theta^2/\sigma_r^2$ velocity anisotropy parameter

$M(<r), \sigma_r(r), \beta(r)$=???

$\beta(r)$=0, or whole v-distribution $\Rightarrow \beta(r)$

$M_V = M_{V,old} - STC$

R_H is OK if $\rho_{mass} \propto \rho$

σ_{proj} is independent of v-anisotropy? (Often) YES!

STC depends on v-anisotropy at b the “boundary radius”

$$STC = M_{V,old}\left(4\pi b^3 \frac{\rho(b)}{\int_0^b 4\pi r^2 \rho dr}(\sigma_r(b)/\sigma(<b))^2\right)$$

(MG et al. 98; see The & White 86; Binney & Tremaine 87, Merritt 88).

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A FEW 100s, 1000 GALS !!!!!!!!

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THE “ENSEMBLE” GALAXY SYSTEM

Ensemble galaxy system:
stacking many clusters together, i.e.
combining together gals of many systems.

Normalized velocities and radii: $(v-\langle v \rangle)/\sigma_v$, R/R200.

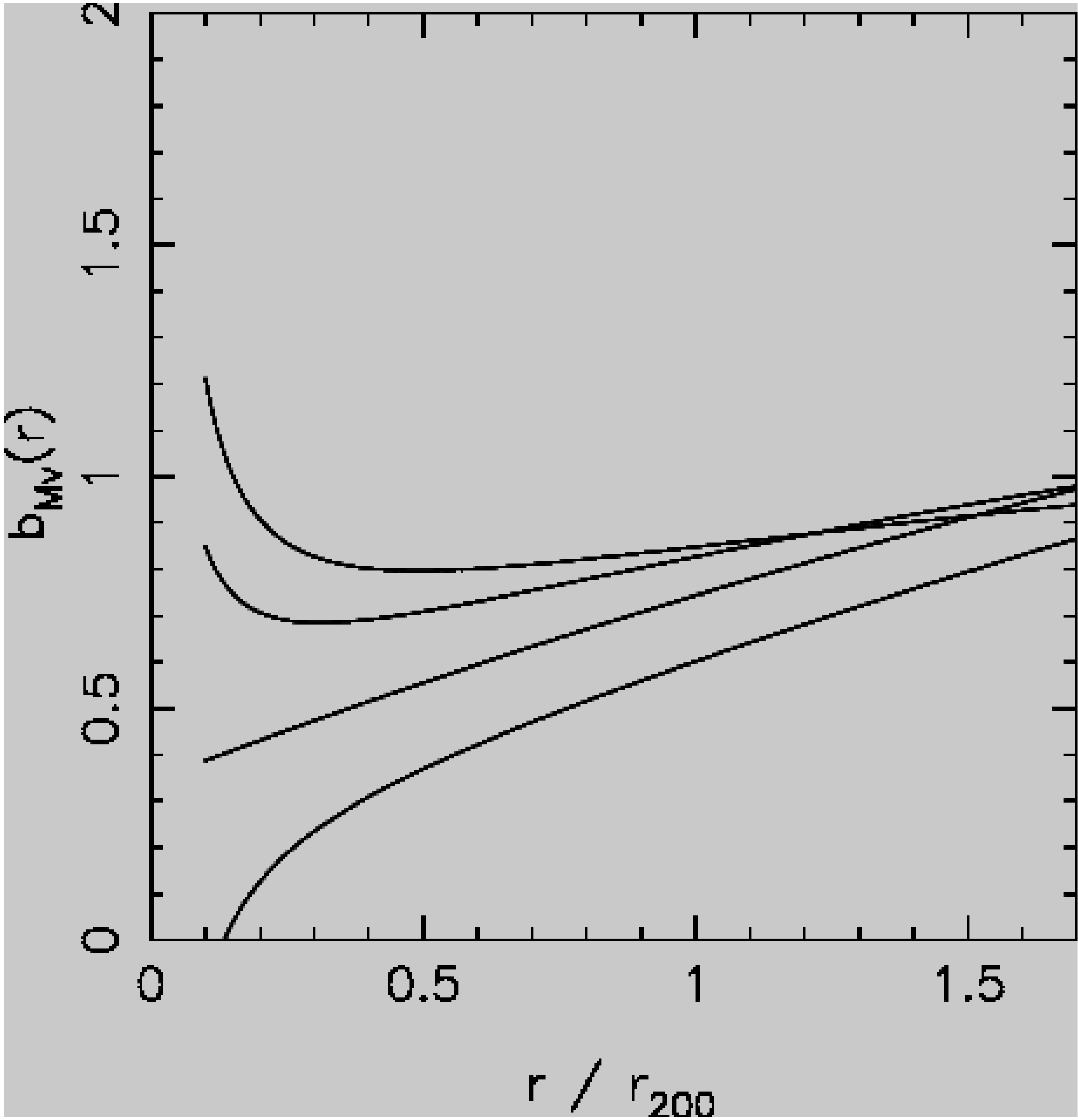
ENSEMBLE SYSTEM IS VERY USEFUL, BUT....
YOU LOOSE THE CLUSTER INDIVIDUALITY!

Mj/Mv,old
(CNOC, Carlberg et al. 1997)

Mj/Mv,old vs. R

For a large range of V-anisotropy params. β

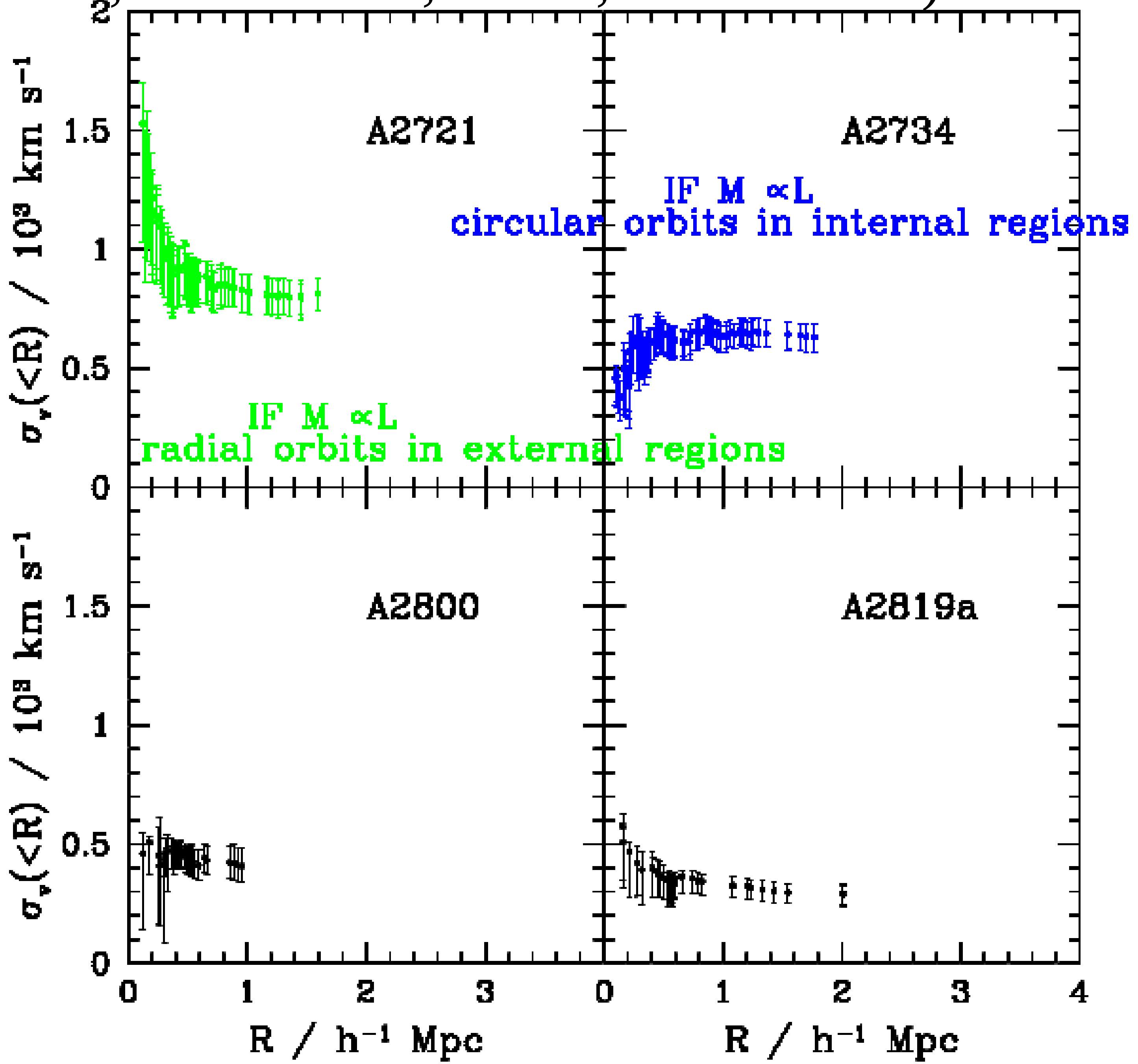
INDIRECT MEASURE OF STCorrection =20%



Integral Velocity Dispersion Profiles

(Hartog & Katgert 96;MG et al. 96; Fadda, MG et al. 96)

Possible velocity anisotropies affect σ_v-estimate in central cluster region, but do not affect global estimate.



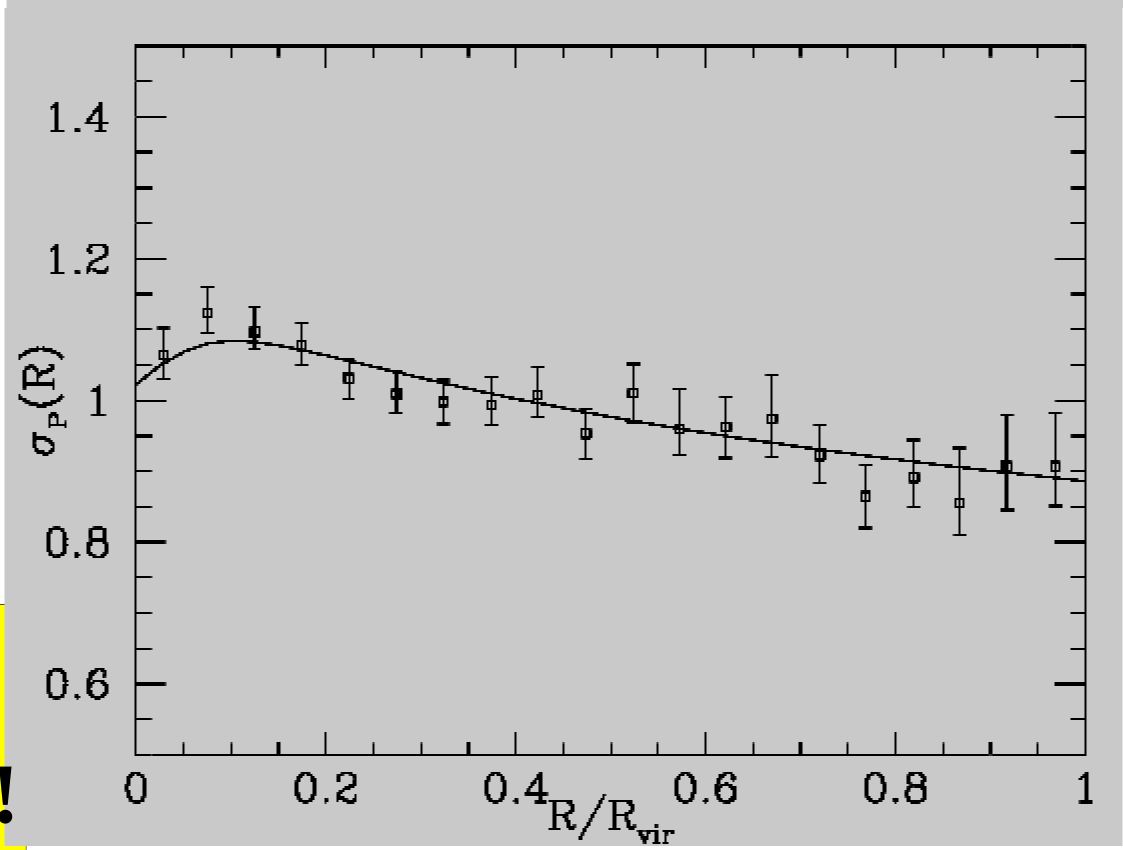
Differential Velocity Dispersion Profile

(MG et al. 98, 160 clusters, 8000 gals)

Ensemble cluster built with gals of 160 nearby clusters⇒obs. profile

Jeans eq.+ mass distribution+assumption for v-anisotropy⇒theoretical profile.

Mass-follows-light assumption



Velocity anisotropy parameter

$\beta(r)=1-\sigma_\tau(r)^2/\sigma_r(r)^2=0$:

χ^2 **goodness of fit is 96%.**

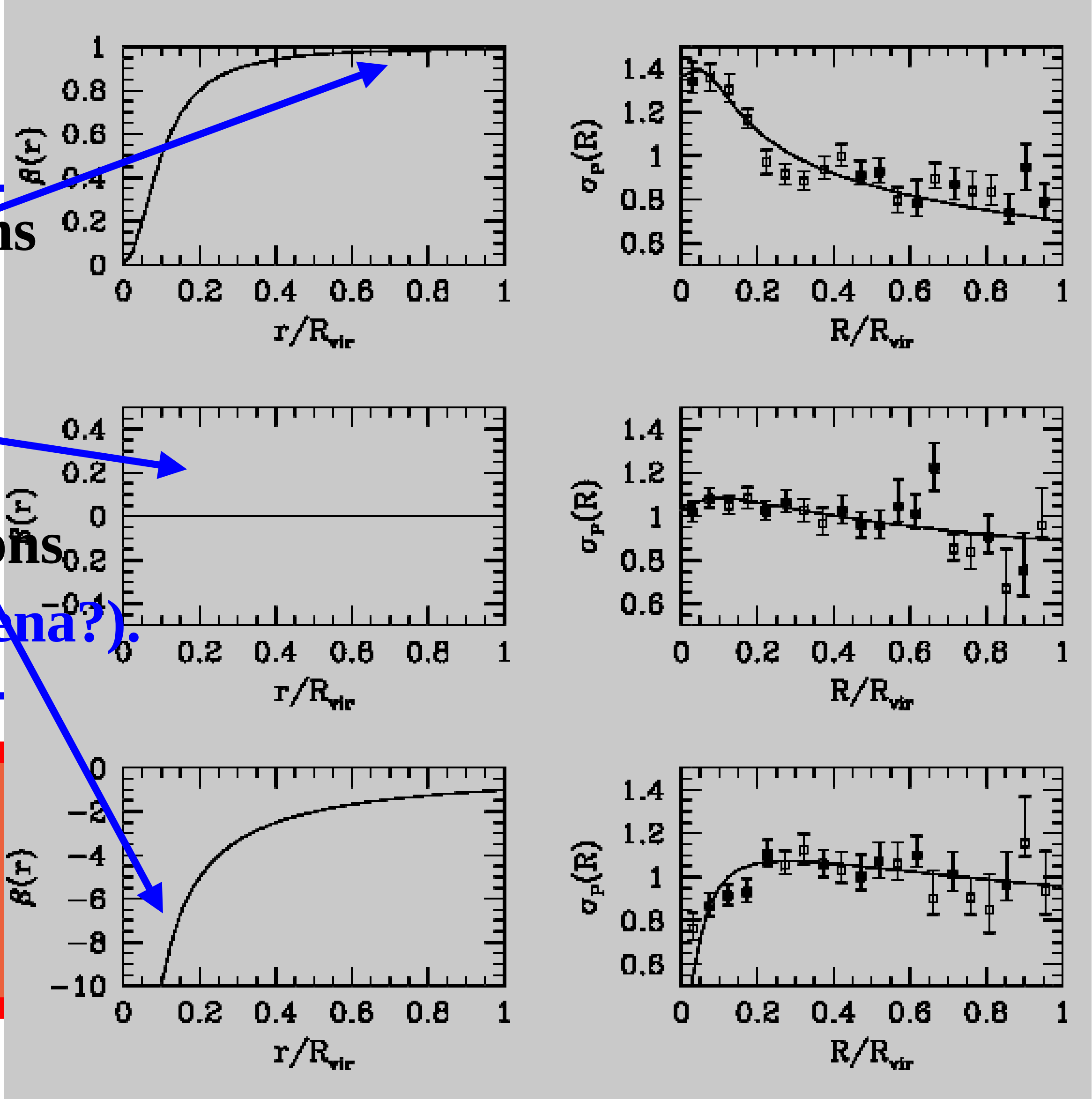
The "average" cluster has isotropic velocities!

DIRECT ESTIMATE OF THE STCORRECTION=20%

Three families of clusters (MG et al. 98) based on the individual integral profiles

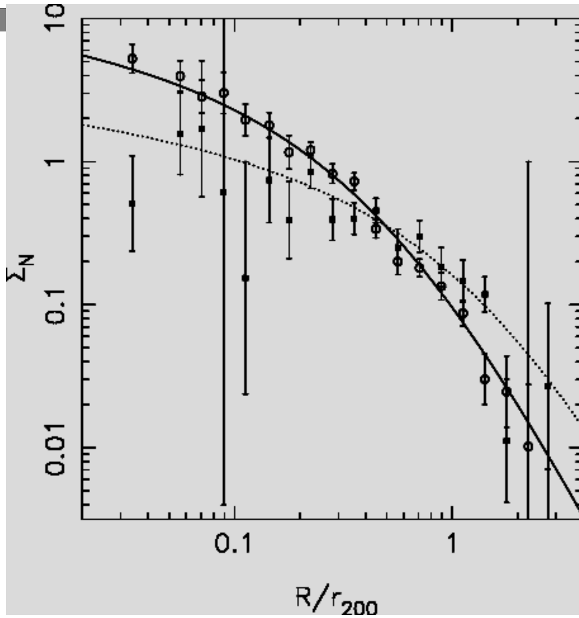
$\beta(r)=1-\sigma_{\tau}(r)^2/\sigma_r(r)^2$

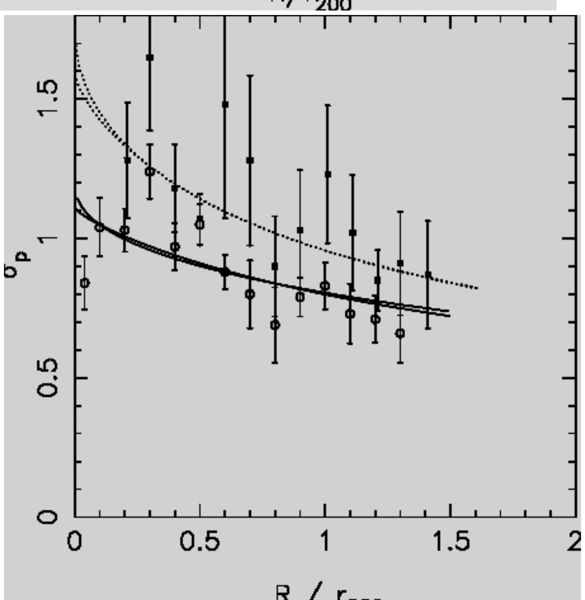
Radial orbits in external regions
(infall of galaxies?);
isotropic orbits
(violent relaxation?);
circular orbits in internal regions
(secondary relaxation phenomena?).



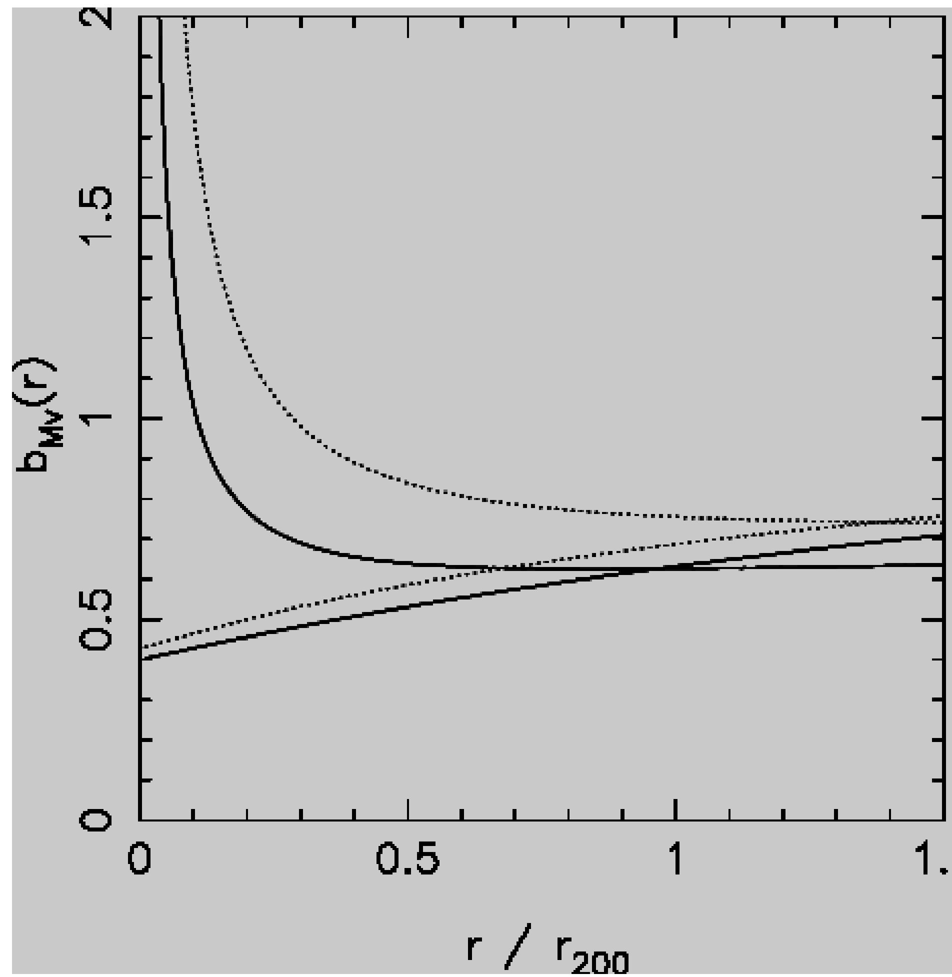
STCorrection can be large
as 40% for a large amount
of radial orbits.

Both red and blue gals are in dynamical equilibrium within clusters(CNOC Carlberg et al. 1997)



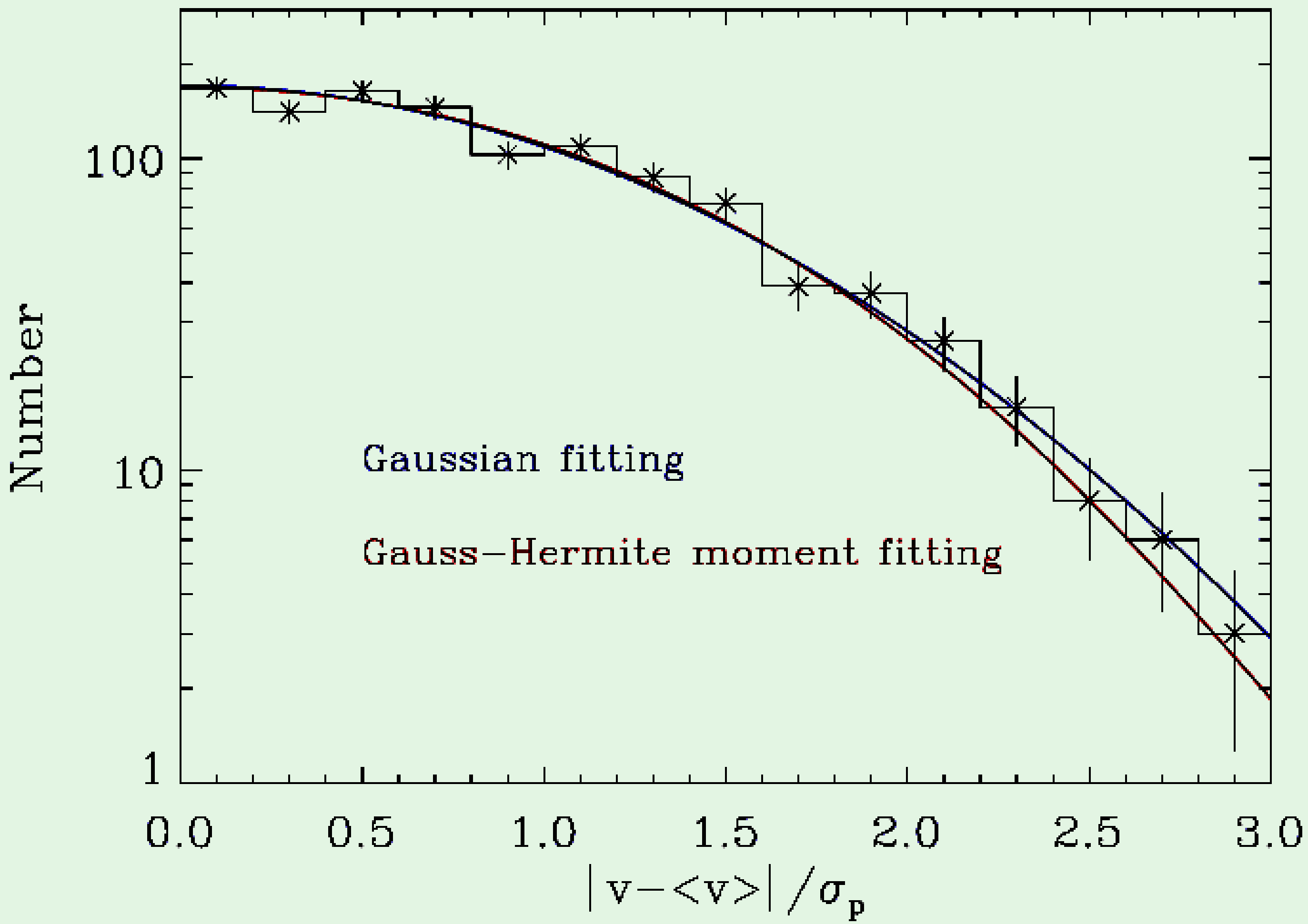


Mj/Mjv,old vs. R



USING THE WHOLE V-DISTRIBUTION, i.e. higher moments, to break the degeneracy between the mass and the velocity distribution **(e.g. Merritt 1993; van der Marel 2000).**
Katgert, Biviano & Mazure (2004)

E+S0 HAVE ISOTROPIC ORBITS (β=0)



“MASS FOLLOWS LIGHT” IPOTHESIS

From gravitational lensing and X-ray studies.

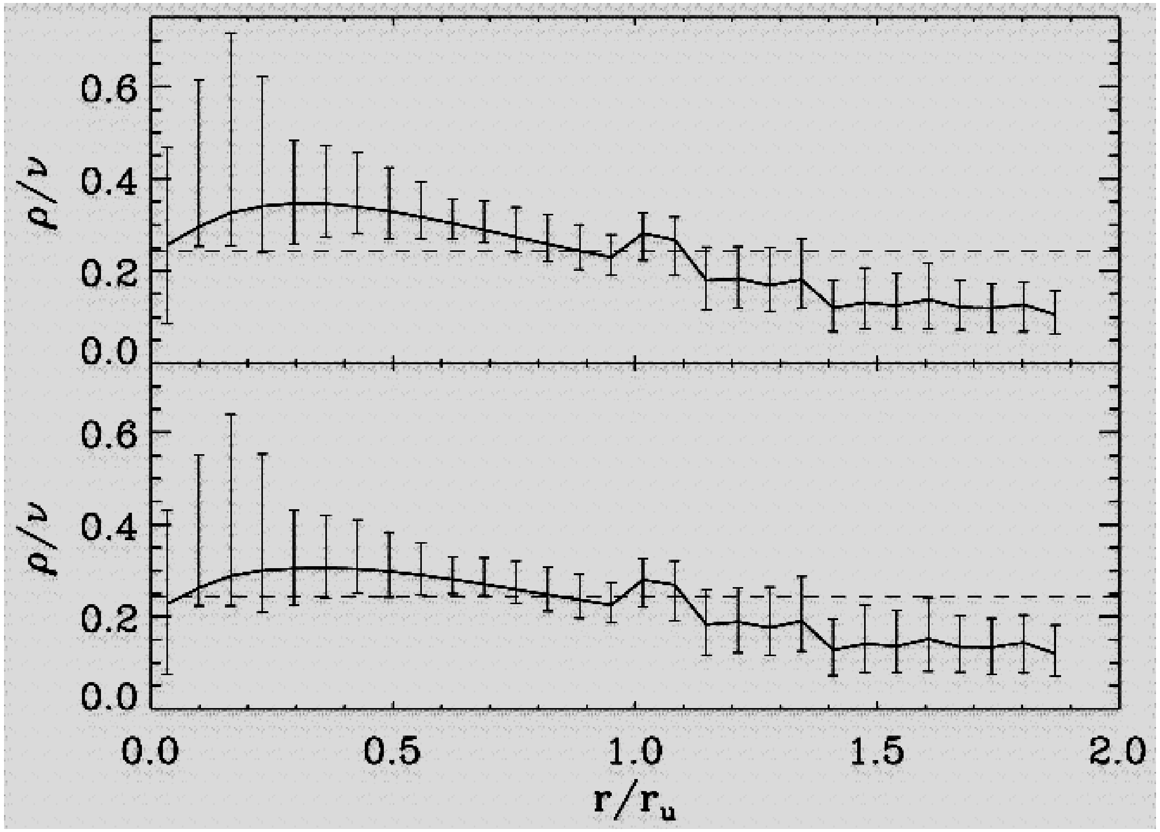
From gals studies, too:

Biviano & MG 03; Katgert, Biviano & Mazure 04

MASS TO NUMBER DENSITY PROFILE (2000 gas of 2dF clusters)

FOR ALL GALAXIES

FOR RED GALAXIES



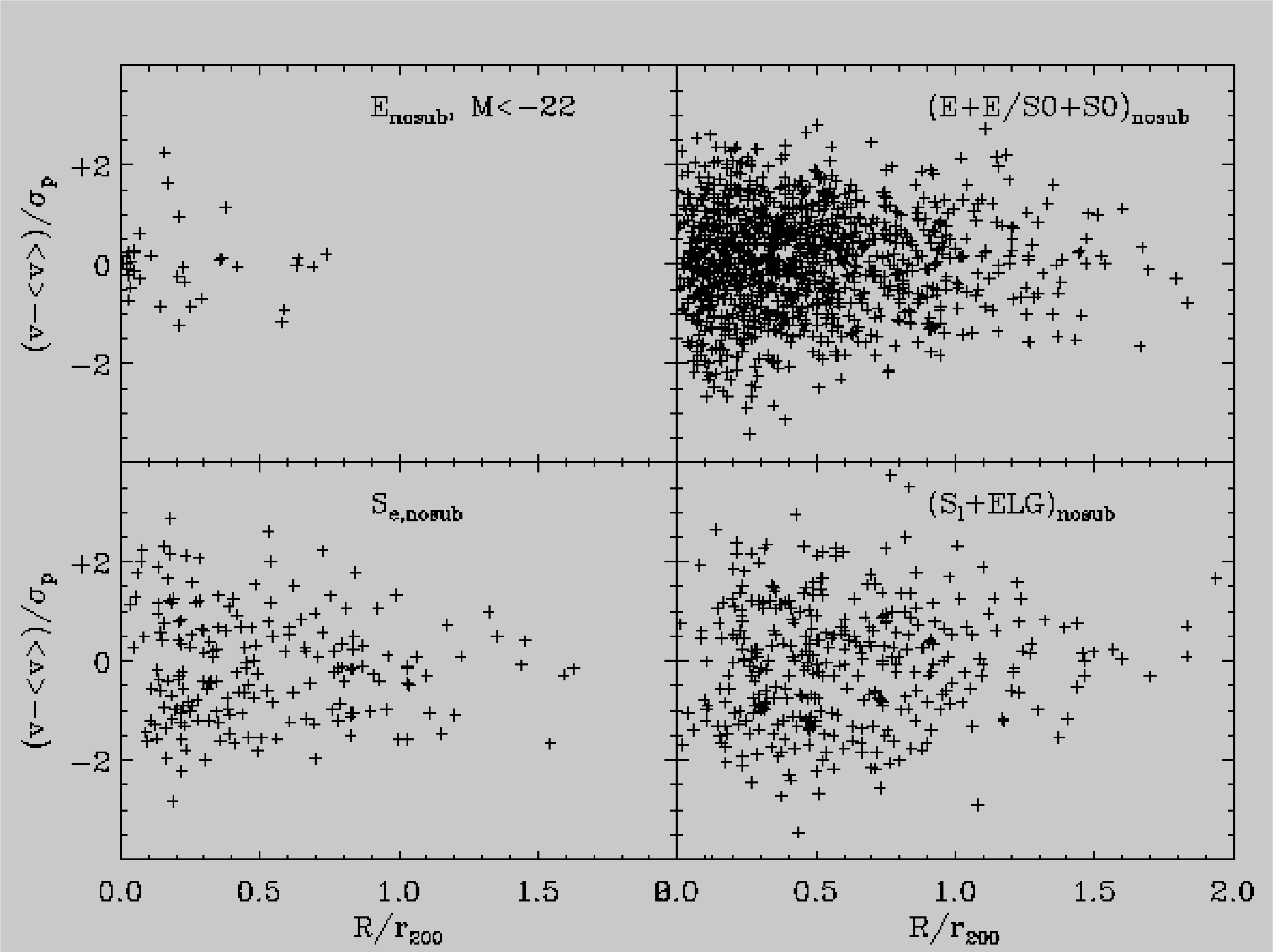
INTERESTING RESULTS ON MASS DISTRIBUTION (OK NFW prof.)

GALAXIES OF DIFFERENT TYPES

IN THE PROJECTED PHASE SPACE

Katgert, Biviano & Mazure (2004)

ENSEMBLE ENACS CLUSTERS = 3000 gals



Biviano & Katgert (2004):

Jeans eq. +

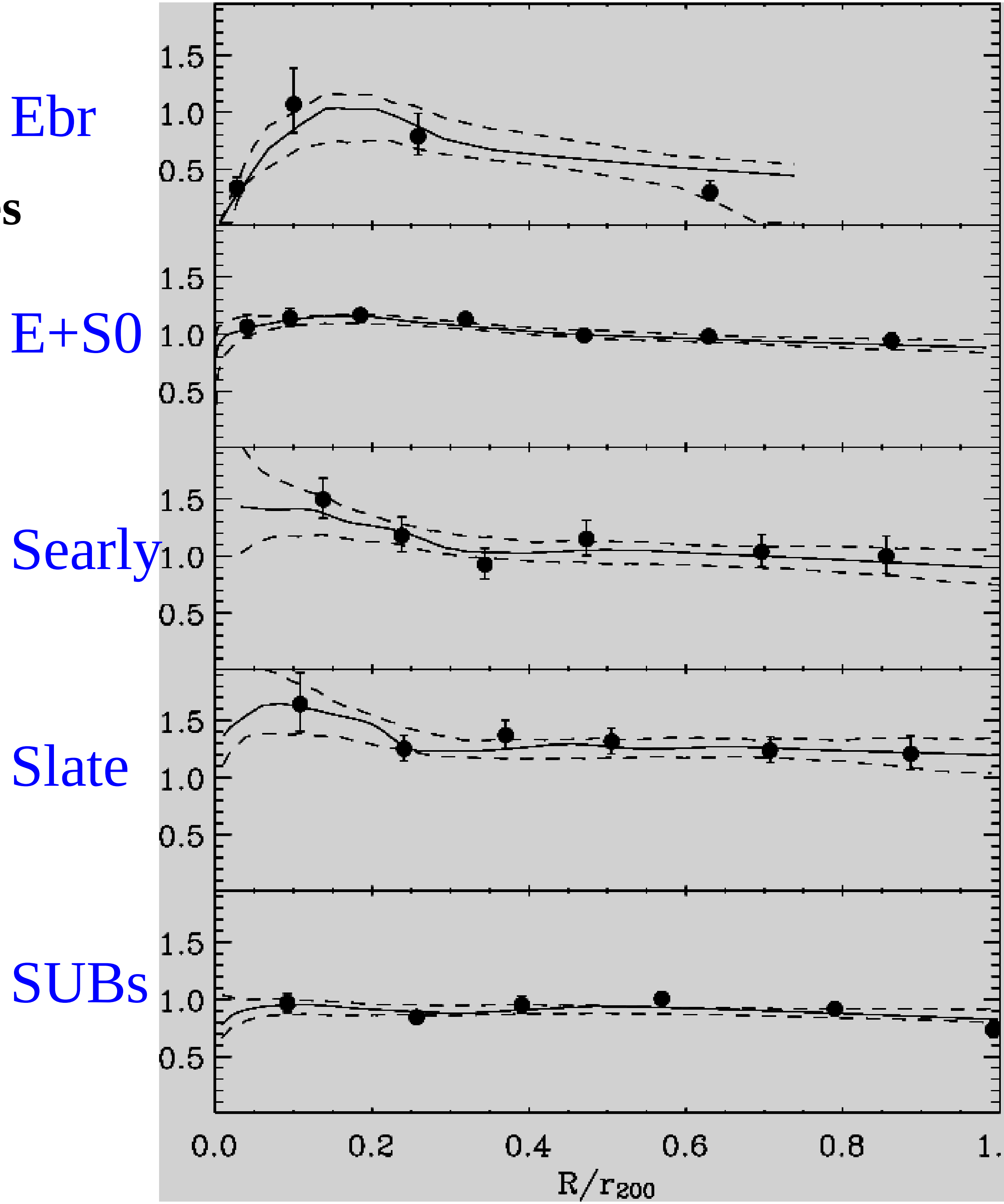
isotropic orbits for E galaxies

V-ANISOTROPY
PROFILES
FOR
DIFFERENT TYPES
OF GALAXIES

+

DENSITY PROFILES

STUDY OF GALS ORBITS.



RESULTS FROM STACKED ENACS CLUSTERS

3000 gals with morphol. Biviano,Katgert and co.

- luminosity density of E+S0 gals traces total-mass density and orbits are isotropic;

- Searly have almost isotropic orbits (Searly ---> S0?);

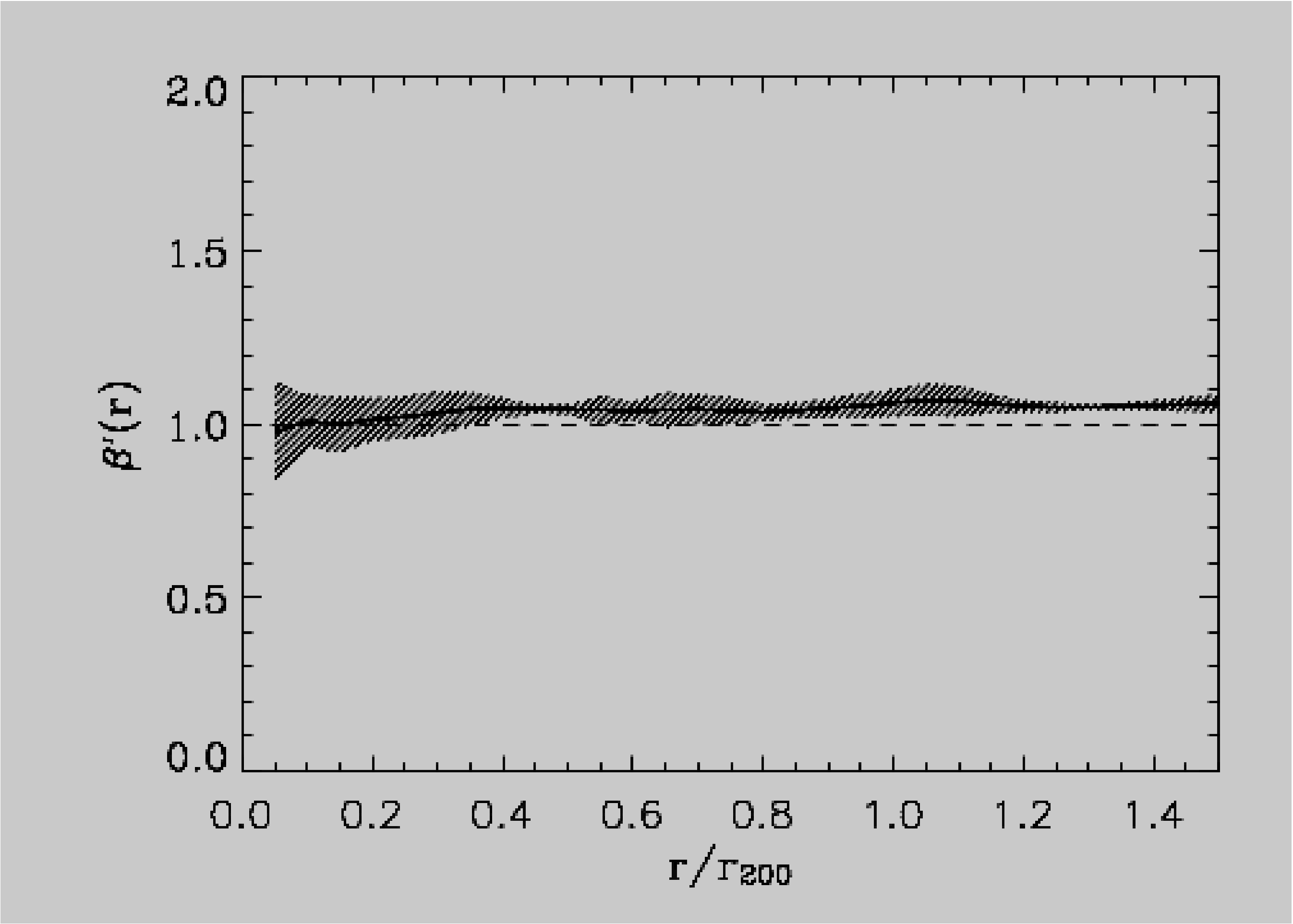
- Slate(Slate+Irr+ELGs) have radial orbits (at their first infall?);

- Ebright no solution of Jeans eq. (dyn.friction?, mergers?).

E+S0 GALAXIES

Quite isotropic orbits

$\beta'=1-\beta$



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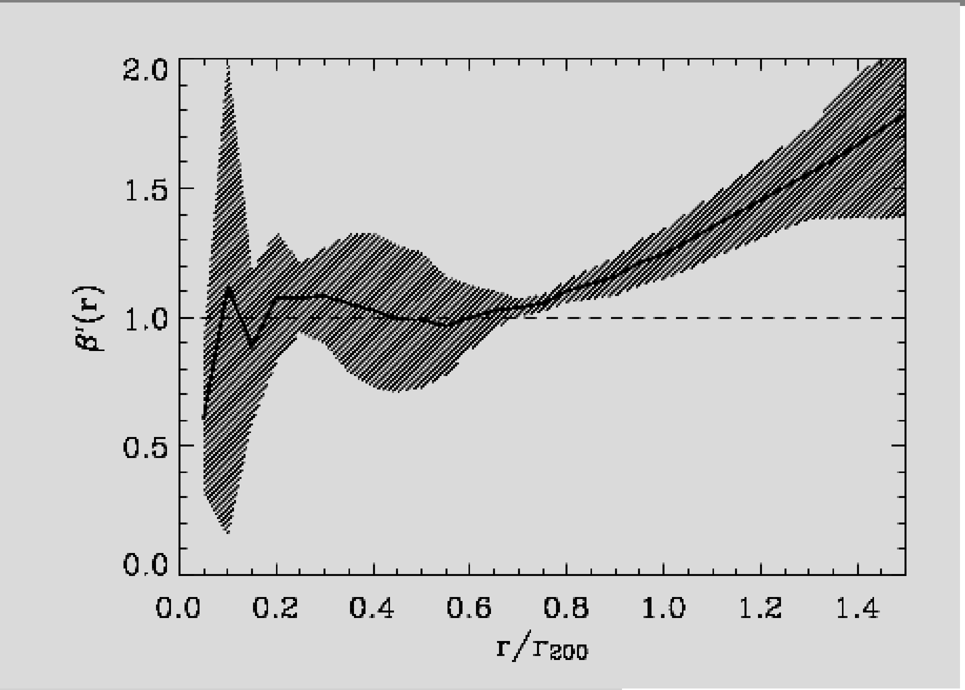
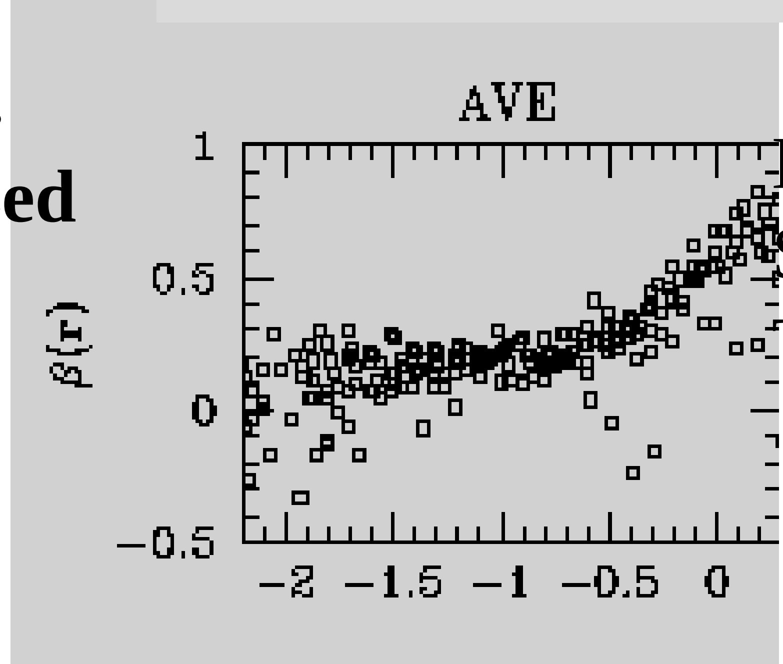
LATE TYPE GALAXIES (Slate+Irr+ELG)

Radial orbits in external cluster Regions. See also Ceccarelli et al. 95.

$\beta' = 1 - \beta$



SCENARIO
Sl are at their first infall.
Then orbits are isotropized
(maybe due to
the effect of ICM,
e.g. Dolag et al. 09?)



N-body Simulations, Tormen 1997

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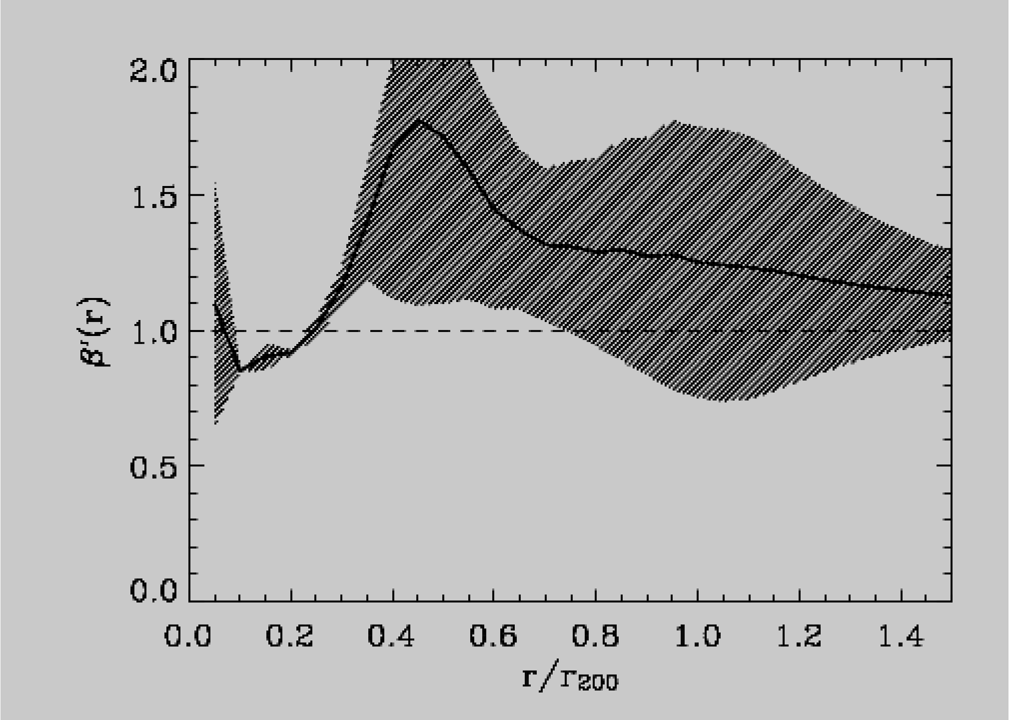
Searly=Sa+Sb

Isotropic orbits: acceptable!

$\beta' = 1 - \beta$



POSSIBLE SCENARIO:

Likely, Se have already crossed the cluster core.

Then Se transform in S0:

-increase of S0 since z=0.5 (Dressler et al. 97;Fasano et al. 00);

-local proj density around Se < S0 (Thomas et al. 04);

-similarity of Se and S0 bulges (Thomas et al. 04).

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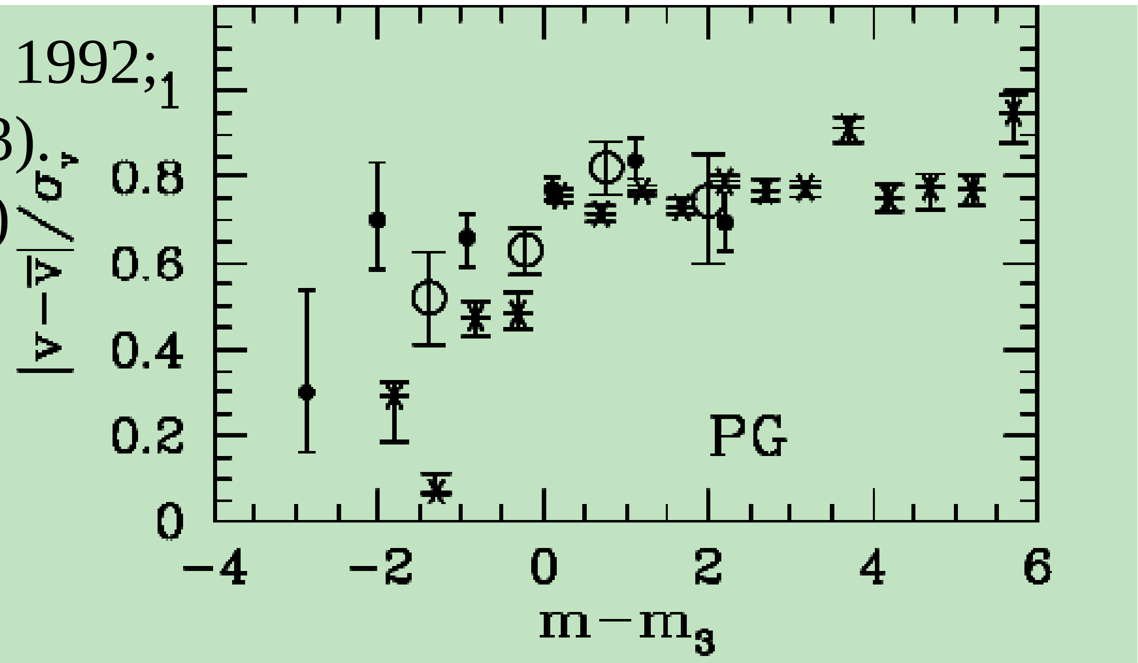
NO Jeans solution for Ebright!

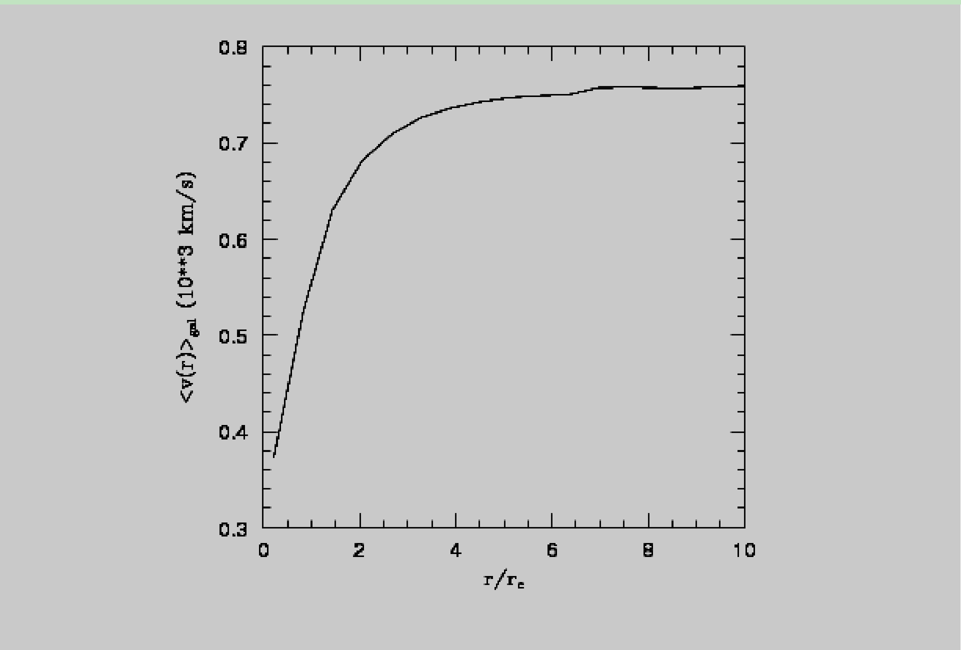
see also luminosity segregation in the velocity space

(3000 cluster galaxies, Biviano et al. 1992;
1500 group galaxies, MG et al. 2003).
See also ENACS (Biviano et al.2002)
e SDSS clusters (Goto 2005).



POSSIBLE EXPLANATION:
DYNAMICAL FRICTION

Menci & Fusco Femiano 98
COLLISIONS
+GALS MERGERS



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- **Searly have almost isotropic orbits (Searly ---> S0?);**
- **Slate have radial orbits (gals at their first infall? cf. N-body);**
- **Ebright no solution of Jeans eq. (dyn.friction?, mergers?).**

OPEN PERSPECTIVES/PROBLEMS:

Cluster outskirts (NO Jeans eq., member selection);

Studying families clusters with different properties (statistics!);

Groups (statistics!,member selection!,gals interactions!);

Other galaxy populations (e.g. dwarfs);

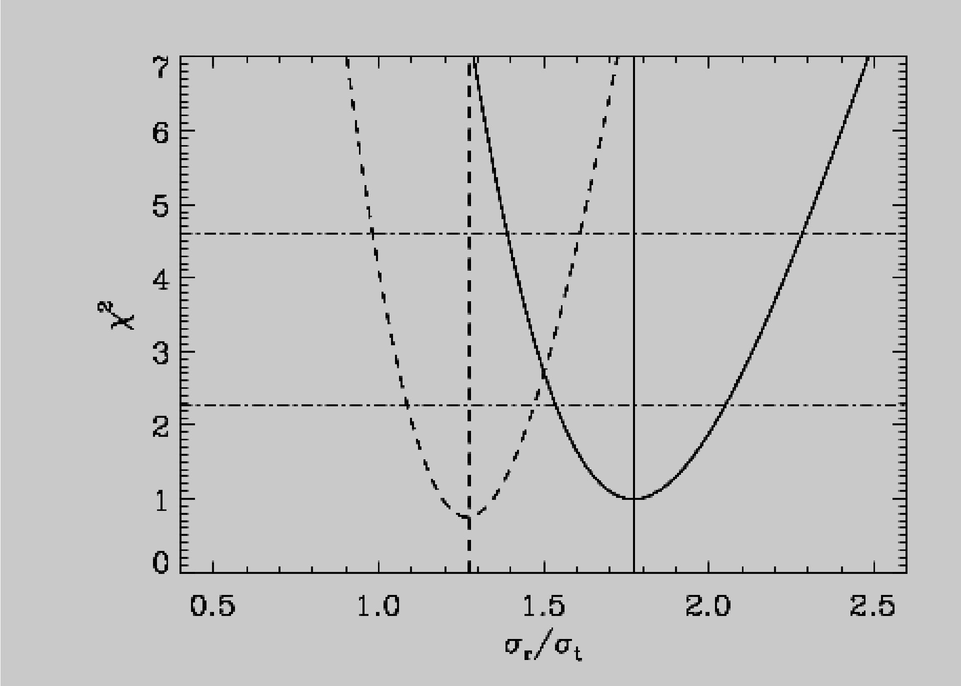
Distant clusters (member selection?;+infall?; +clust. merger?).

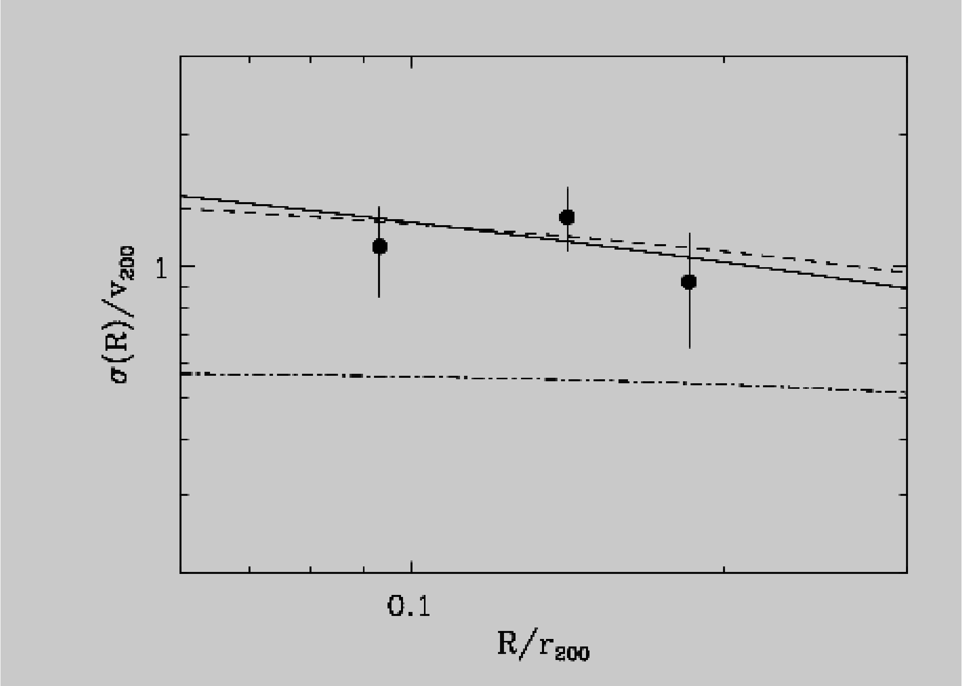
COMA DWARFS
(Adami, Le Brun, Biviano et al. 2009)

Coma dwarfs show radial orbits even close to the cluster center!

POSSIBLE SCENARIO:

Dwarfs are remnants of gals that fall into Coma with radial orbits....e.g. Sl transformed in Dwarfs?





DISTANT CLUSTERS

CNOC (van der Marel et al. 2000) at z=0.3.

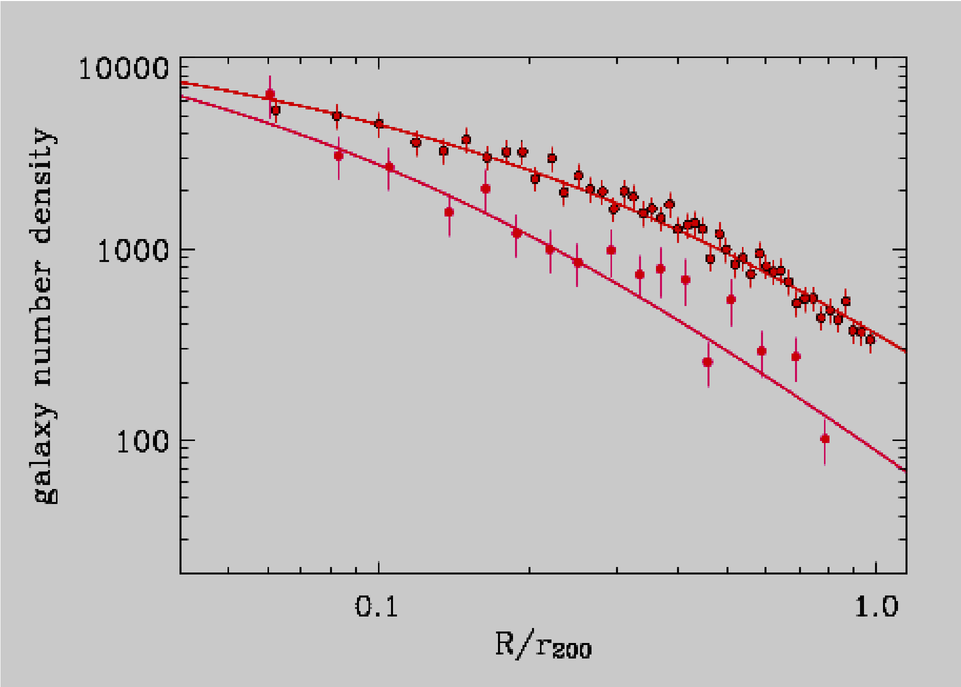
Results on V-anisotropy OK with ENACS.

(EdisCS+) Biviano & Poggianti 2009 at z=0.4-0.8

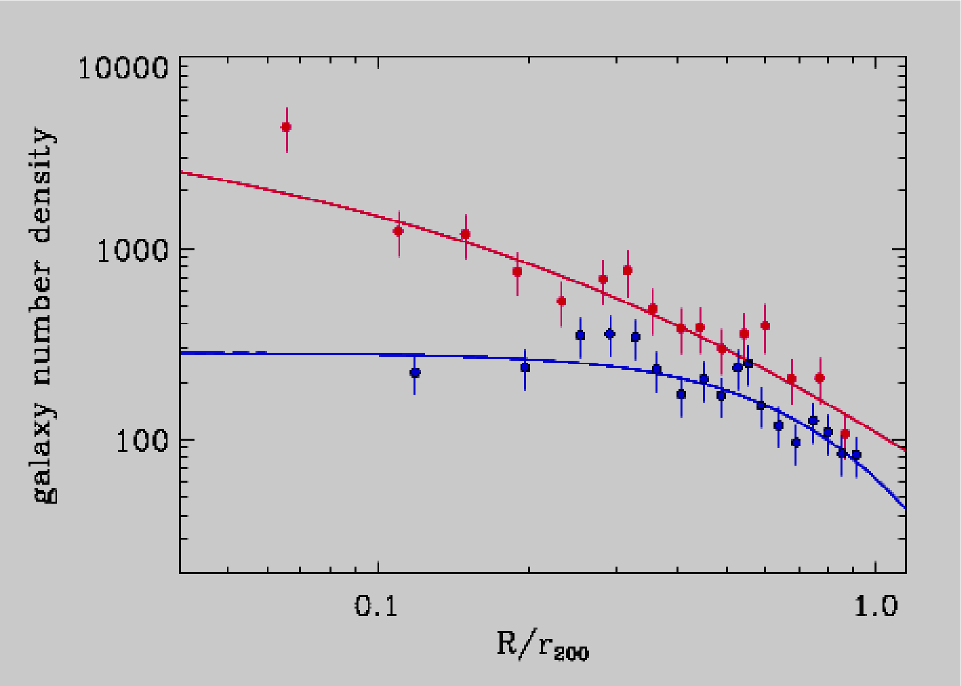
“Progenitors of ENACS clusters”

High-z NELGs are more concentrated than low-z ones

NELGs



ELGs

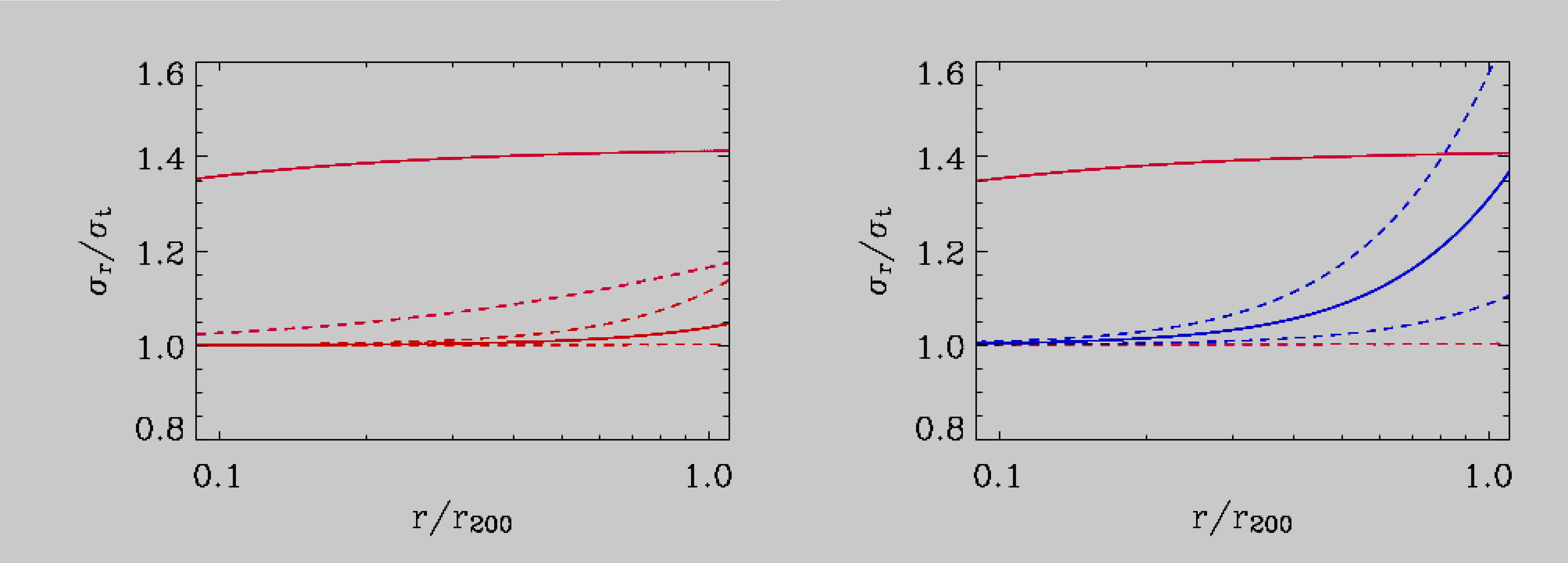


DISTANT CLUSTERS

High-z galaxies have somewhat more radial orbits.

Are we looking at the cluster formation?

NELGs ELGs



WHAT ABOUT
(VERY) UNRELAXED CLUSTERS?

FIRST RESULTS
FROM DARC SAMPLE

Ongoing DARC program

http://adlibitum.oat.ts.astro.it/girardi/darc/DARC_Welcome.html

Dynamical Analysis of Radio Clusters based on galaxies

MG, R. BARRENA(IAC),W. BOSCHIN (TNG),+...

Biviano, Ellingson, Feretti, Mercurio, Ramella, Spolaor,...

See, e.g. Feretti and Giovannini papers on halo/relics topic.

Connenction between extended diffuse radio-emission (radio halos/relics) and cluster dynamics ?

SPECTRA acquired at the TNG
Telescopio nazionale Galileo
+WHT+ESO3.6+lit.
+IMAGING at the INT
 (+Chandra archive)

STATUS OF THE ART & RESULTS

Each cluster with **80 member gals tracing a large part of R200.**

DARC CLUSTERS ARE FAR FROM DYN. EQUILIBRIUM, LIKELY CLUSTER MERGERS:

we detect subclumps and estimate relative dynamics.

Pilot: A209, Mercurio et al. 2003, z=0.21, Tx=10keV, NTT+ 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.

A697, Girardi et al. 2006, z=0.28, Tx=10keV, TNG+INT+Chandra arch.

A773, Barrena et al. 2007, z=0.22, Tx=9keV, TNG+INT+Chandra arch.

A115, Barrena et al. 2007, z=0.19, Tx=8keV, TNG+INT

A610-A725-A796, Boschin et al. z=0.1, poor clusters, WHT+SDSS+INT

A520, Girardi et al. 08,z=0.2, Tx=8keV, TNG+CNOCspec

A959, Boschin et al. 09 , z=0.28, Tx=6keV, TNG+SDSS

A1240, Barrena et al. 09, z=0.19, Tx=4keV, TNG+INT+Chandra arch.

A2294, Girardi et al. in prep., TNG+INT+Chandra arch.

A2345, A1758,A1995 data reduced

A2254, A545,ZwCl2341 to complete observations.

RESULTS:

MAJOR MERGERS (BIMODAL CLUSTERS)--->
2 Dominant gals far in V and/or 2D.

COMPLEX MERGERS--->
A few luminous galaxies.

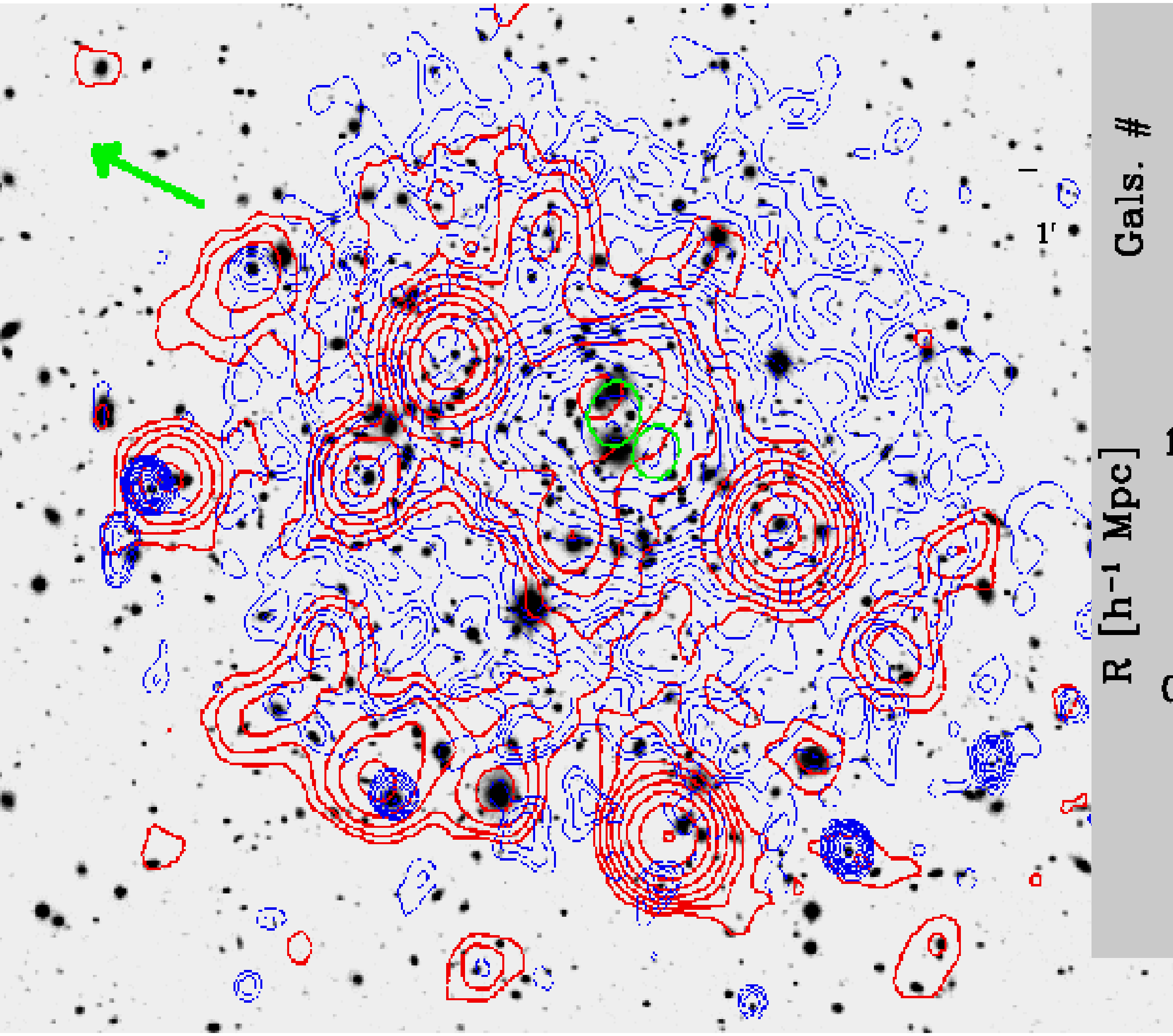
SUBSTRUCTURE (REMNANTS OF A MERGER?)--->
2 close Dominant galaxies,
1 Dominant gal (+a few luminous galaxies).

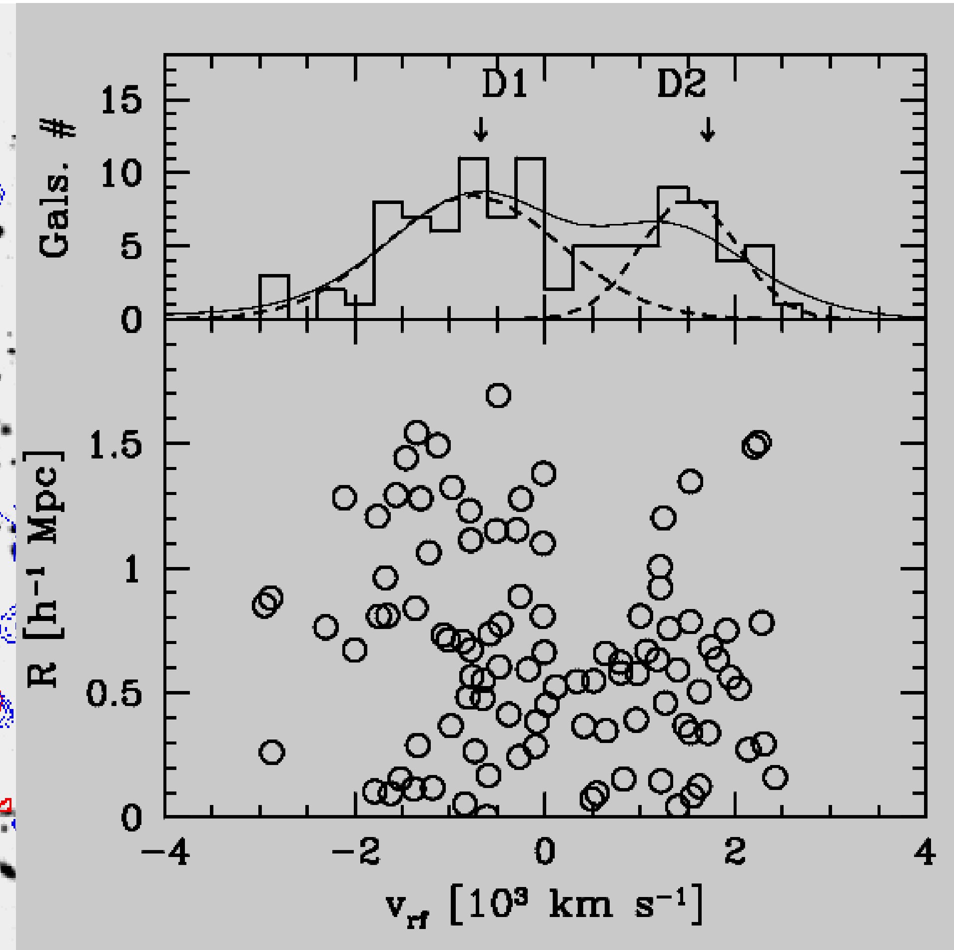
MOST LUMINOUS GALAXIES TRACE CLUSTER SUBSTRUCTURE

A773, z∼0.22

σ_v about 1400 kms-1

Barrena, Boschin, MG, and Spolaor, AA 2007





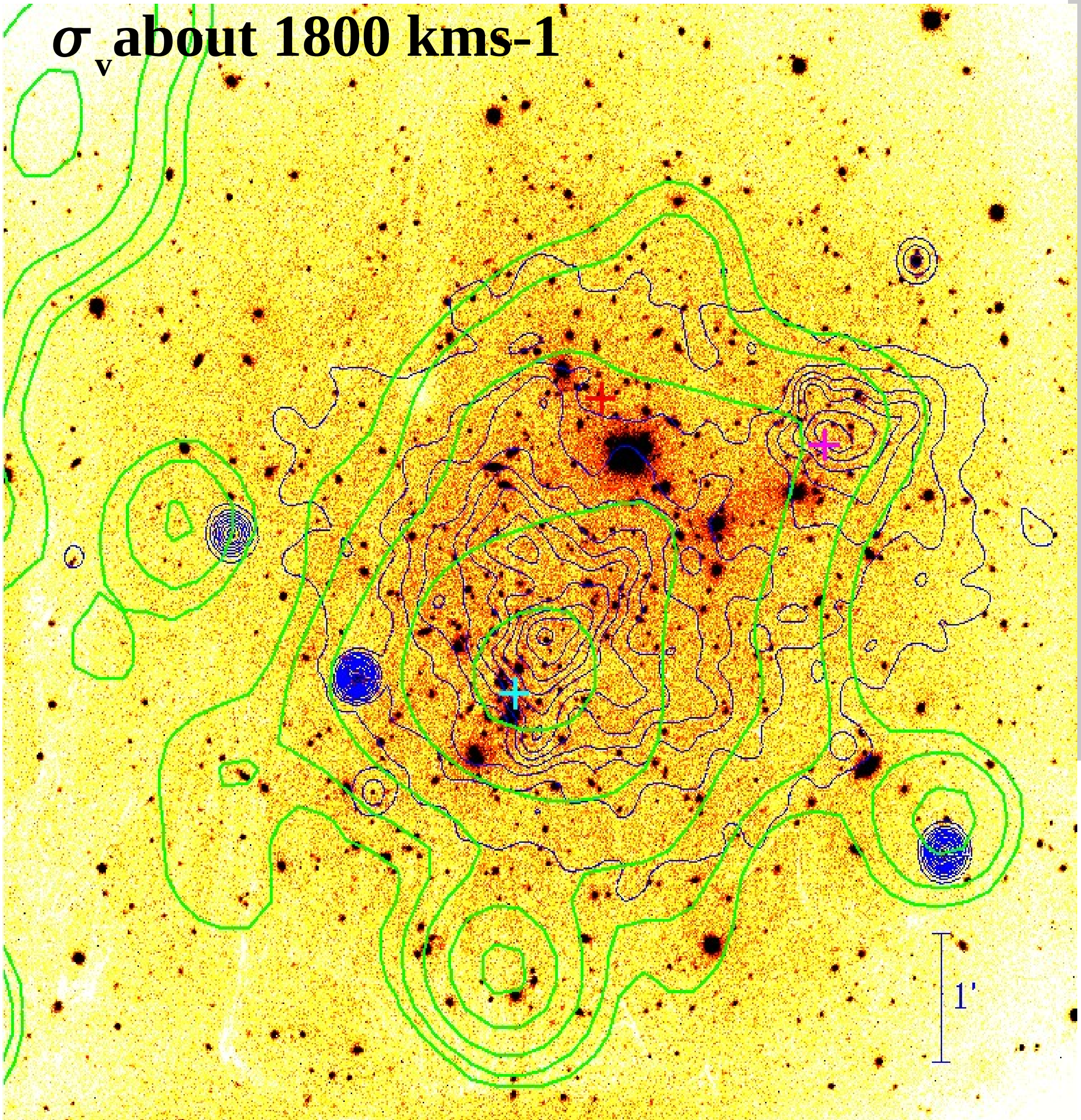
2 clumps in los V, 2DOMs

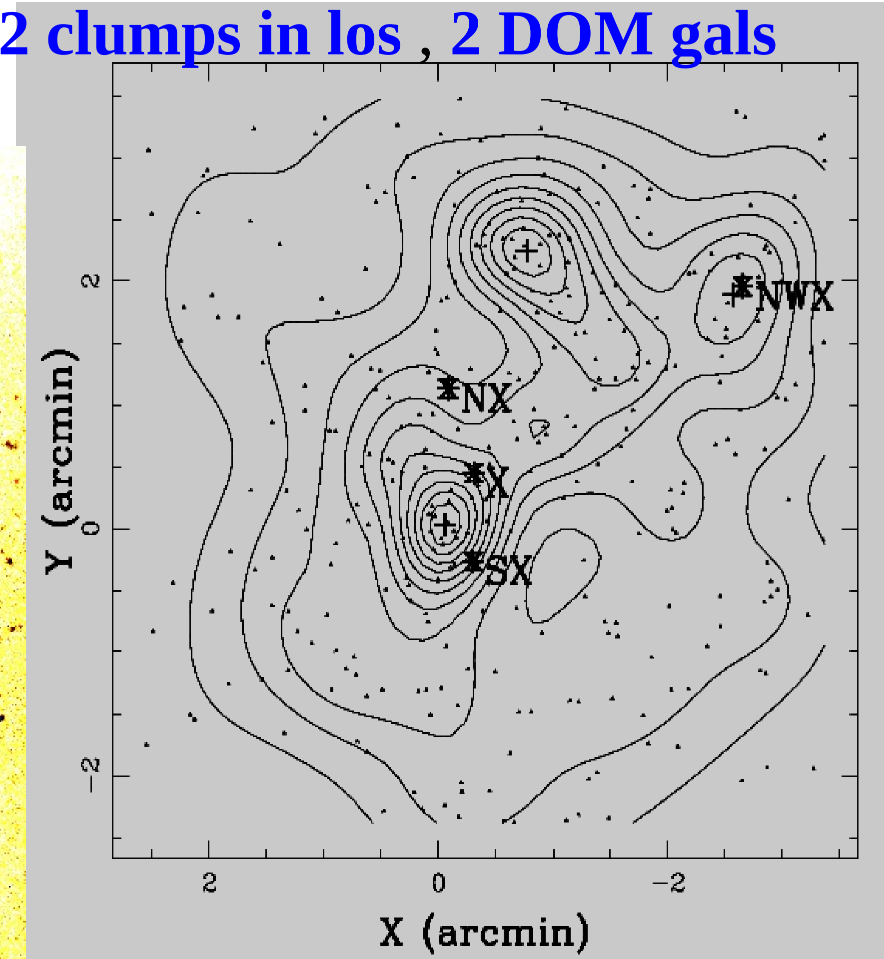
A2744, z ~ 0.31

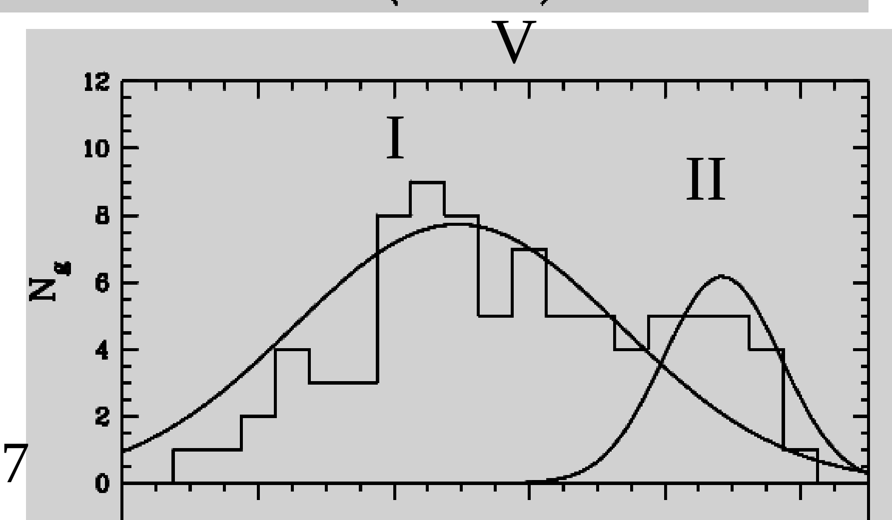
(Boschin, MG, Spolaor, and Barrena AA, 2006)

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

σ_v about 1800 kms-1







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

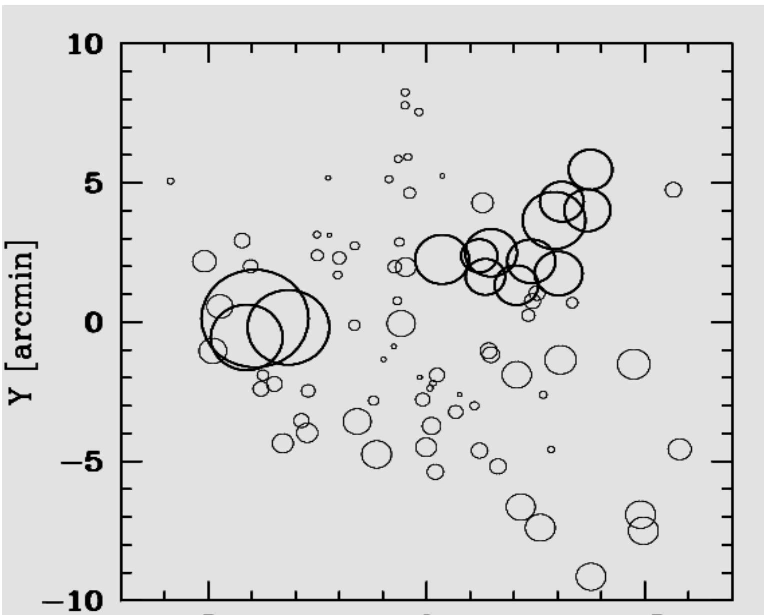
A115, z~0.19

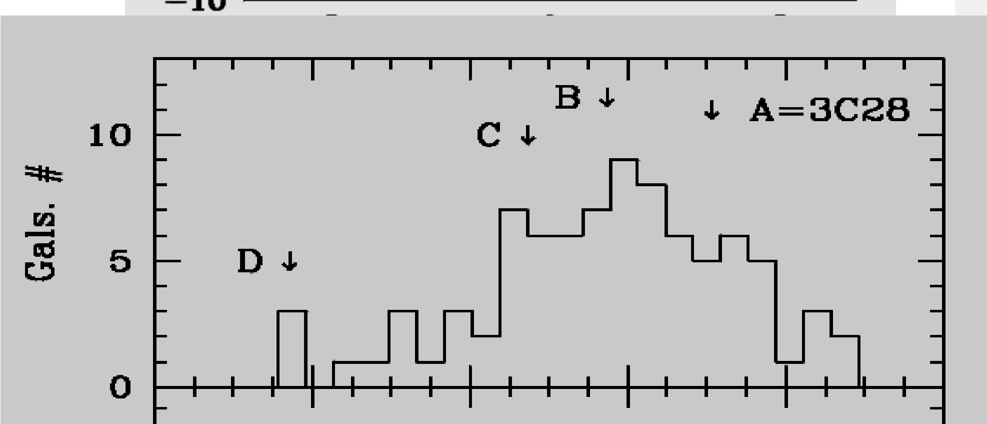
σ_v about 1400 kms-1

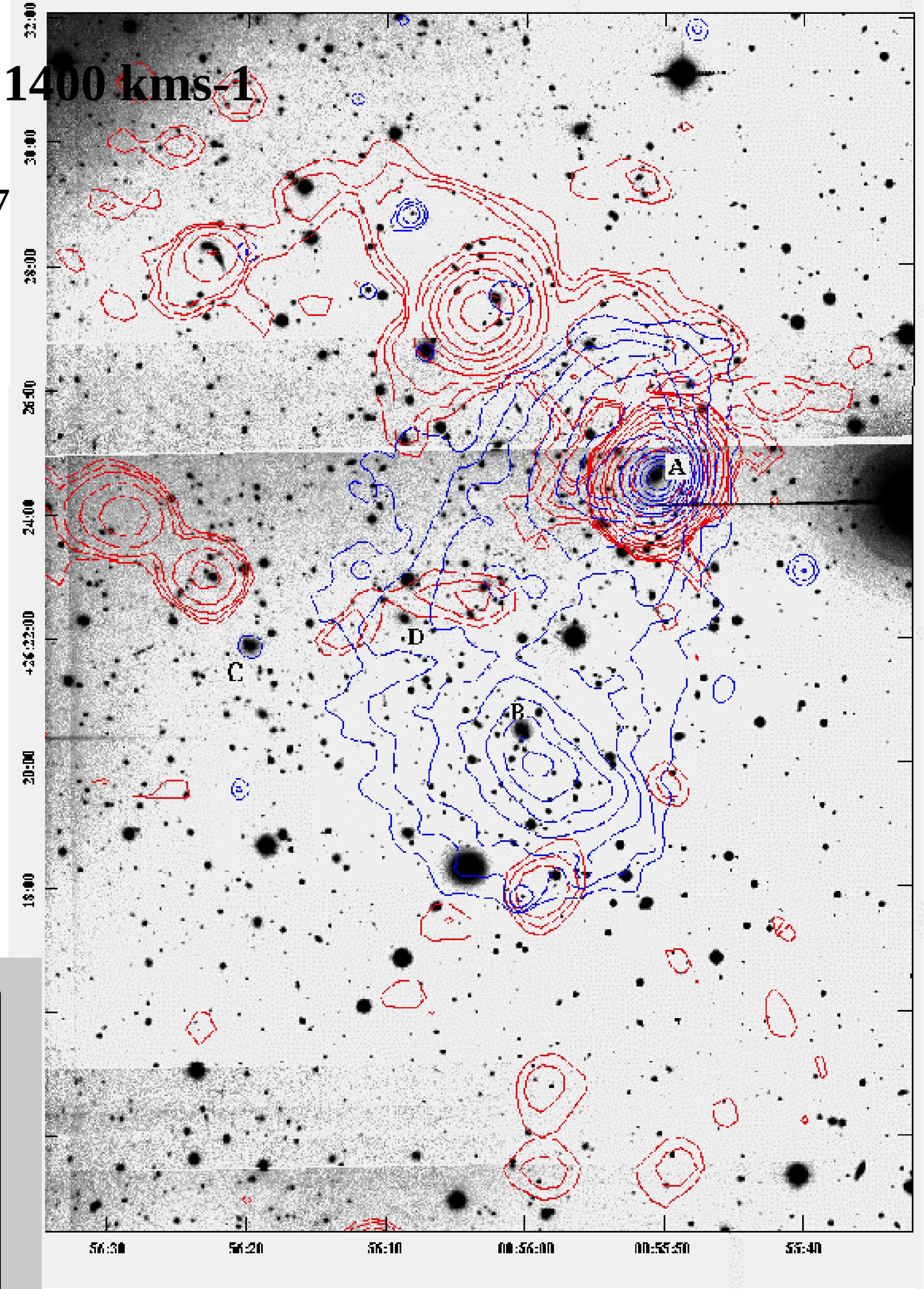
Barrena, Boschin, MG, & Spolaor 07

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

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



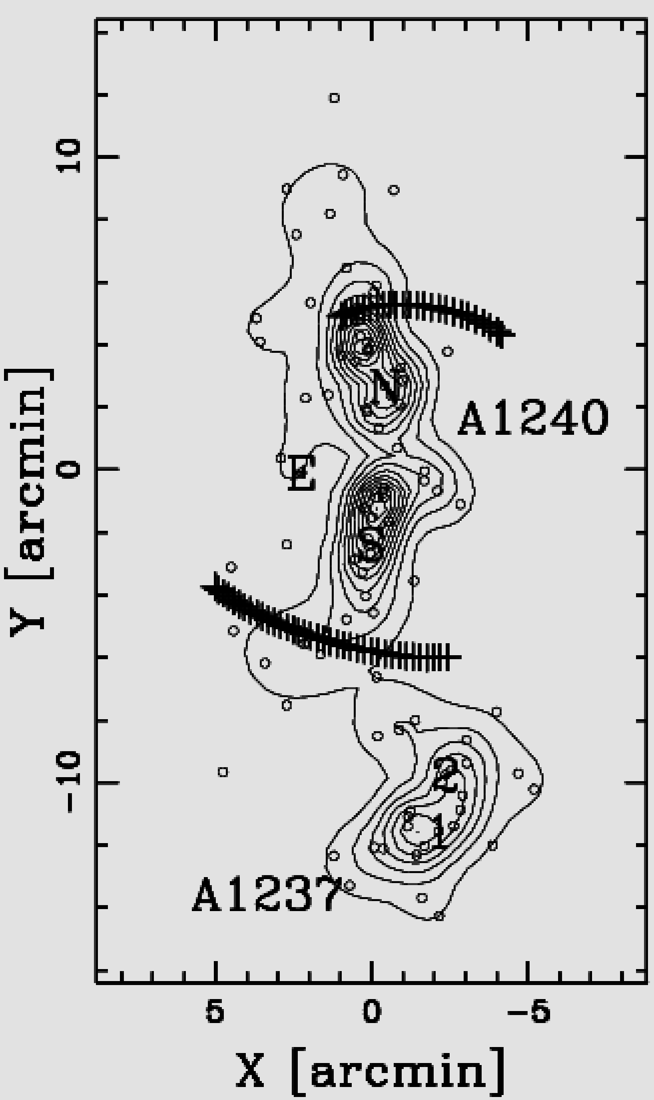


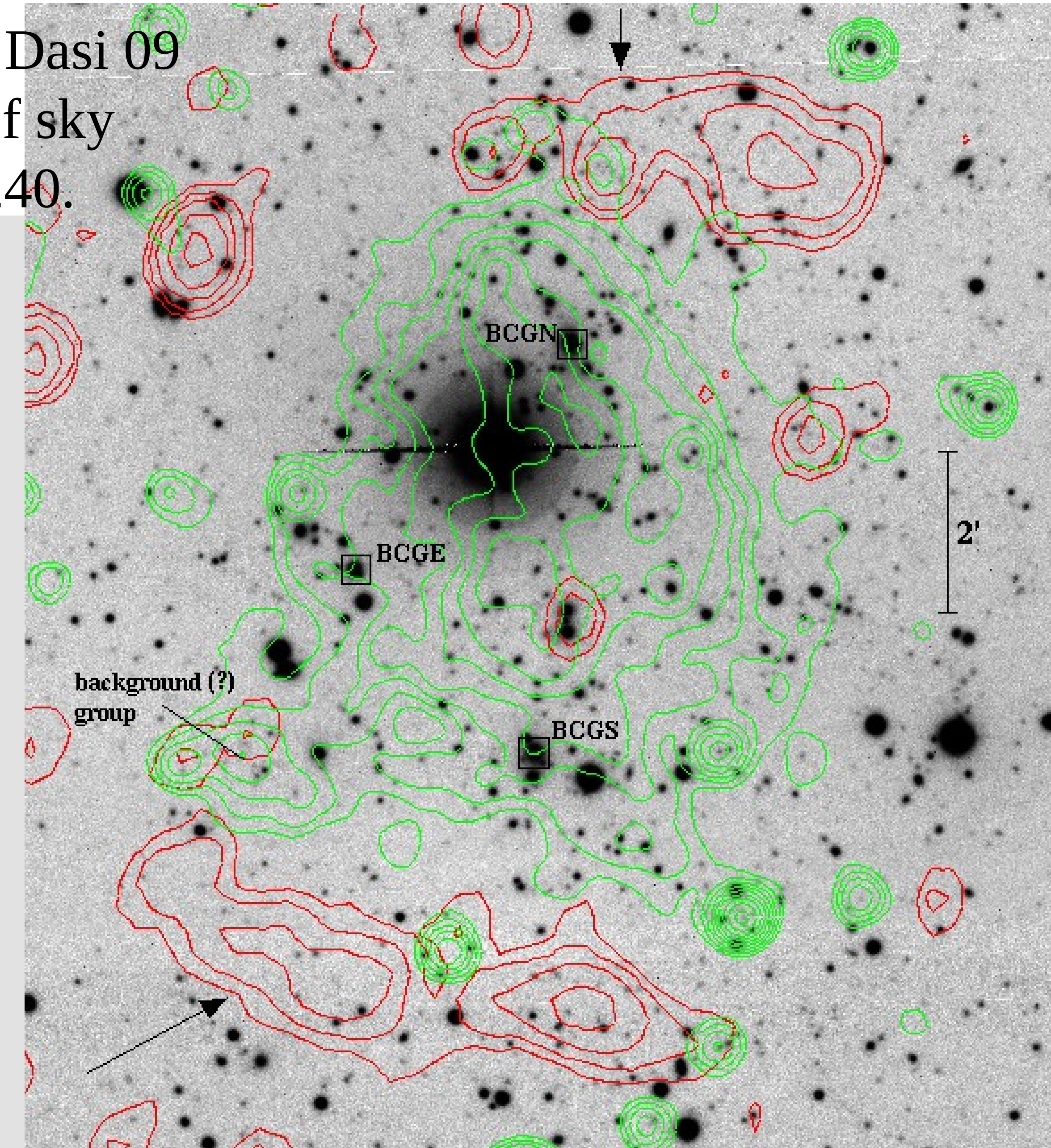


A1240, z~0.19

σ_v about 900 kms-1

Barrena, MG, Boschin, MG, & Dasi 09
2clumps merging in the plane of sky
+A1237 still infalling onto A1240.



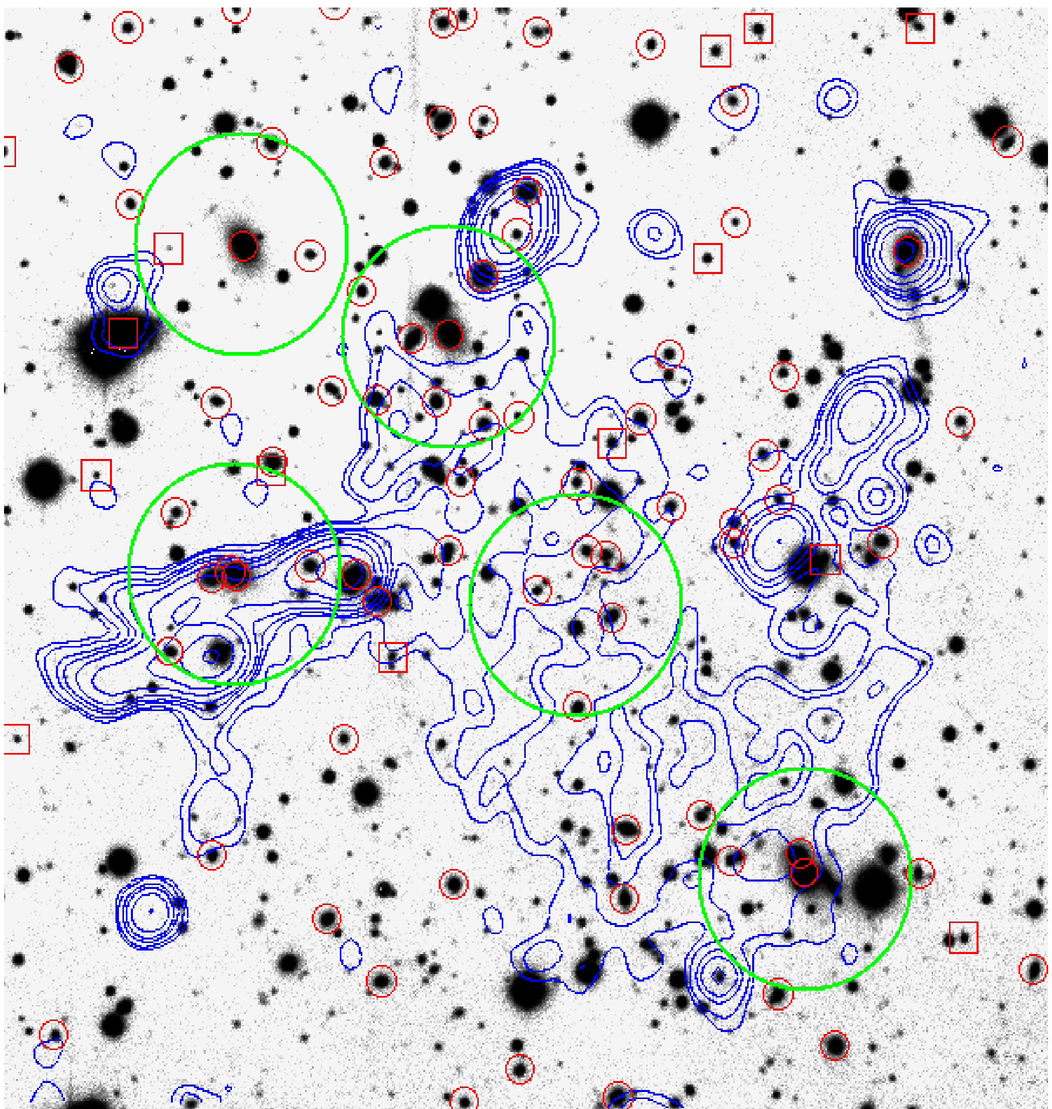


A520 (MG, Barrena, Boschin & Ellingson 2008)

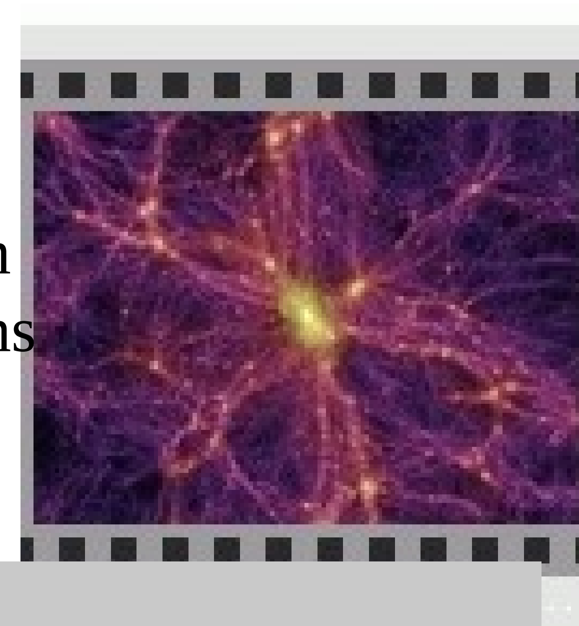
A520 at the crossing of 3 LSS filaments, the projection of the LOS filament is the likely cause of the DM core

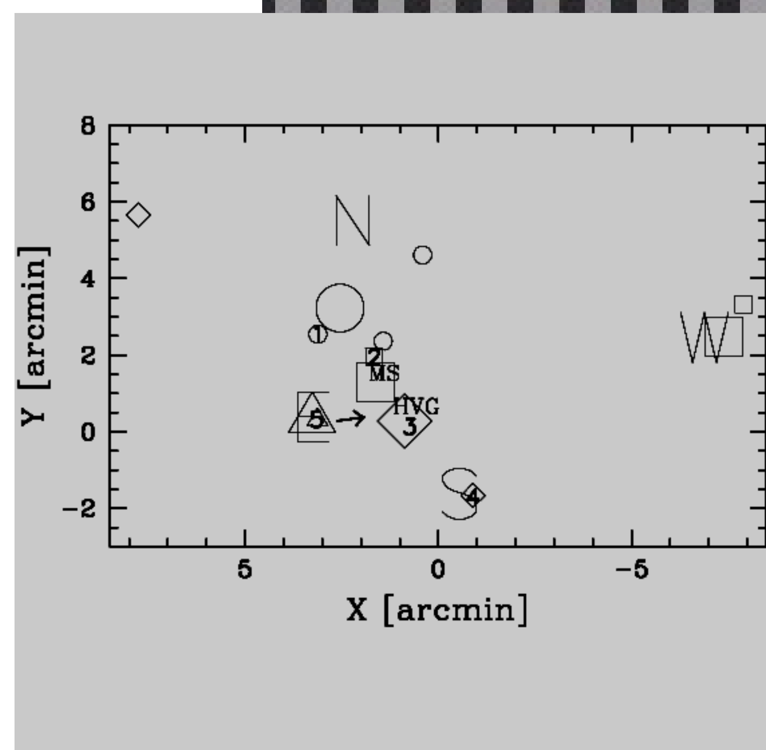
167 member galaxies: **high velocity group HVG**

+substructured main system



Millenium simulations

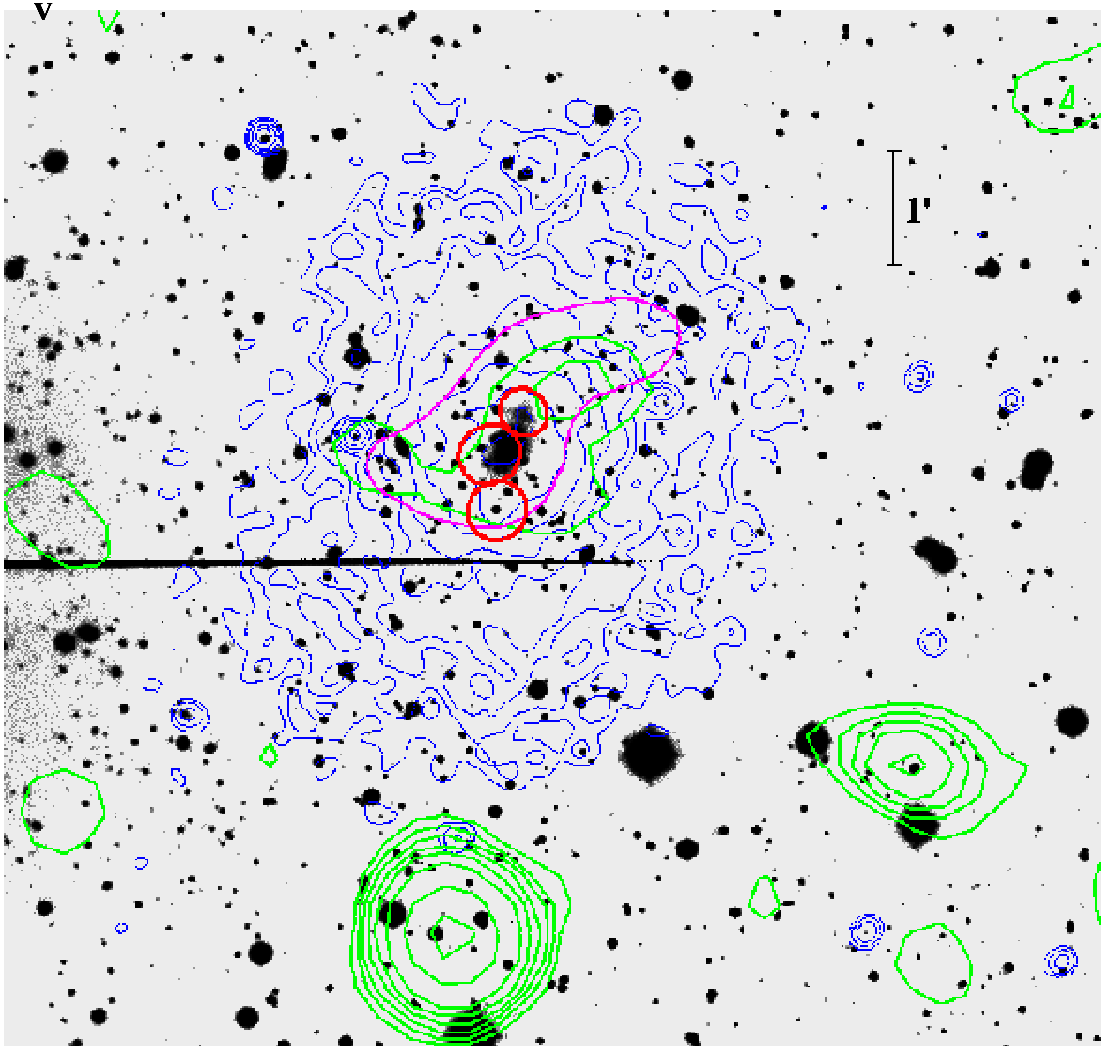




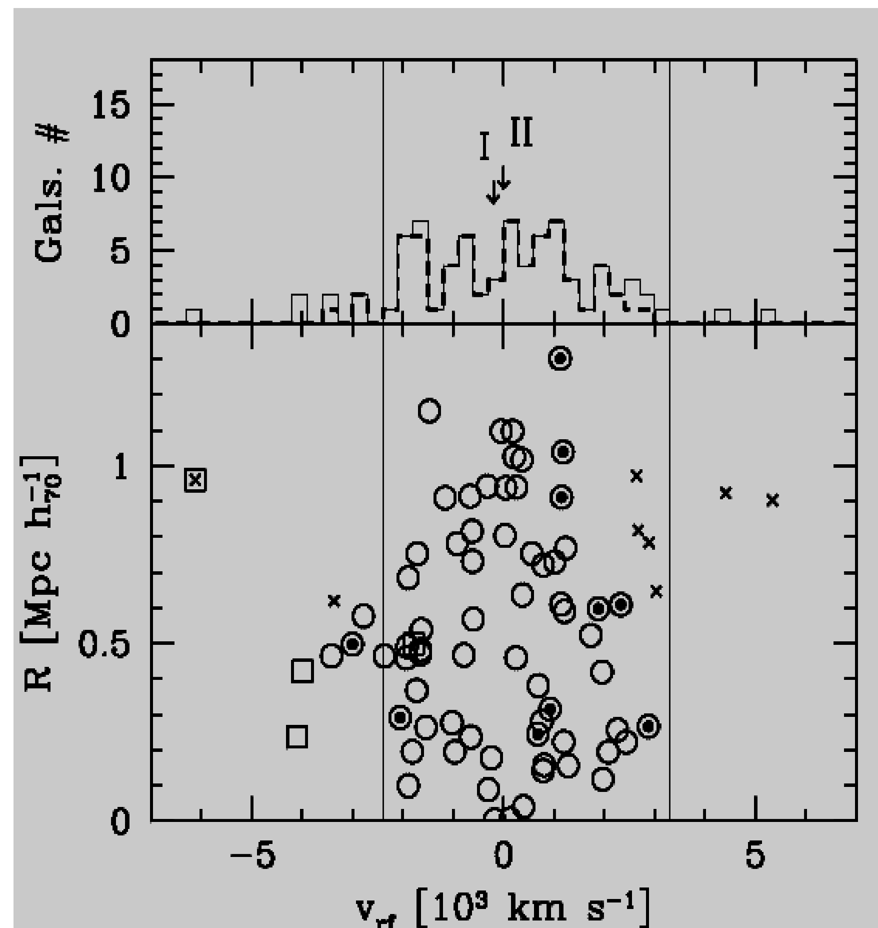
A697, z~0.28

(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.

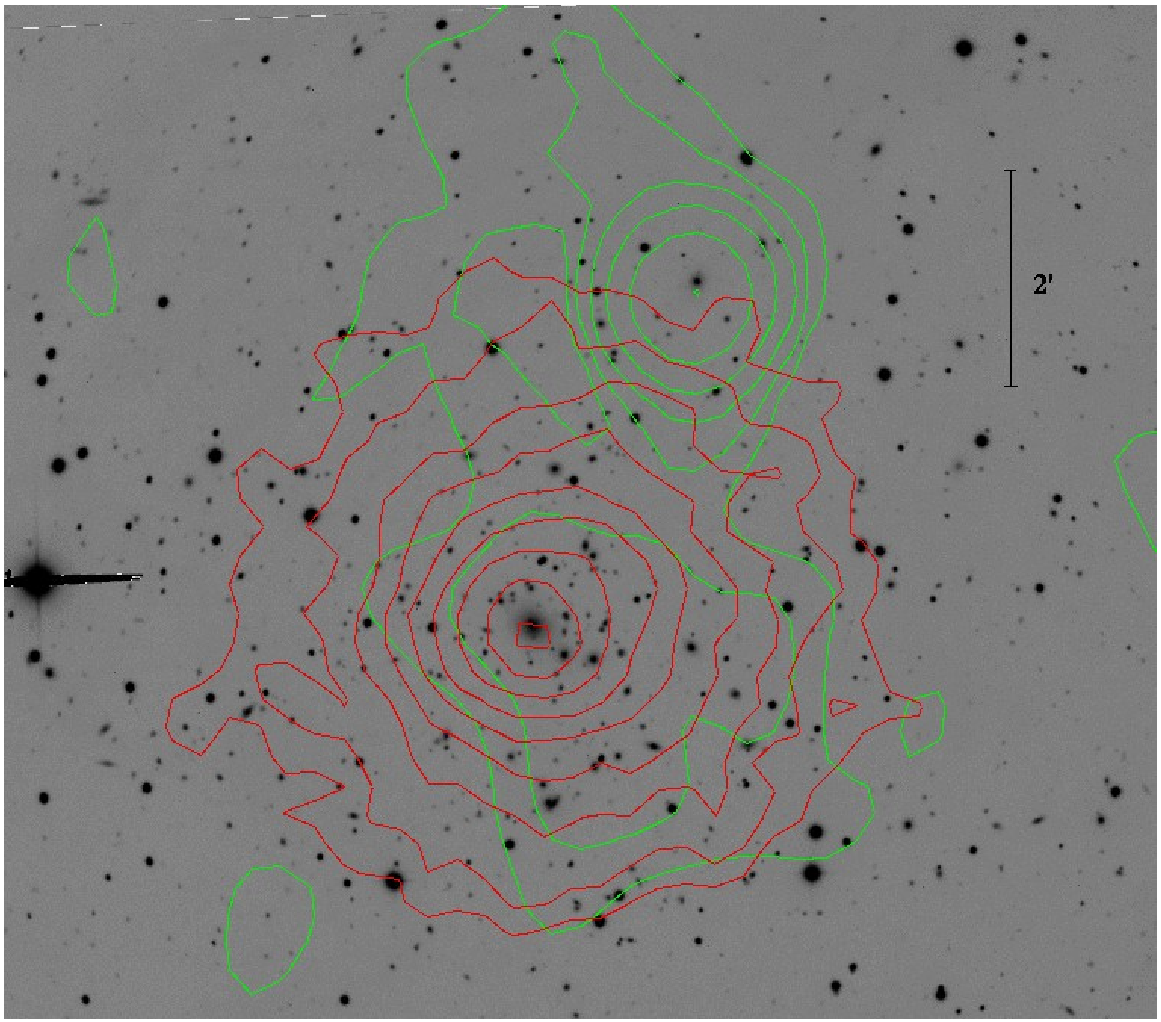


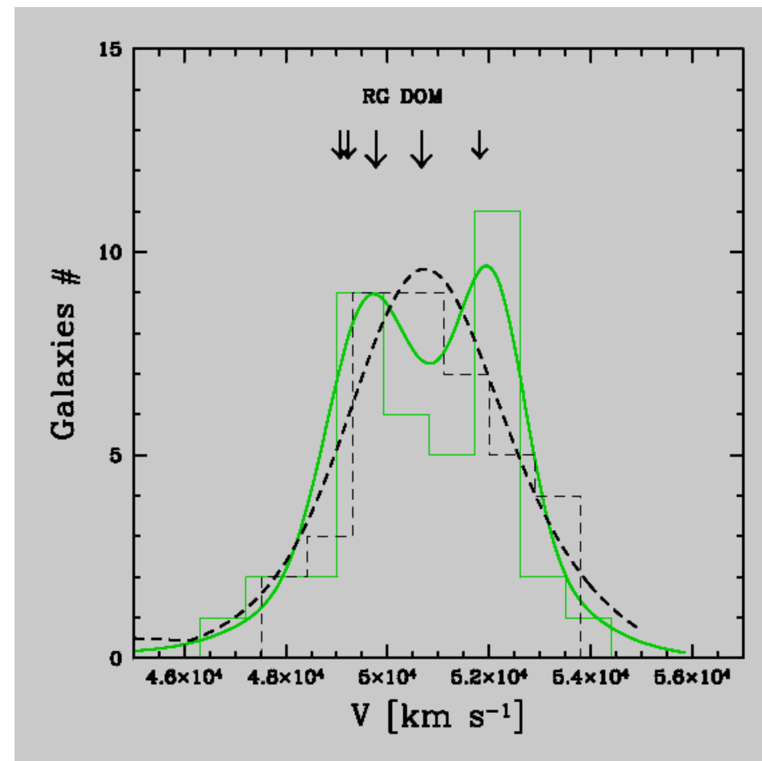
A2294, z~0.17

MG et al.09 in prep.
TNG-Dolores

σ_v about 1400 kms-1

Some evidence of substructure.





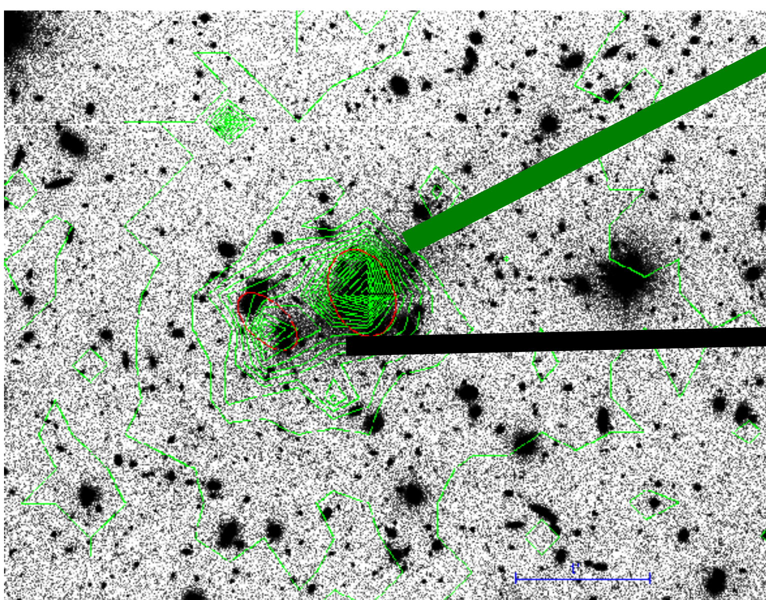
GALS OF DIFFERENT LUMINOSITY TRACE THE DYNAMICS OF CLUSTER MERGERS IN A DIFFERENT WAY

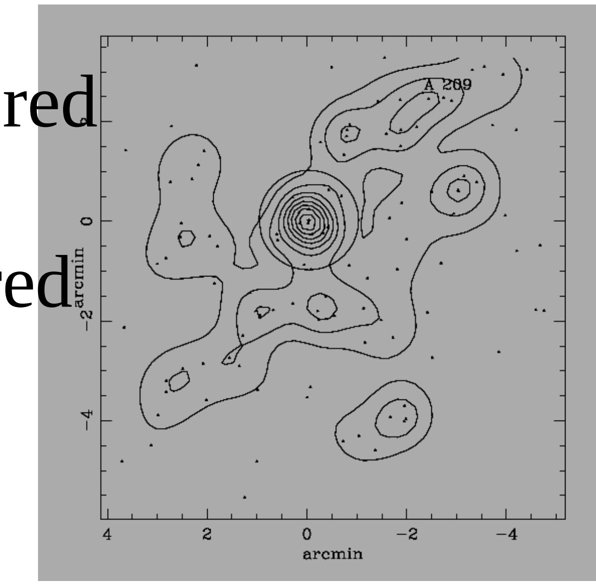
“Biviano et al. 96: the two cD galaxies of the Coma cluster are surrounded by luminous galaxies, accompanied by the two main X-ray peaks, while the distribution of faint galaxies tend to form a structure not centered with one of the cD, but rather coincident with a secondary peak detected in X-ray."

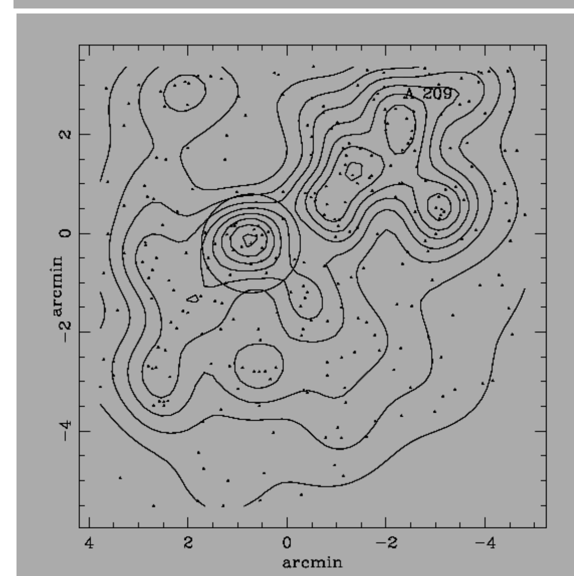
When merging is an advanced phase:
faint galaxies trace the forming cluster,
more luminous galaxies still trace the remnants of the core-halo structure of premerging subclumps.

A209 z=0.21 cD gal
(Mercurio,MG,Boschin,Merluzzi & Busarello)

More luminous galaxies R<19.5 are centered around the cD and the main X-ray peak.
Less luminous R>19.5 galaxies are centered around the secondary X-ray peak.

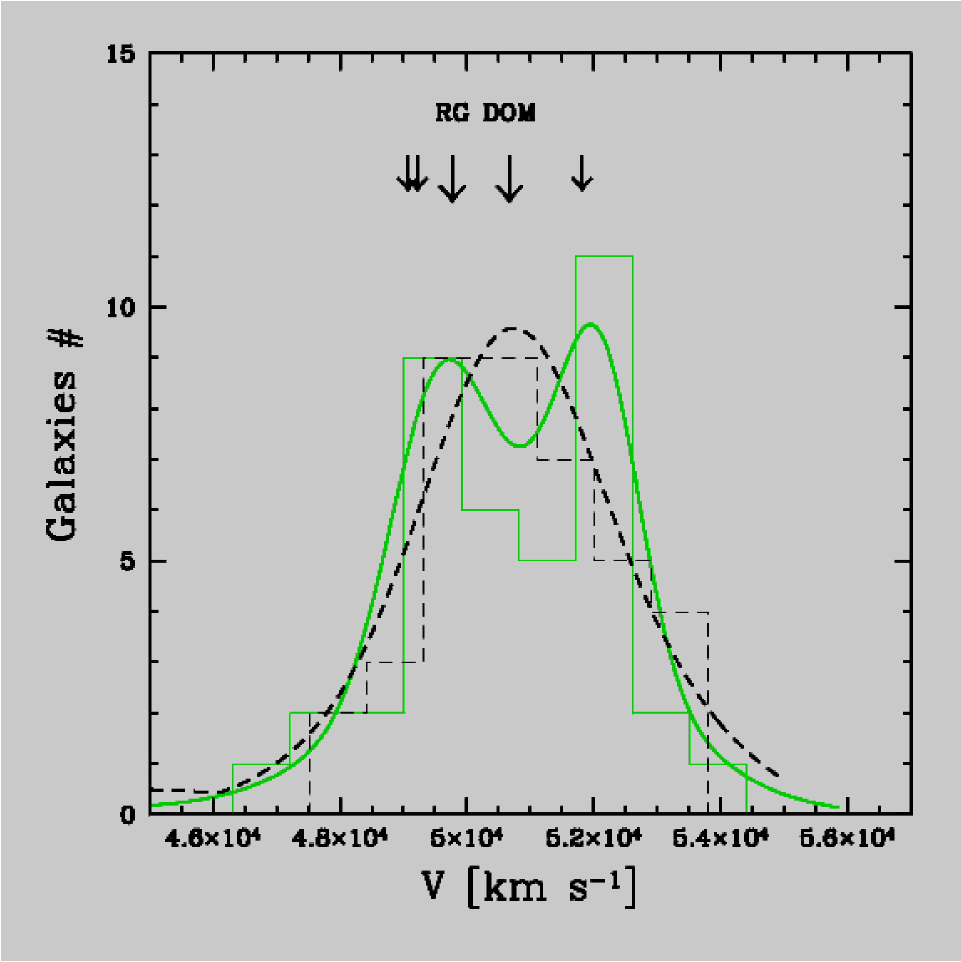






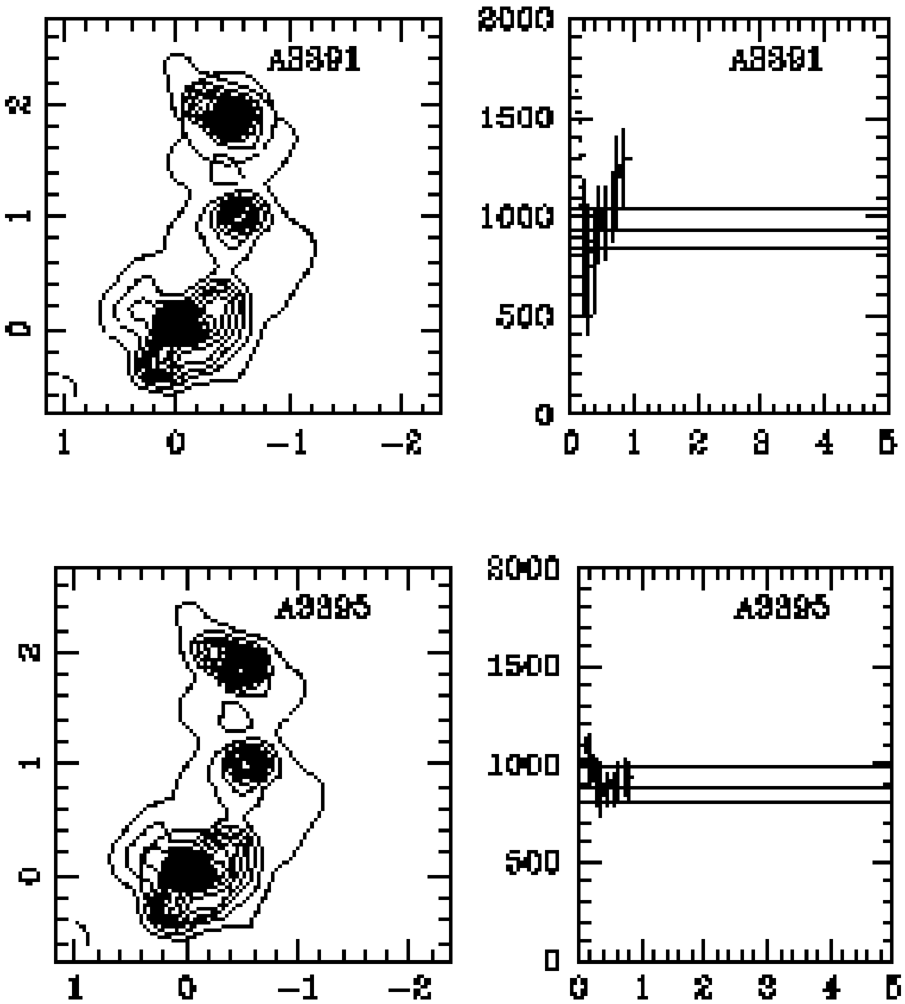
A2294 z=0.17, 1 Dominant gal. (MG et al. in prep.)

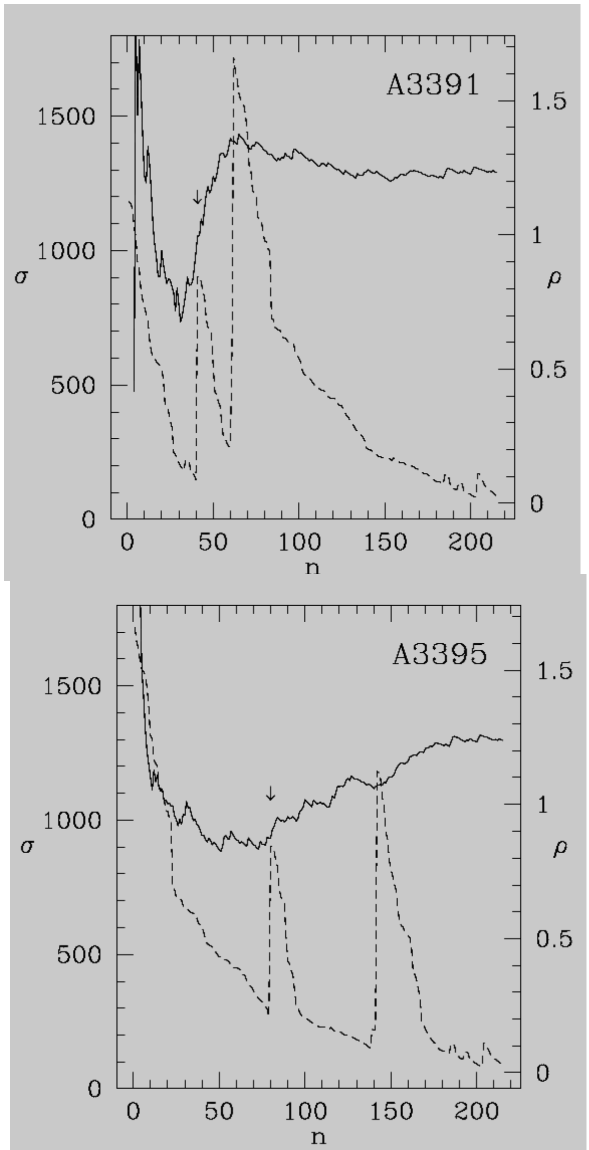
More luminous galaxies
show the presence
of two peaks
in the velocity distribution.



CLOSE CLUSTERS: THE VELOCITY DISPERSION PROFILE INCREASES DUE TO THE COMPANION

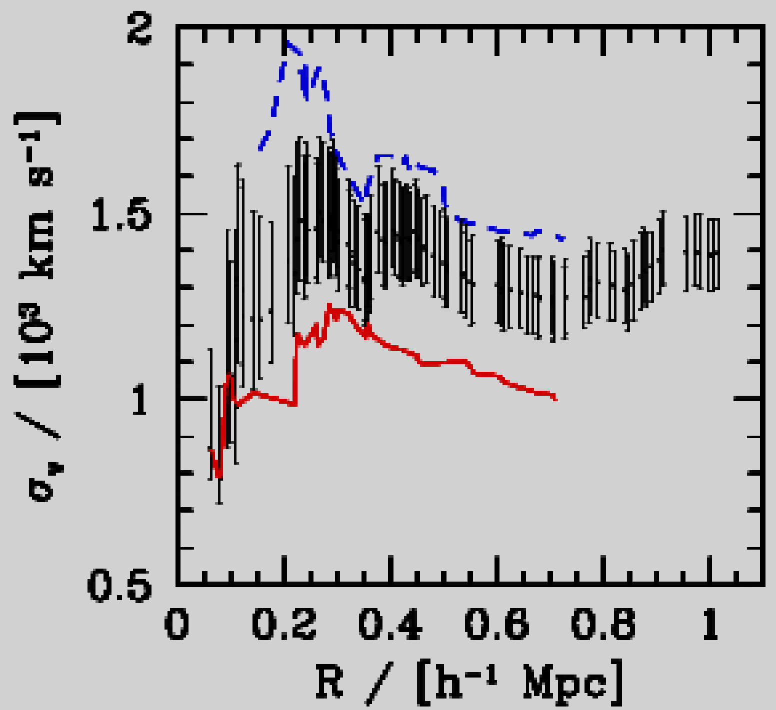
THE CASE OF A3391-A3395 (MG et al. 96)

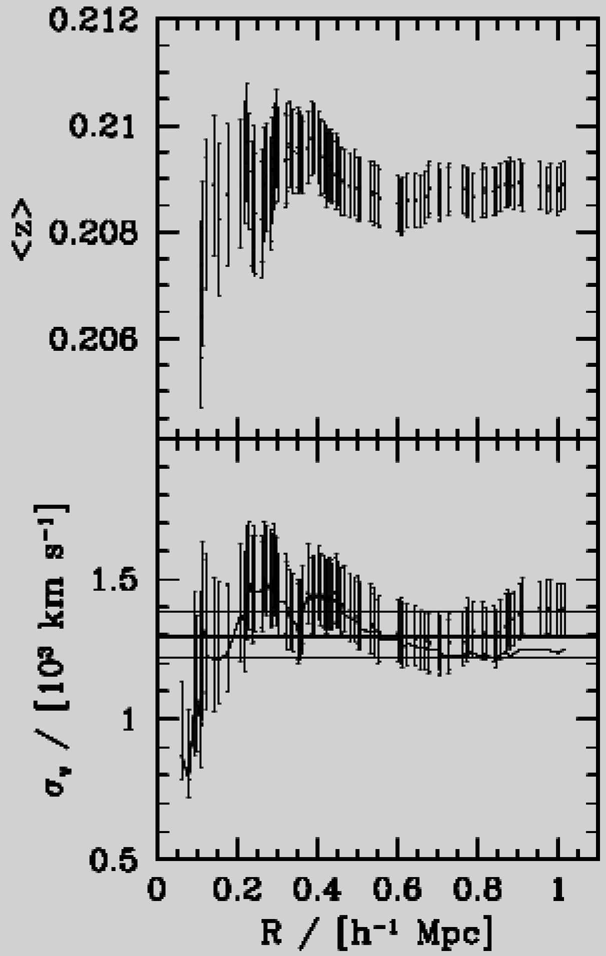


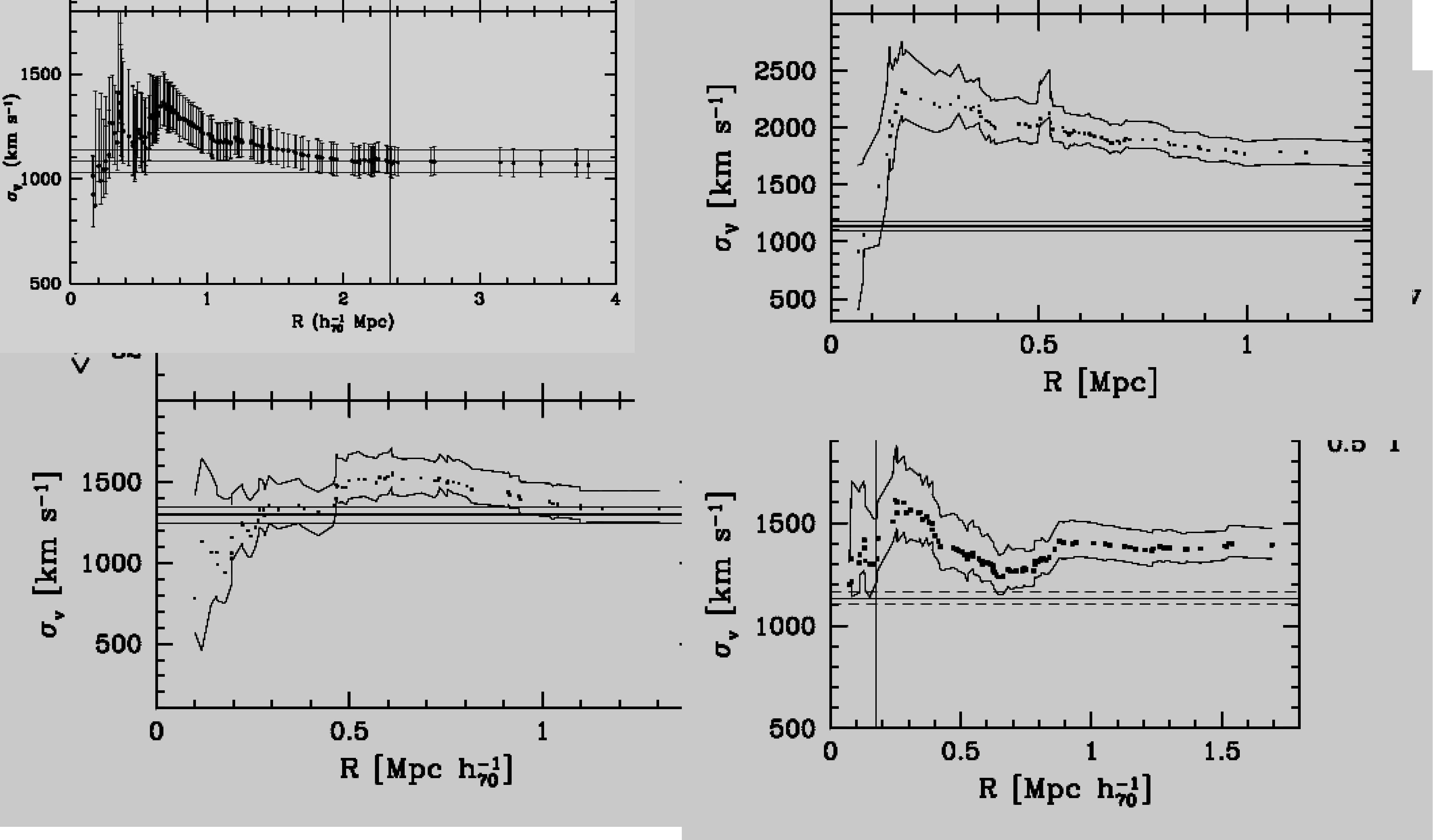


VELOCITY DISPERSION PROFILES FOR DARC CLUSTERS

A209





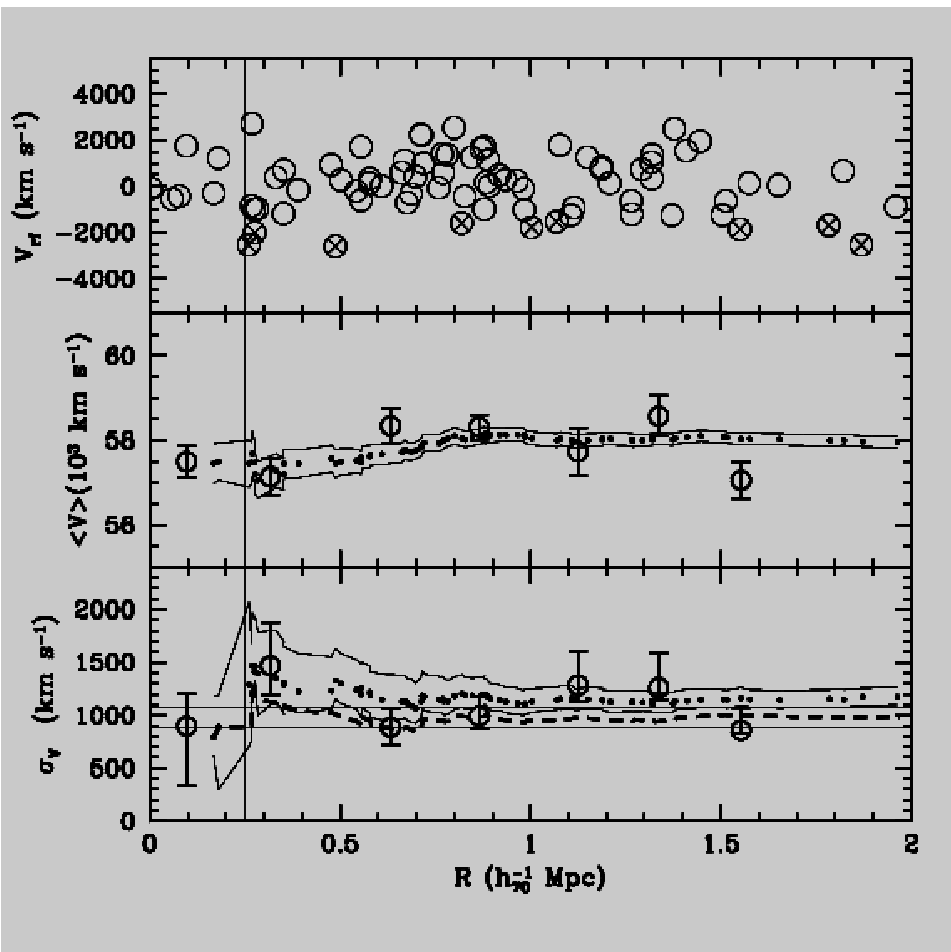


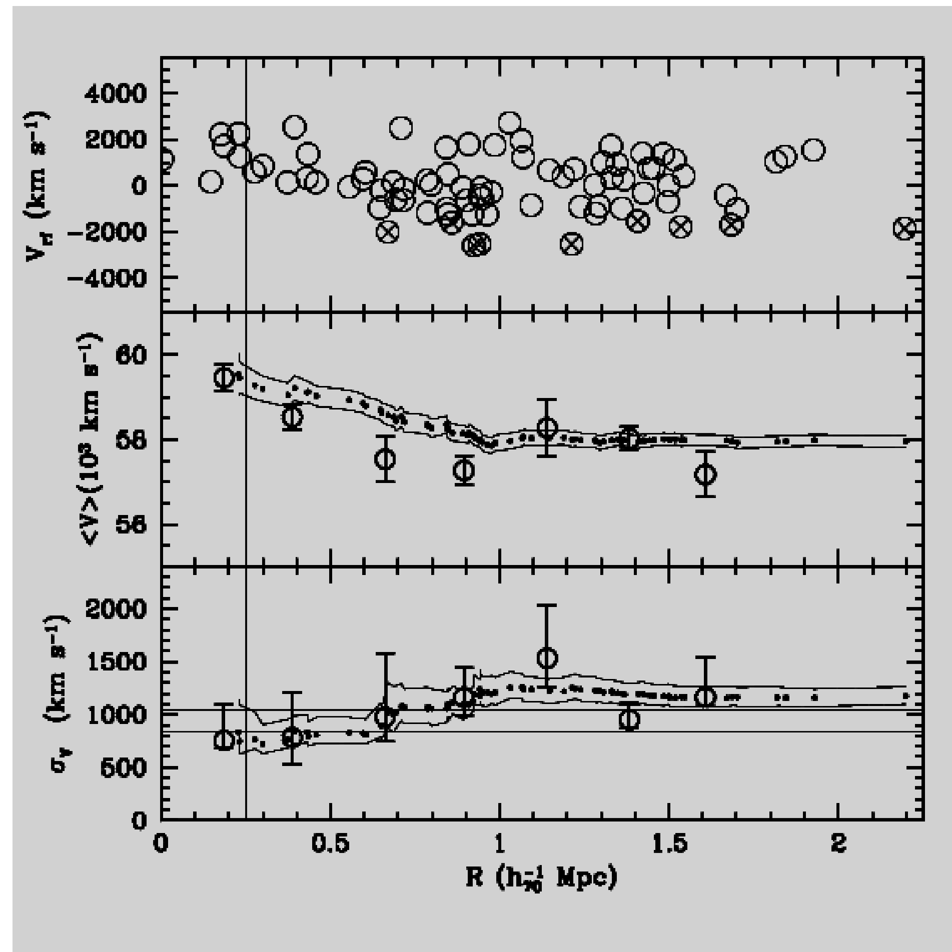
Abell 520
Abell 697

Abell 2744
Abell 773

V and SIGMA PROFILES CAN BE USED TO SELECT “UNCONTAMINATED” PARTS OF SUBSYSTEMS

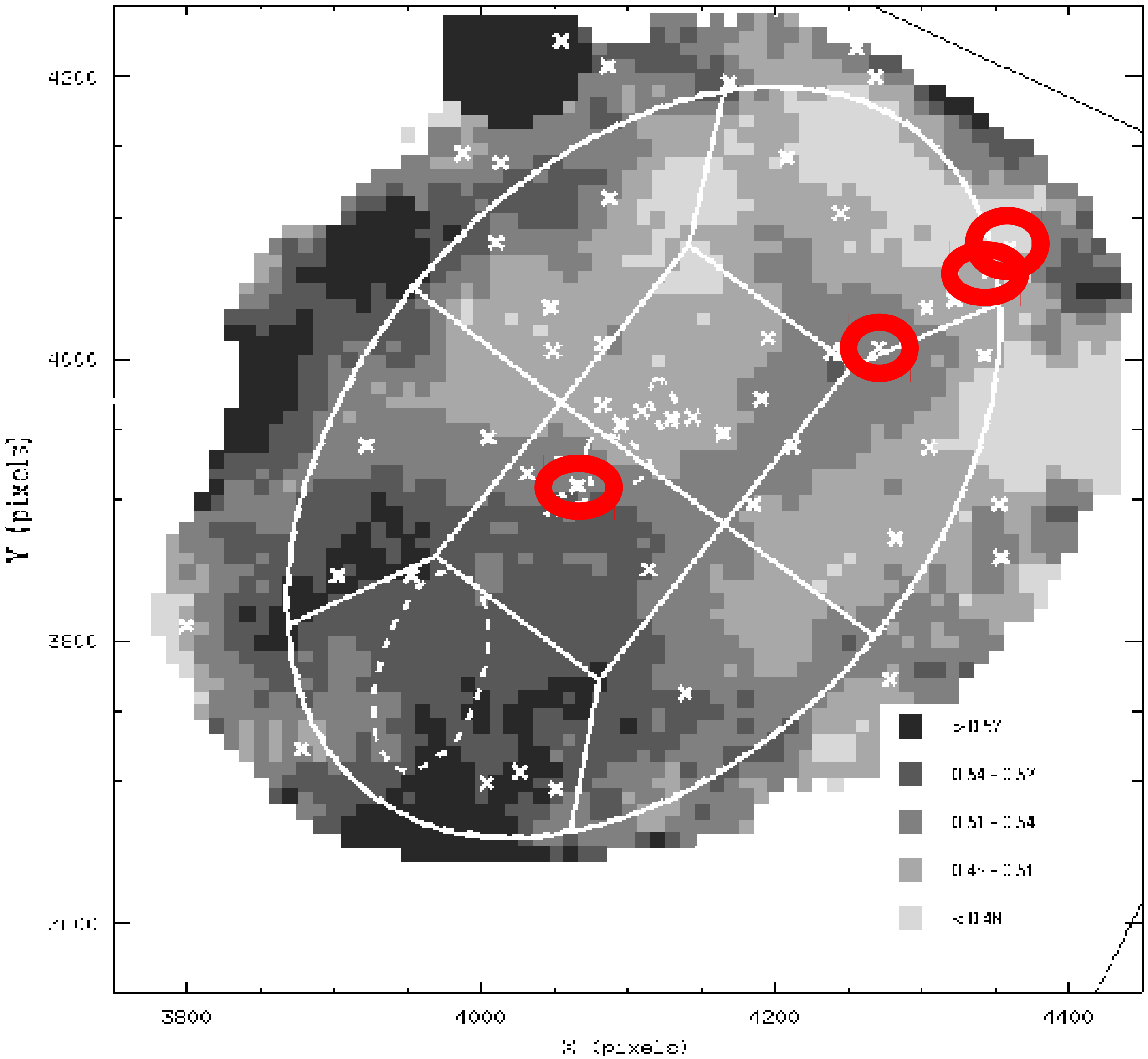
A115 South e North





CLUSTER MERGERS & POSTSTARBURSTs

cluster mergers could stimulate SF? e.g. Bekki 1999



A2219: poststarbursts + cold gas filament

ONGOING PROJECT: FOGO

FOssil Groups Origin J.A. Aguerri (P.I.),

Barrena, Sanchez, ...SPAIN; D'Onghia USA;

Boschin, M.Girardi, Corsini...ITALY; de Burgo PORTOG-; ...

Based on 34 FGs by Santos et al (07) detected in SDSS (z=0.-0.5).

ITP International Time Program

About 35 nights of observations in 2years on Spanish telescopes: Optical, MOS spec., NIR, IFSpectr.

A NEW "NICE" FUTURE:

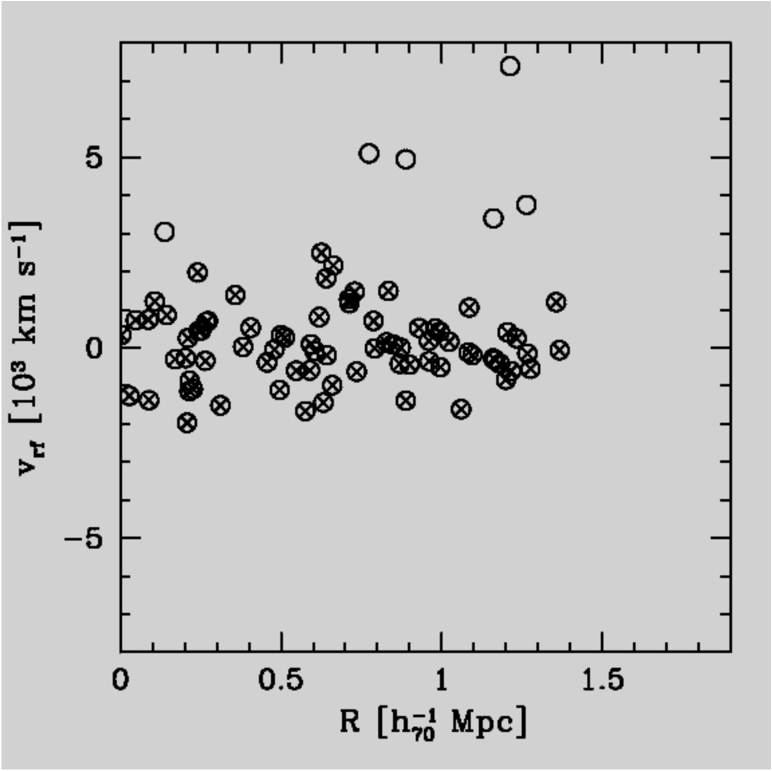
many (100) gals per group;

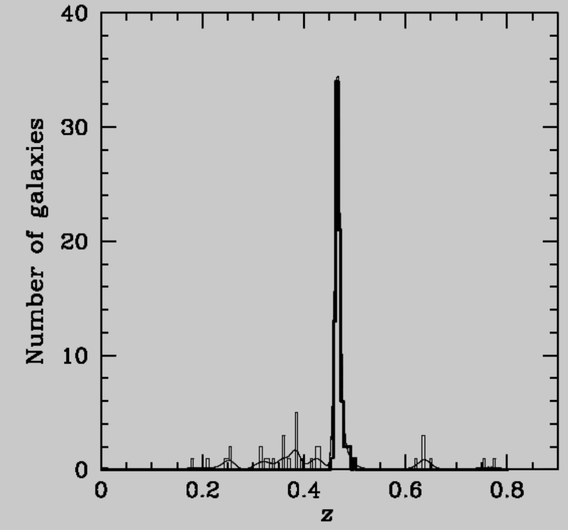
quite homogeneous family of objects;

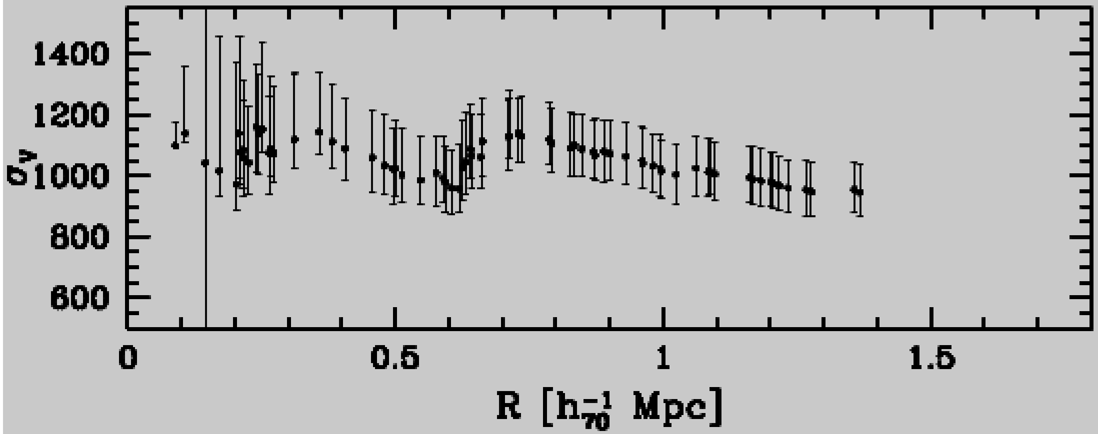
easy to build the ensemble system;

likely very relaxed systems.

FG10 PRELIMINARY RESULTS







115 gals, 76 members, z=0.46, σ_v=900 km/s,

R200=1.8Mpc, M=1x10exp15 Msun, quasi flat σ_v profile.

V-distr. is Gaussian, NO Dressler-Schectman substructure,

NO V-gradient...other tests must to be performed!

FG10 SEEMS A RELAXED CLUSTER!

We are understanding “typical”kinematics
of galaxy populations within clusters.

BUT

The connection type-motion of galaxies
is the same in any cluster?
Or depends on the cluster properties
(e.g. mass, cool core presence, cD presence,
 relaxed or substructured, cluster environment
density).