TRACING THE MASS PROFILES OF GALAXY CLUSTERS WITH MEMBER GALAXIES

Andrea Biviano
INAF / Oss. Astron. Trieste

Why use member galaxies to trace the mass profile of galaxy clusters?

Why use member galaxies to trace the mass profile of galaxy clusters?

2 main advantages:

- tracing the mass profile to large radii

Why use member galaxies to trace the mass profile of galaxy clusters?

2 main advantages:

- tracing the mass profile to large radii
- getting informations on the orbits of galaxies in clusters
  (provide constraints on their evolution)

Methods

How to derive a cluster mass profile from the observables R,v?

(R, radial distance from the cluster centre
v, rest-frame velocity wrt the cluster <v>)

How to derive a cluster mass profile from the observables R,v?

(R, radial distance from the cluster centre
v, rest-frame velocity wrt the cluster <v>)

- Jeans analysis

  (e.g. Binney & Tremaine 1987)

  Assumes dynamical equilibrium of the system

How to derive a cluster mass profile from the observables R,v?

(R, radial distance from the cluster centre
v, rest-frame velocity wrt the cluster <v>)

- Jeans analysis
  (e.g. Binney & Tremaine 1987)
  Assumes dynamical equilibrium of the system

- Caustic method
  (Diaferio & Geller 1997)
  Valid where dynamical eq. condition not met
  Based on results of num.sims., which predict cluster dynamics dominates v-field around cluster

Jeans analysis:

I(R) and σ_v(R) $\leftrightarrow$ ν(r), σ_r(r), M(<r), through β(r)

or, more generally: f_p(R,v) $\leftrightarrow$ Φ(r) + f(E,L^2)

Jeans analysis:

$I(R)$ and $\sigma_v(R) \leftrightarrow \nu(r)$, $\sigma_r(r)$, $M(<r)$, through $\beta(r)$

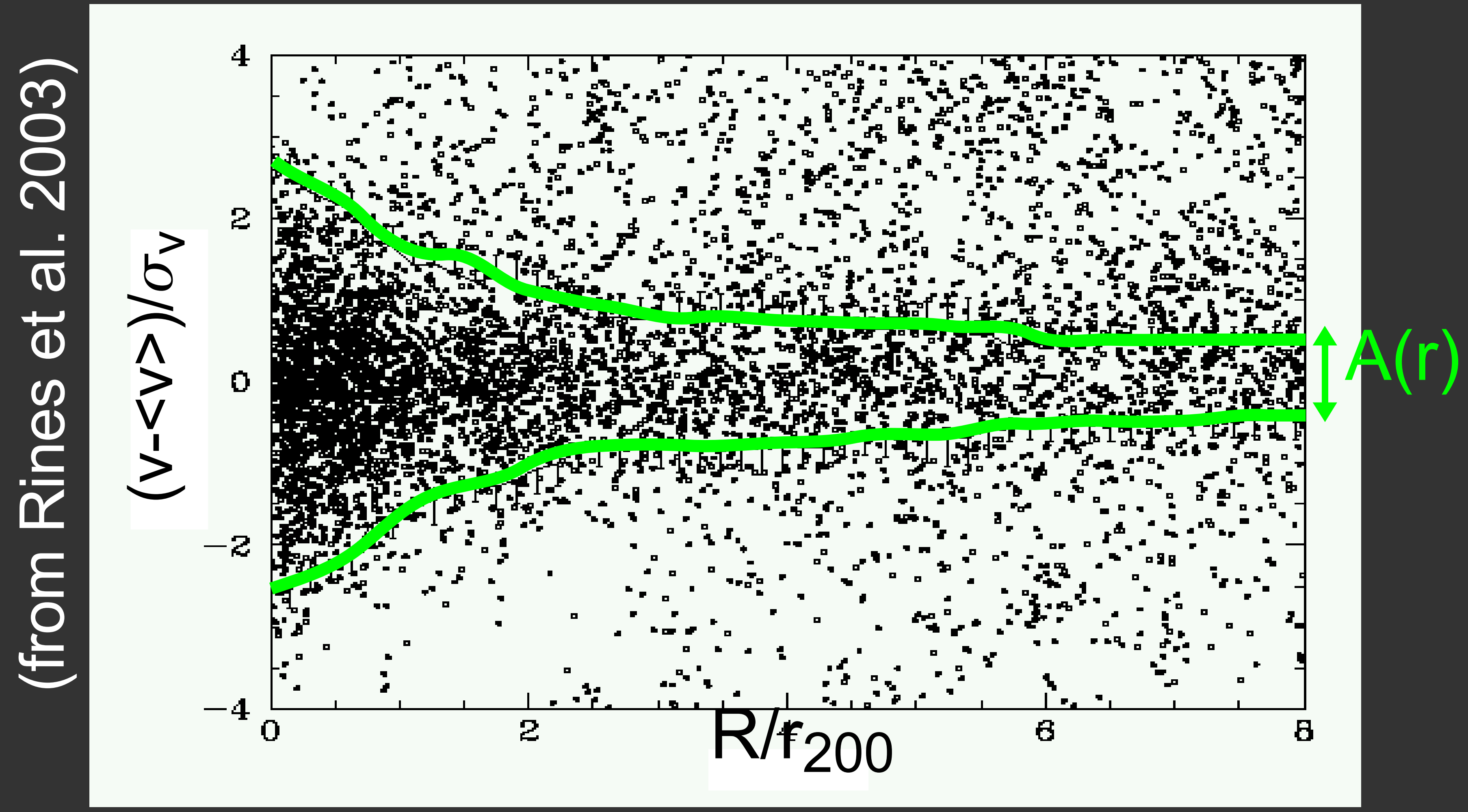
or, more generally: $f_p(R,v) \leftrightarrow \Phi(r) + f(E,L^2)$

Technical issues:

- Use smooth models or use raw data
- Bin the data or use individual galaxies R_i,v_i
- Start from observables to obtain $M(<r)$, or guess $M(<r)$ and project onto observables

Caustic method:

The (R,v) caustic amplitude A(r) is a measure of Φ(r)



A(r) → Φ(r) through F(Φ,β,r)≈const ...*only at large radii*

Main mathematical problem: the mass – orbits degeneracy

Given R,v the M(<r) solution depends on the adopted $\beta(r)$

($\beta(r) \equiv 1 - \sigma_t^2/\sigma_r^2$, velocity anisotropy profile)

- True for the Jeans method
- Also true (to a lesser extent) for the Caustic method
- Also true for virial theorem mass estimates *(because of the surface term – see The & White 1986 and Girardi et al. 1998)*

The degeneracy pbm: proposed approaches

- Choose a tracer "likely" to have $\beta(r) \approx 0$ from indirect evidence (e.g. Biviano & Girardi 03)

The degeneracy pbm: proposed approaches

- Choose a tracer "likely" to have $\beta(r) \approx 0$ from indirect evidence (e.g. Biviano & Girardi 03)

- Try several model $\beta(r)$ (e.g. Carlberg et al. 97)

The degeneracy pbm: proposed approaches

- Choose a tracer "likely" to have $\beta(r) \approx 0$ from indirect evidence
  (e.g. Biviano & Girardi 03)

- Try several model $\beta(r)$ (e.g. Carlberg et al. 97)

- Perform a full dynamical modelling, $f(E,L^2)$ with β=const
  (e.g. Merritt & Saha 93, van der Marel et al. 00, Mahdavi & Geller 04)

The degeneracy pbm: proposed approaches

- Choose a tracer "likely" to have $\beta(r) \approx 0$ from indirect evidence (e.g. Biviano & Girardi 03)

- Try several model $\beta(r)$ (e.g. Carlberg et al. 97)

- Perform a full dynamical modelling, $f(E,L^2)$ with β=const (e.g. Merritt & Saha 93, van der Marel et al. 00, Mahdavi & Geller 04)

- Use higher moments of v-distribution, assuming β=const: kurtosis profile (Łokas & Mamon 03), Gauss-Hermite moments (e.g. van der Marel et al. 00, Katgert, Biviano & Mazure 04)

The degeneracy pbm: proposed approaches

- Choose a tracer “likely” to have $\beta(r) \approx 0$ from indirect evidence (e.g. Biviano & Girardi 03)

- Try several model $\beta(r)$ (e.g. Carlberg et al. 97)

- Perform a full dynamical modelling, $f(E,L^2)$ with β=const (e.g. Merritt & Saha 93, van der Marel et al. 00, Mahdavi & Geller 04)

- Use higher moments of v-distribution, assuming β=const: kurtosis profile (Łokas & Mamon 03), Gauss-Hermite moments (e.g. van der Marel et al. 00, Katgert, Biviano & Mazure 04)

- Use several tracers with different R,v distributions and solve for M(<r) and $\beta(r)$ (e.g. Biviano & Katgert 04)

Practical problems

- <u>Departure from dynamical relaxation</u> – *Flattens the inner profile (Czoske et al. 02)* - Exclude unrelaxed cls from the sample (van der Marel et al. 00), exclude galaxies in subclusters (Katgert, Biviano & Mazure 04) – Not a pbm for the Caustic method? (Rines et al. 03, but see Diaferio 99)

Practical problems

- Departure from dynamical relaxation – *Flattens the inner profile (Czoske et al. 02)* - Exclude unrelaxed cls from the sample (van der Marel et al. 00), exclude galaxies in subclusters (Katgert, Biviano & Mazure 04) – Not a pbm for the Caustic method? (Rines et al. 03, but see Diaferio 99)

- Dynamically evolving systems – *Infall from the field is ongoing (Moss & Dickens 77)* – Moderate for nearby cls, more serious for distant ones (Ellingson et al. 01) - Since it occurs by accretion of groups, easy to identify: exclude cls with substructures

Practical problems

- Interlopers – *OK for velocity dispersion, pbm for kurtosis:*
  → robust estimators (GH moments, van der Marel et al. 00)

Practical problems

- Interlopers – *OK for velocity dispersion, pbm for kurtosis:*
  → robust estimators (GH moments, van der Marel et al. 00)

- Few bright galaxies per cluster – *M(<r) only for very few (one? Coma) clusters* – Combine several cls
  (e.g. Carlberg et al. 97, Katgert, Biviano & Mazure 04)
  Scale radii R by r_{200} and vel.s v by l.o.s. σ_V:
  robust procedure for rich cls, not for low-σ_V systems
  Are the results meaningful for a stacked cluster?

Practical problems

- Interlopers – *OK for velocity dispersion, pbm for kurtosis:*
  → robust estimators (GH moments, van der Marel et al. 00)

- Few bright galaxies per cluster – *M(<r) only for very few (one? Coma) clusters* – Combine several cls
  (e.g. Carlberg et al. 97, Katgert, Biviano & Mazure 04)
  Scale radii R by r_{200} and vel.s v by l.o.s. σ_V:
  robust procedure for rich cls, not for low-σ_V systems
  Are the results meaningful for a stacked cluster?
  ∃ FP for global cluster properties
  (Schaeffer et al. 93, Adami et al. 98b) → homology
  Less projection effects pbms (Sanchis, Łokas & Mamon 04)

Dark matter or total matter profile?

Both Jeans and Caustic methods sample total mass

To get DM profile ⇒ subtract the baryonic component in galaxies (small) and in IC gas (substantial)
⇒ X-ray data are needed!! (Łokas & Mamon 03)

Also subtract galaxy DM haloes? (Biviano & Salucci 05)

Dark matter or total matter profile?

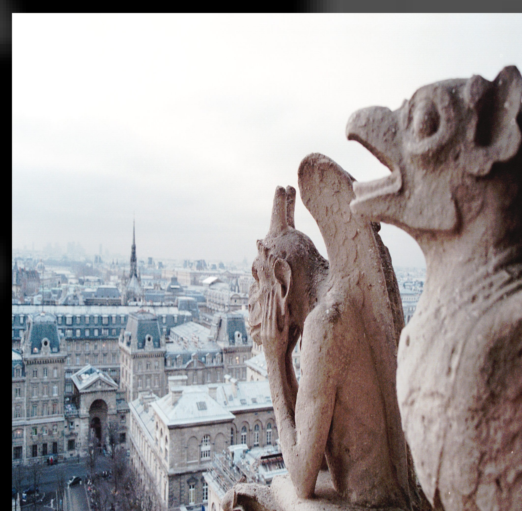
Both Jeans and Caustic methods sample total mass

To get DM profile ⇒ subtract the baryonic component in galaxies (small) and in IC gas (substantial)
⇒ X-ray data are needed!! (Łokas & Mamon 03)

Also subtract galaxy DM haloes? (Biviano & Salucci 05)

Most of the following results concern total mass profiles!

Results



Individual clusters: Coma

Merritt & Saha 93

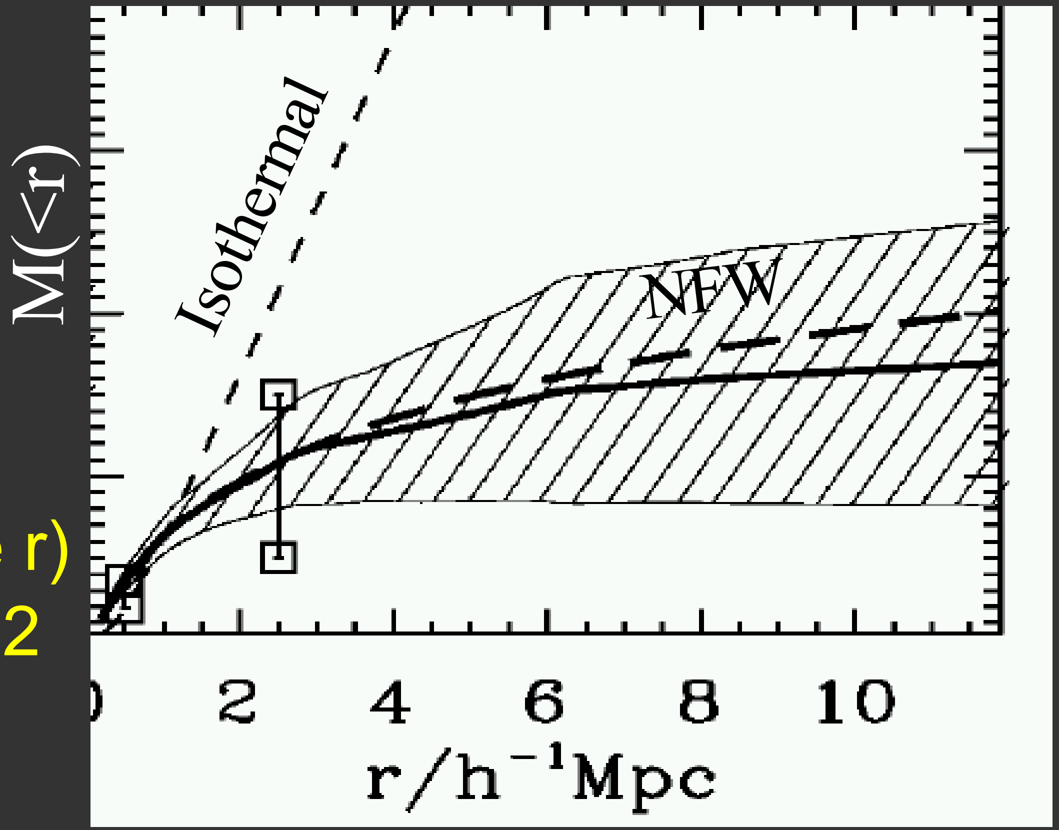
$\simeq$220 member galaxies, Jeans method

No core radius, ρ(r) ~ r^{-2} for r~0 and r^{-4} for r large and β=0 at r<0.7 Mpc,
or: Large core radius, ρ(r) ~ r^{-3} at large r and radial anis. at r<1.4 Mpc

Individual clusters: Coma

Merritt & Saha 93
$\simeq$220 member galaxies, Jeans method
No core radius, $\rho(r) \sim r^{-2}$ for r~0 and r^{-4} for r large and β=0 at r<0.7 Mpc,
or: Large core radius, $\rho(r) \sim r^{-3}$ at large r and radial anis. at r<1.4 Mpc

Geller, Diaferio & Kurtz 99
$\simeq$330 member galaxies
Caustic method
Softened Isoth. model rejected
(=core radius + $\rho(r) \sim r^{-2}$ at large r)
NFW fits well, r_{200}=2 Mpc, c=8$\pm$2



Individual clusters: Coma

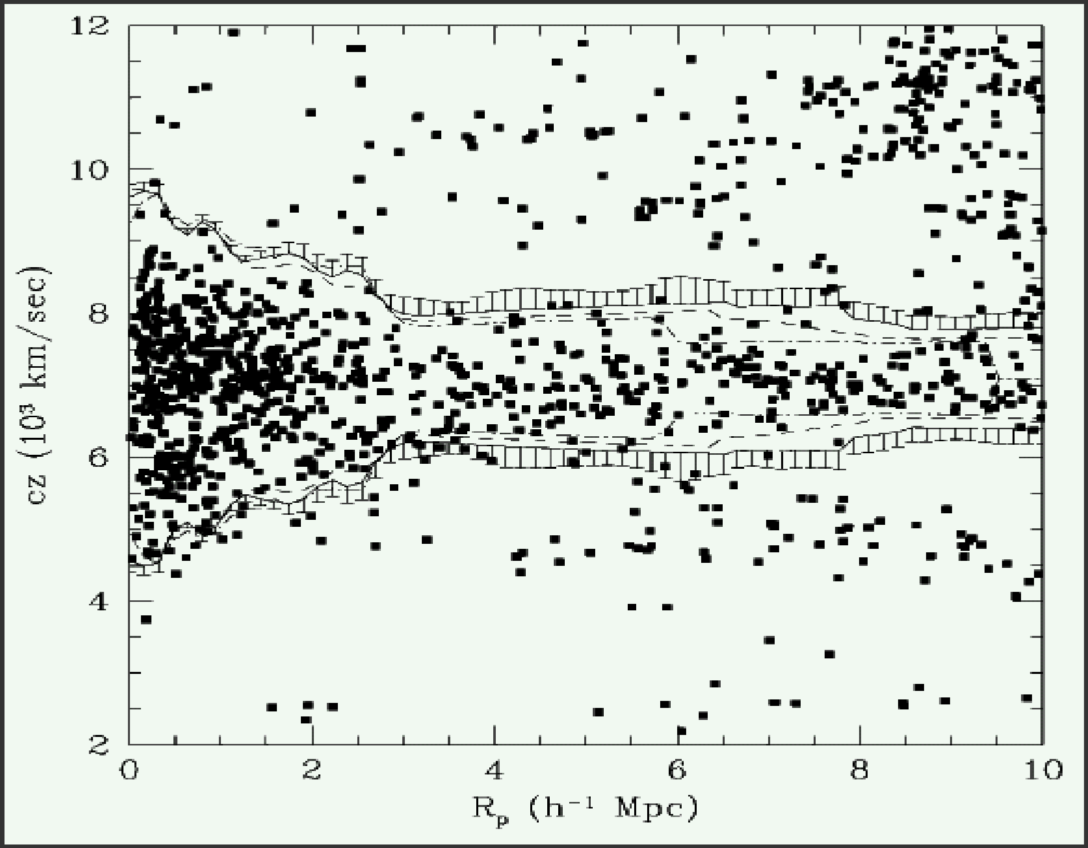
Rines et al. 01

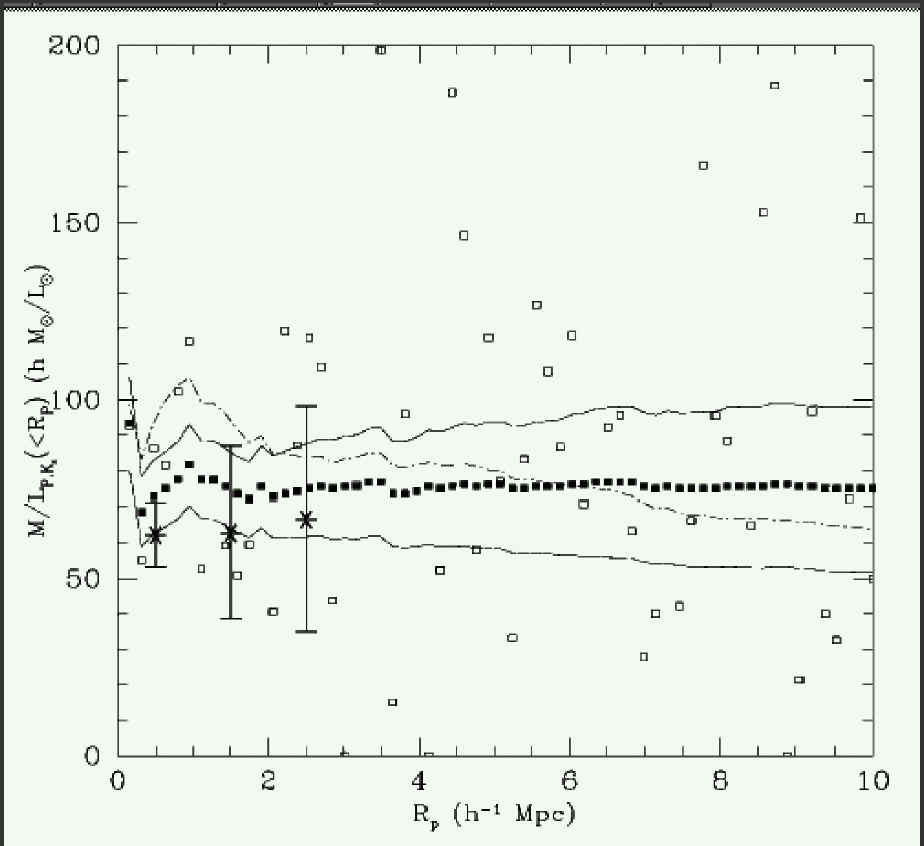
1779 galaxies (how many members?) - Caustic method

Both NFW and Hernquist models fit well, NFW with c=8

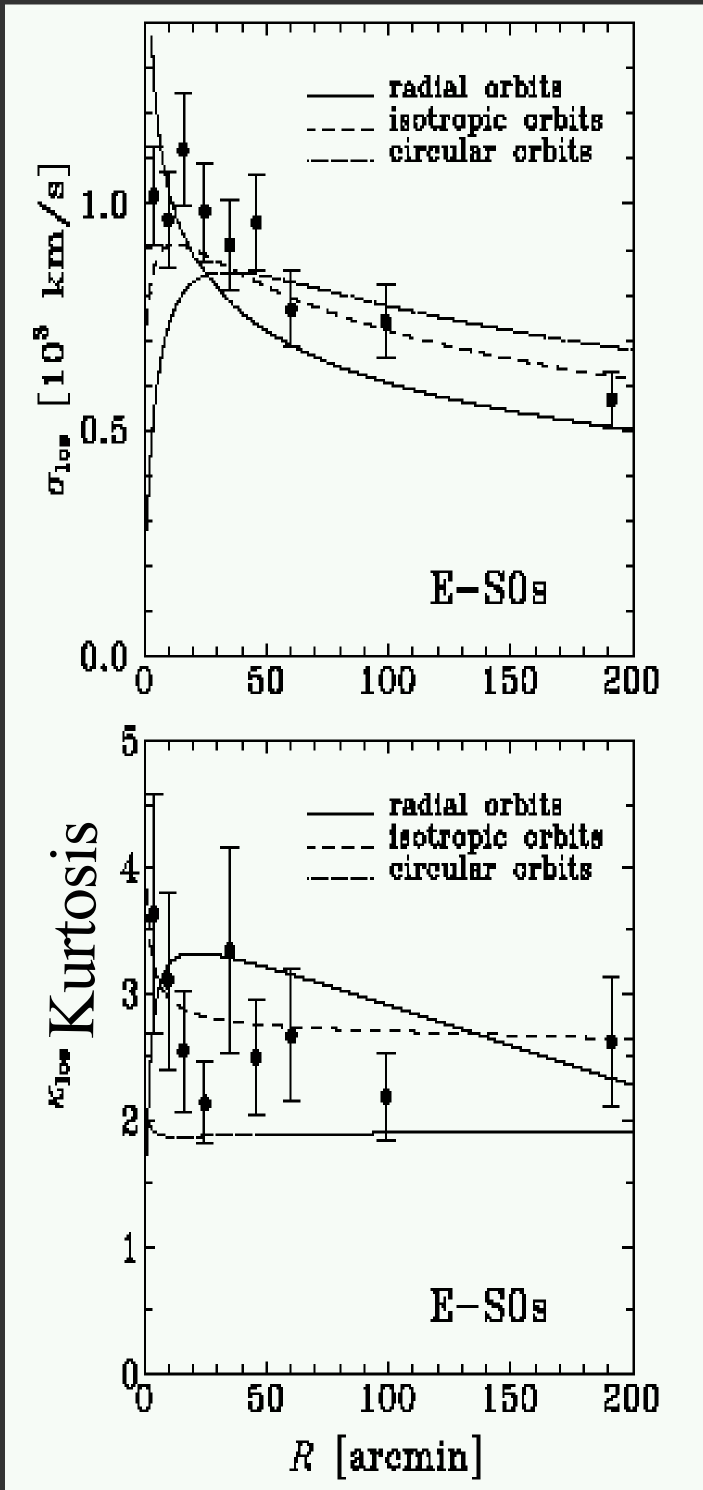
Isothermal model rejected

M/L_K roughly constant within r<12 Mpc





Individual clusters: Coma



Łokas & Mamon 04

355 E,S0 from >900 member galaxies;

Jeans method

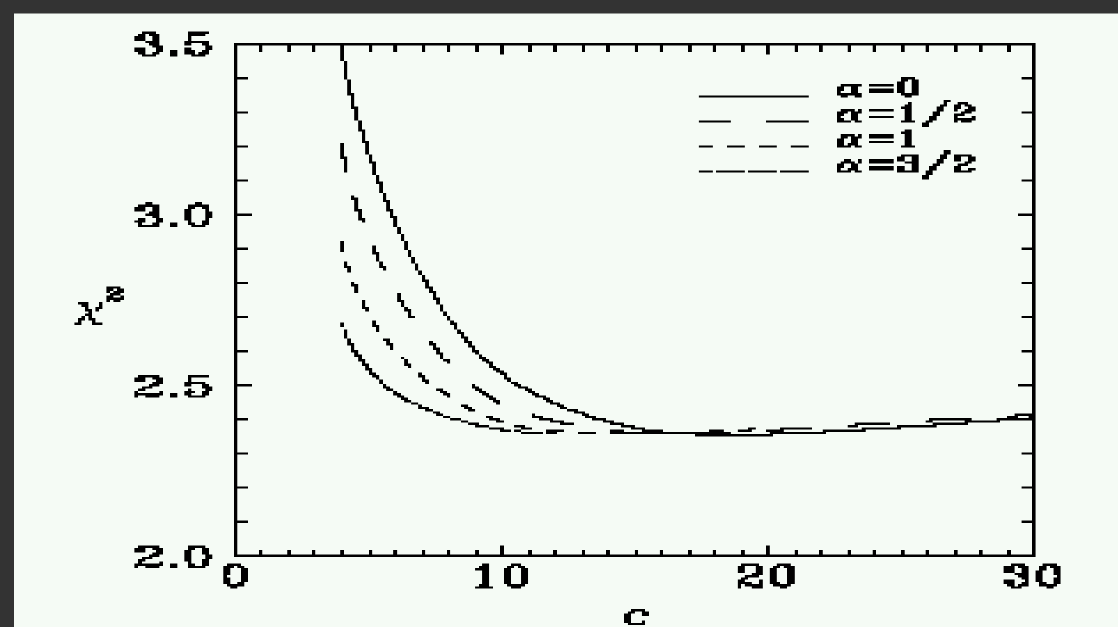
Dark (not total) mass profile

Near isotropy, $-1.2 \leq \beta \leq 0.3$

Best fit $\rho(r) \sim r^{-2}$ for r~0 and r^{-3} for r large

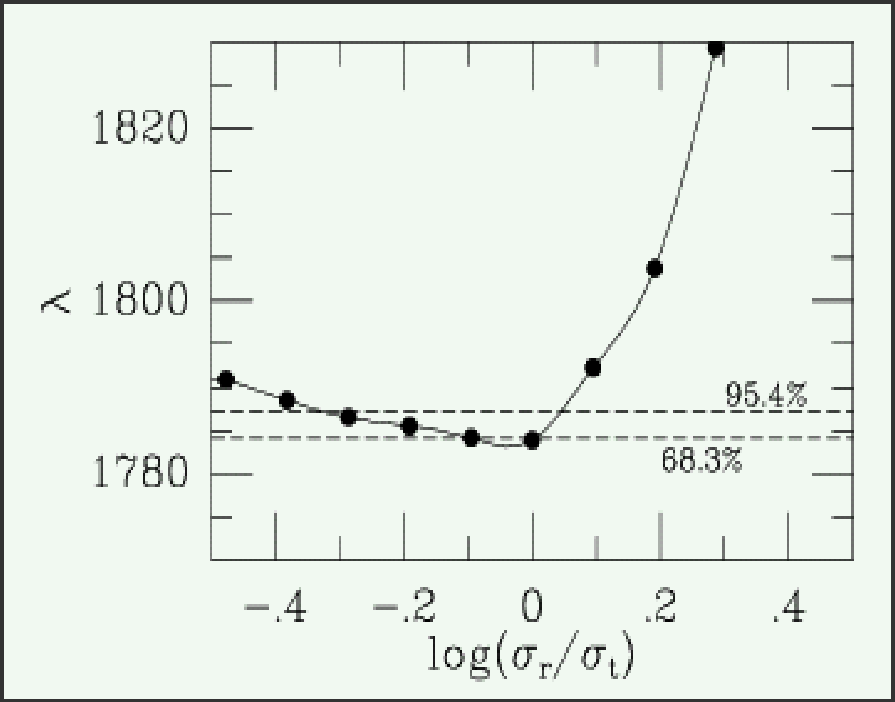
Other inner slopes also fit well,

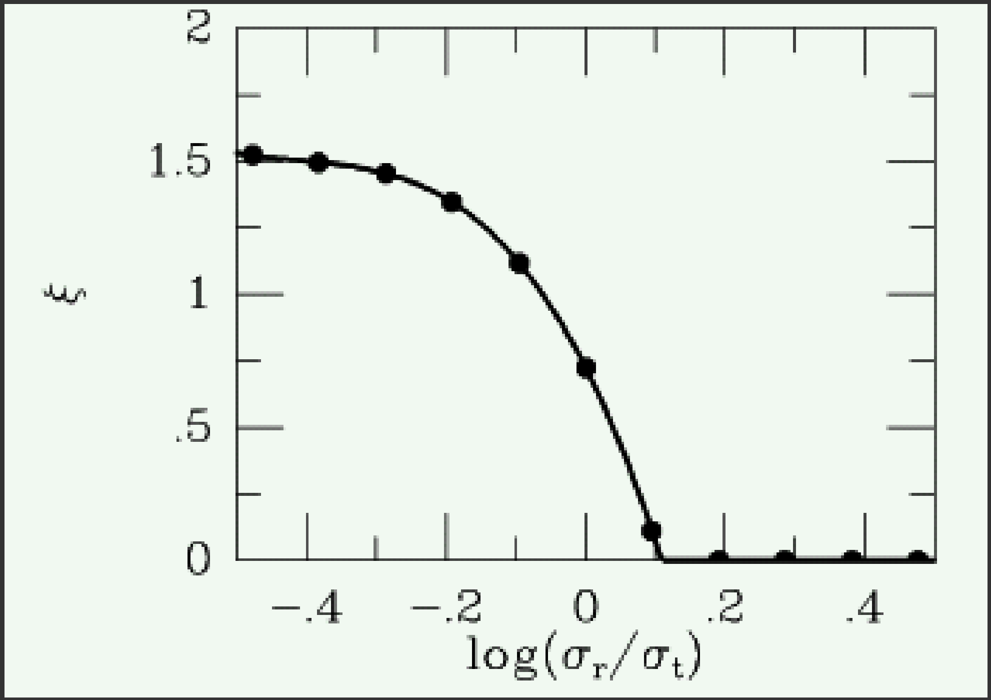
e.g. NFW with c=9.4



Stacked clusters: CNOC

Carlberg et al. 97, van der Marel et al. 00
990 member galaxies in 16 clusters at z=0.17-0.55
Jeans method
Near isotropy, -0.6 $\leq \beta \leq$ 0.1
Best fit ρ(r) ~ $r^{-\xi}$ for r~0, 0.7 $\leqslant \xi \leqslant$ 1.2, and r^{-3} for r large
e.g. NFW with c=4.2
Mass-to-number density profile nearly constant

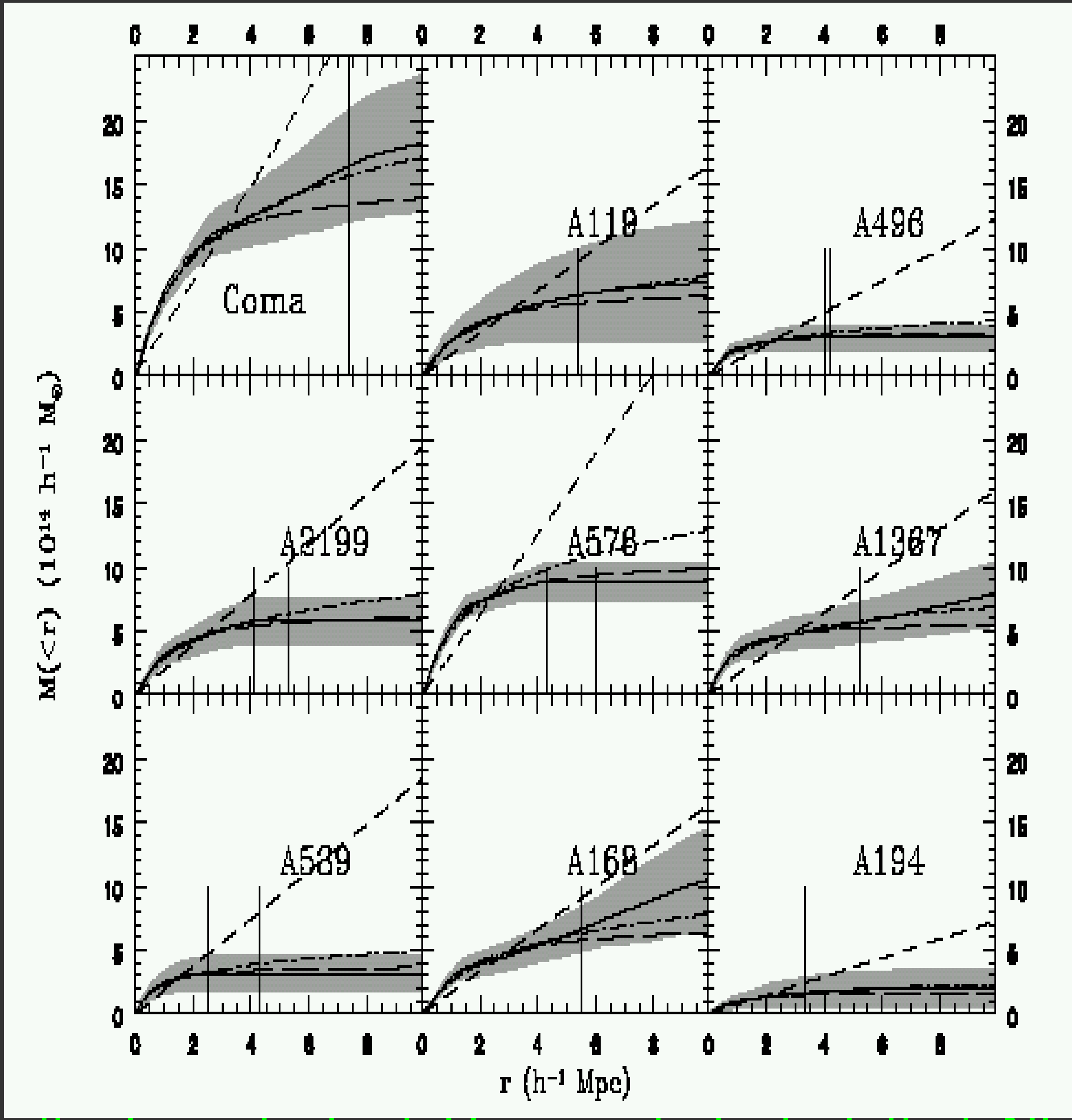




Stacked and individual clusters: CAIRNS

Rines et al. 00,03, 04
15,000 galaxies
(3900 members)
in 8 nearby clusters
Caustic method
+ Jeans method

Best fit $\rho(r) \sim r^{-1}$ for r~0,
and r^{-3} or r^{-4} for large r
NFW with $5 \leqslant c \leqslant 17$
Isotropic orbits
M/L_K ~const $r<r_{200}$,
then decreases
(x2 at r_{turn})



Short-dashed: isoth., long-dashed: Hernquist, dash-dotted: NFW

Stacked Groups

Mahdavi et al. 99:	Mahdavi et al. 04:	Carlberg et al. 01:
Deep Optical Cat.	*RASSCALS*	*CNOC2*
588 gal.s	893 gal.s	~800 gal.s
20 nearby groups	41 nearby gps	~200 gps, z=0.1-0.55

Stacked Groups

Mahdavi et al. 99:	Mahdavi et al. 04:	Carlberg et al. 01:
Deep Optical Cat.	*RASSCALS*	*CNOC2*
588 gal.s	893 gal.s	~800 gal.s
20 nearby groups	41 nearby gps	~200 gps, z=0.1-0.55
Hernquist model OK	$\rho(r) \sim r^{-n}$	cored $\rho(r)$ at r~0
	n=1.6-2.2 for $r<2\ r_{200}$	$\rho(r) \sim r^{-1.75}$ for $r>r_{200}$

Stacked Groups

Mahdavi et al. 99: *Deep Optical Cat.* 588 gal.s 20 nearby groups	Mahdavi et al. 04: *RASSCALS* 893 gal.s 41 nearby gps	Carlberg et al. 01: *CNOC2* ~800 gal.s ~200 gps, z=0.1-0.55
Hernquist model OK	$\rho(r) \sim r^{-n}$ n=1.6-2.2 for $r<2\,r_{200}$	cored $\rho(r)$ at r~0 $\rho(r) \sim r^{-1.75}$ for $r>r_{200}$
$0.0 \leq \beta \leq 0.7$ ELGs: 1st infall?	$-0.5 \leq \beta \leq 0.5$	$\beta \approx 0$

Stacked Groups

Mahdavi et al. 99: *Deep Optical Cat.* 588 gal.s 20 nearby groups	Mahdavi et al. 04: *RASSCALS* 893 gal.s 41 nearby gps	Carlberg et al. 01: *CNOC2* ~800 gal.s ~200 gps, z=0.1-0.55
Hernquist model OK	$\rho(r) \sim r^{-n}$ n=1.6-2.2 for $r<2\, r_{200}$	cored $\rho(r)$ at r~0 $\rho(r) \sim r^{-1.75}$ for $r>r_{200}$
$0.0 \leq \beta \leq 0.7$ ELGs: 1st infall?	$-0.5 \leq \beta \leq 0.5$	$\beta \approx 0$
$(\rho/\nu)(r)$~constant		M/L ↑ steeply with r↑

Stacked Groups

Mahdavi et al. 99: *Deep Optical Cat.* 588 gal.s 20 nearby groups	Mahdavi et al. 04: *RASSCALS* 893 gal.s 41 nearby gps	Carlberg et al. 01: *CNOC2* ~800 gal.s ~200 gps, z=0.1-0.55
Hernquist model OK	$\rho(r) \sim r^{-n}$ n=1.6-2.2 for $r<2\ r_{200}$	cored $\rho(r)$ at r~0 $\rho(r) \sim r^{-1.75}$ for $r>r_{200}$
$0.0 \leq \beta \leq 0.7$ ELGs: 1st infall?	$-0.5 \leq \beta \leq 0.5$	$\beta \approx 0$
$(\rho/\nu)(r)$~constant		M/L ⬆ steeply with r⬆

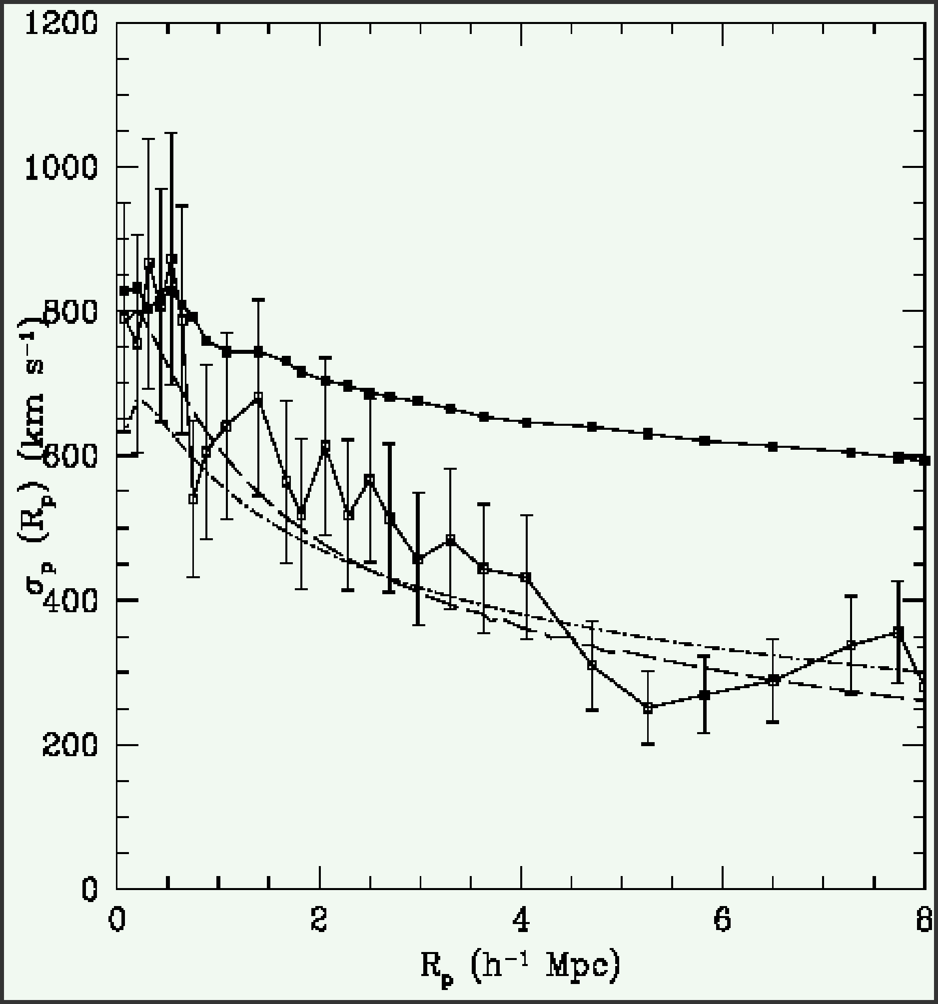
Not a general consensus about the GROUPS M(<r)!

Superclusters

Reisenegger et al. 00; Rines et al. 02
~3000 galaxies in Shapley,
~1300 galaxies in A2197/A2199,
Caustic method

NFW (c=8) and Hernquist
models fit well,
Isothermal does not
Most of the Supercluster
mass is in the clusters

Groups masses overestimated,
their dynamics is dominated
by the SC

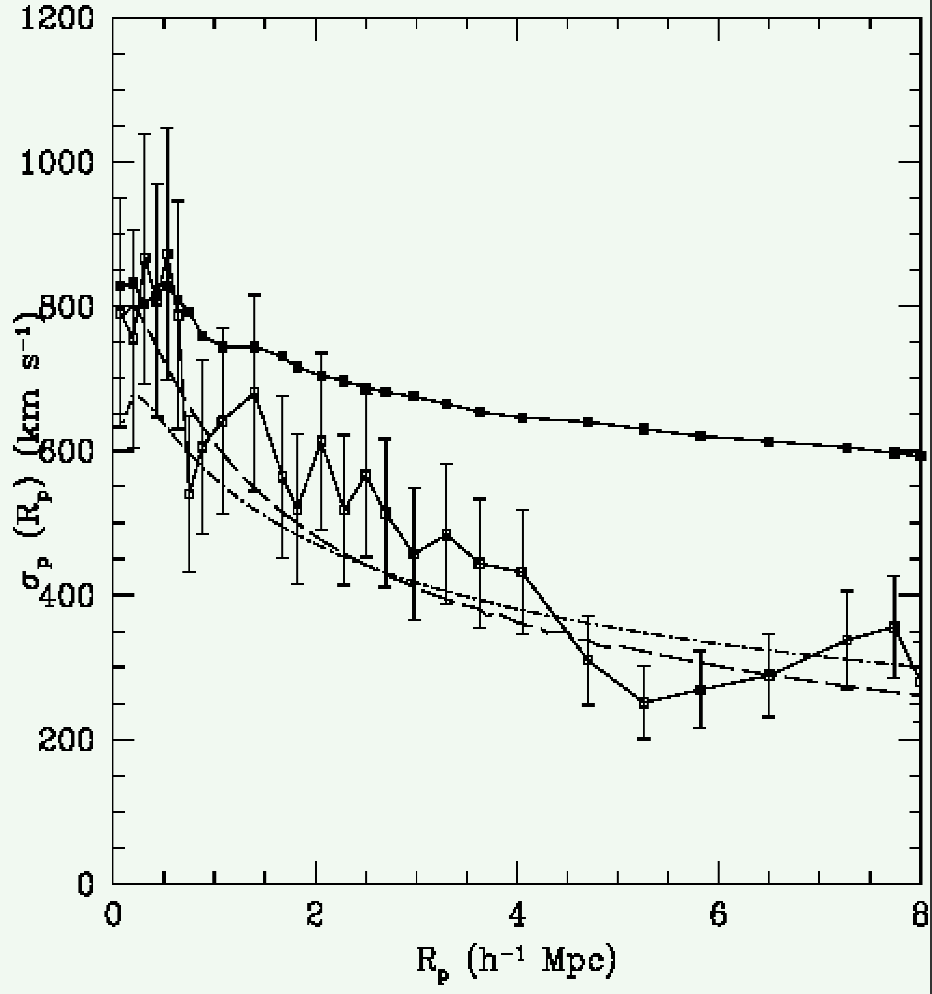


Superclusters

Reisenegger et al. 00; Rines et al. 02
~3000 galaxies in Shapley,
~1300 galaxies in A2197/A2199,
Caustic method

NFW (c=8) and Hernquist
models fit well,
Isothermal does not
Most of the Supercluster
mass is in the clusters

Groups masses overestimated,
their dynamics is dominated
by the SC



Explain why results on groups are still controversial?

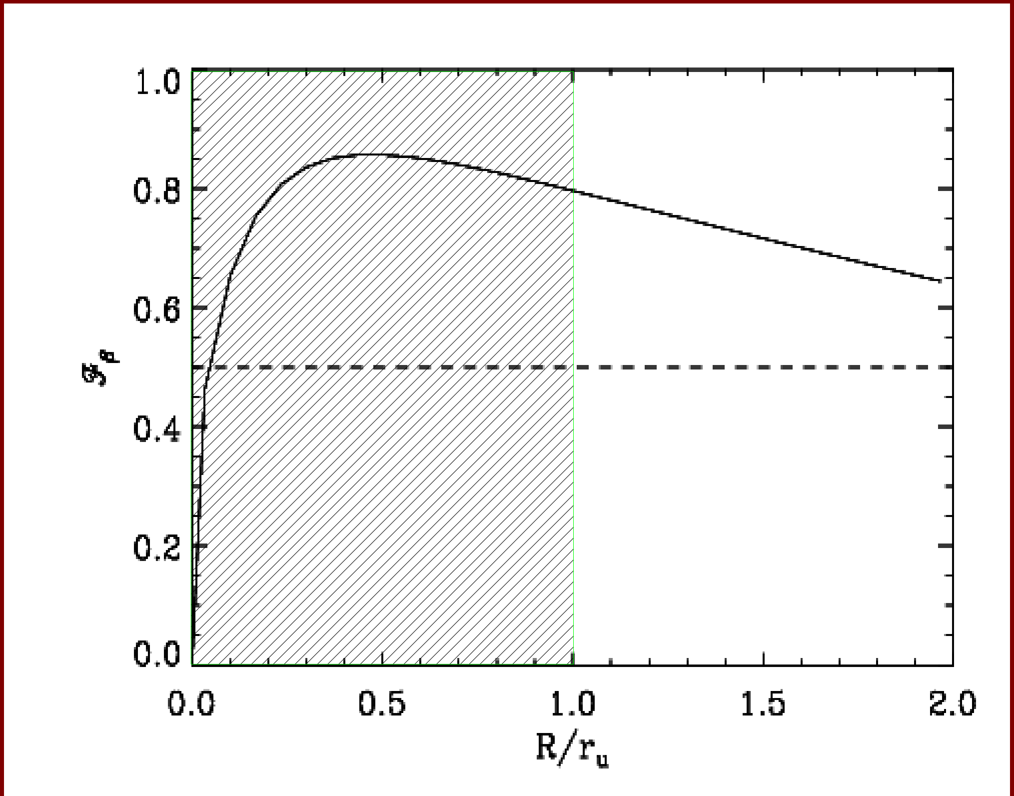
More Results

M(<r) for clusters from the 2dFGRS

Biviano & Girardi 03:
1345 member gals at r $\leq$ 2 r_{200}
in 43 non-interacting nearby clusters

Combine the Jeans and the Caustic methods

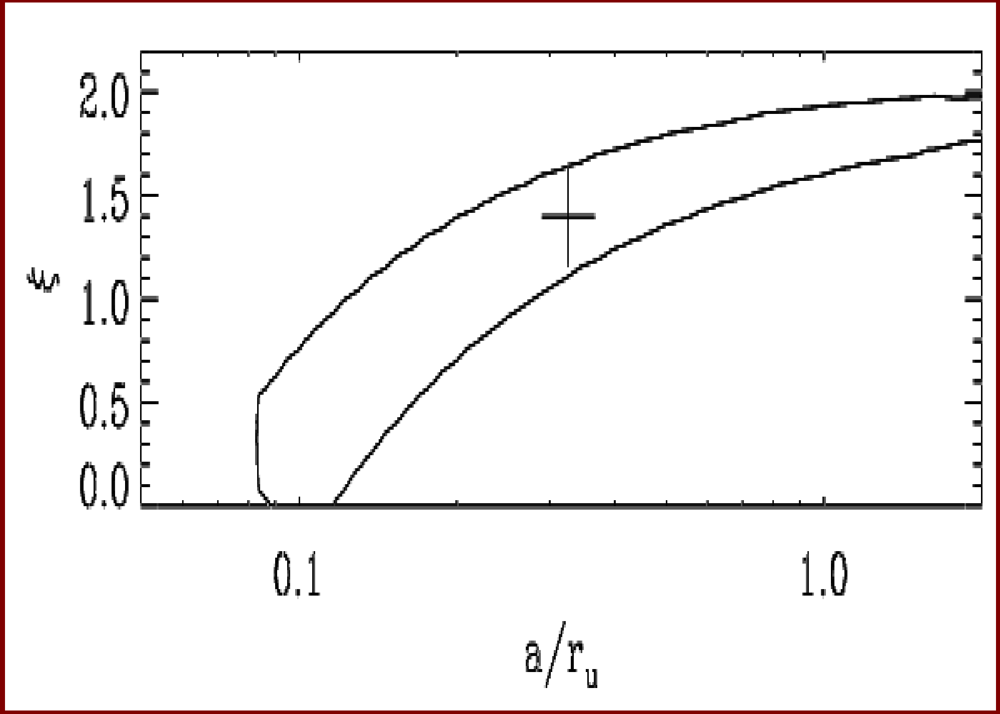
- *since Jeans OK within the virialized region, where also member selection is easier*
- *and Caustic less dependent on Φ,β,r for r>r_{200}*



M(<r) for clusters from the 2dFGRS

Jeans method applied to 642 early-type member gals at $r \leq r_{200}$

(β=0 assumed, reasonable for early-type gals)



Models:

$\rho(r) \propto (r/a)^{-\xi} (1+r/a)^{\xi-3}$

fit well with best-fit ξ=1.4

NFW c=5.6 also OK,

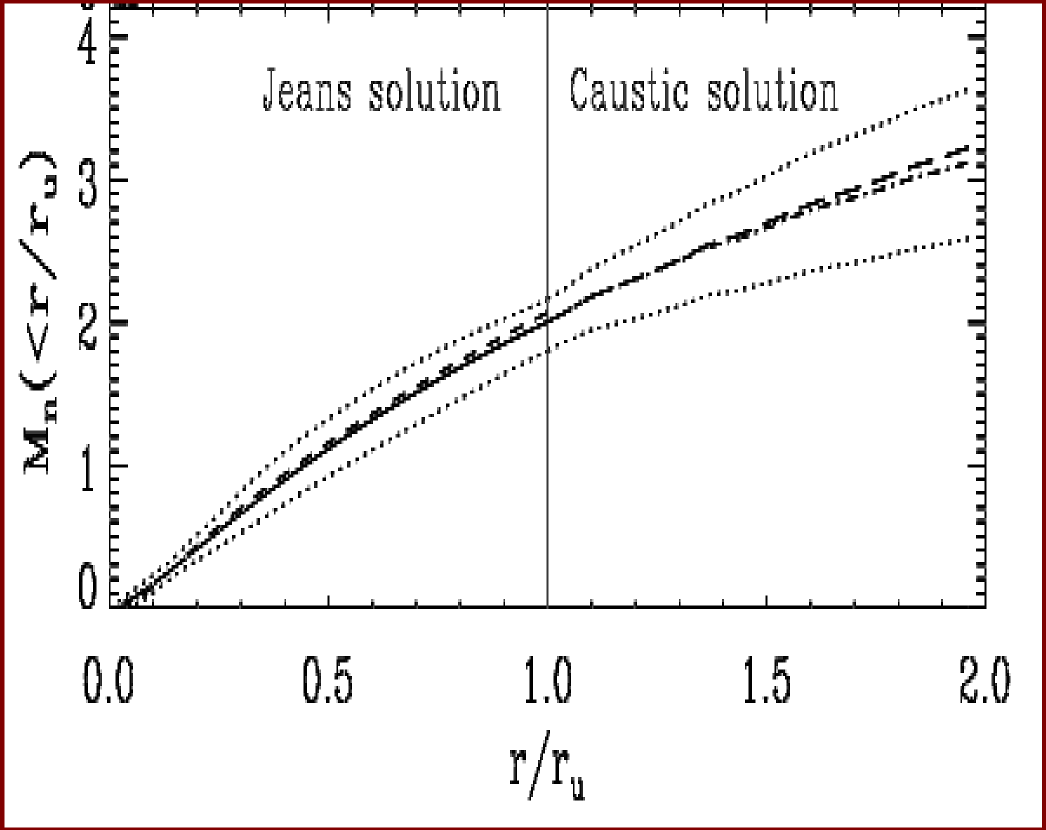
cored profiles only OK if

core radius small < $0.1r_{200}$

M(<r) for clusters from the 2dFGRS

Caustic method applied to extend mass profile at r > r_{200}

(no need to assume β)

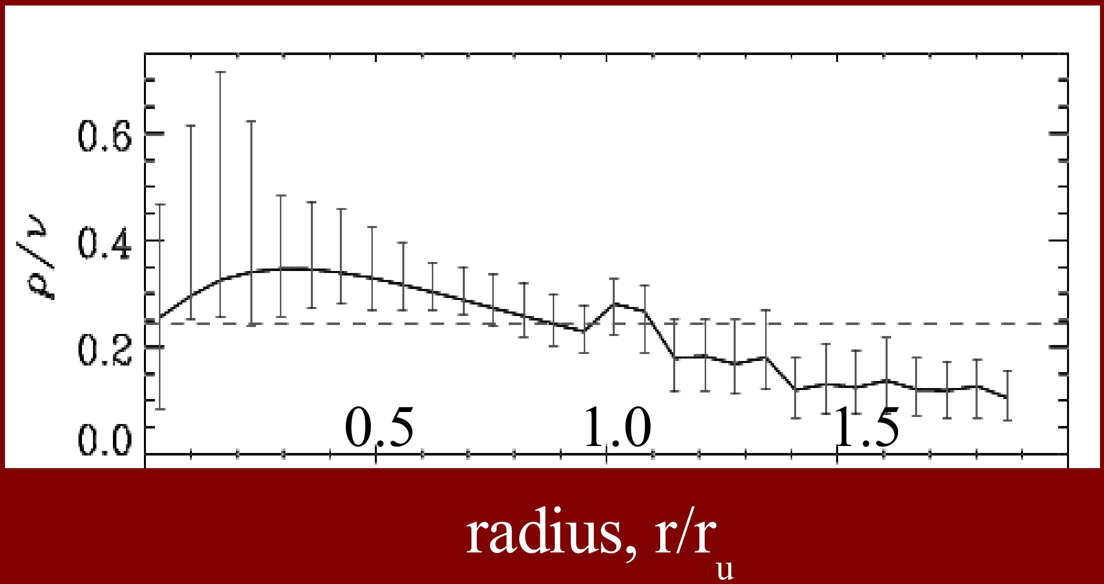


The caustic M(r) nicely continues the M(r) found with the Jeans solution i.e. $\rho(r) \sim r^{-3}$ at large r

M(<r) for clusters from the 2dFGRS

Mass density to galaxy number density ratio $\rho(r)/\nu(r)$

- is constant at $r<r_{200}$ but decreases over the 0 - 2 r_{200} range

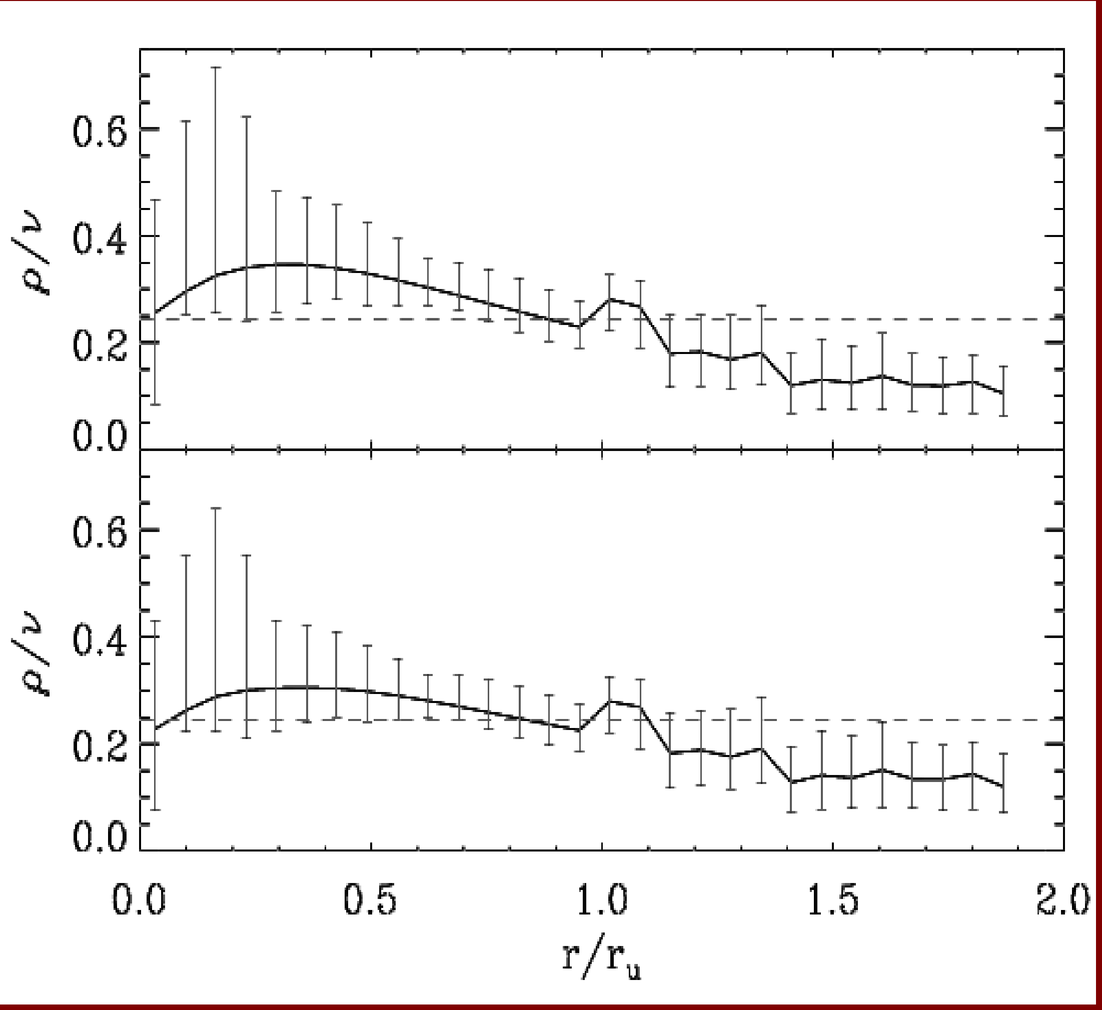


M(<r) for clusters from the 2dFGRS

Mass density to galaxy number density ratio $\rho(r)/\nu(r)$

- is constant at $r<r_{200}$ but decreases over the 0 - 2 r_{200} range

- is constant if only early-type galaxies are considered



M(<r) for clusters from the ENACS

Katgert, Biviano & Mazure 04 + Biviano & Katgert 04:
3056 member gals at $r \leq 1.5\, r_{200}$
in 59 nearby clusters

Jeans method:

- *Use directly the raw data to determine M(<r) – no model*

M(<r) for clusters from the ENACS

Katgert, Biviano & Mazure 04 + Biviano & Katgert 04:
3056 member gals at $r \leq 1.5\ r_{200}$
in 59 nearby clusters

Jeans method:

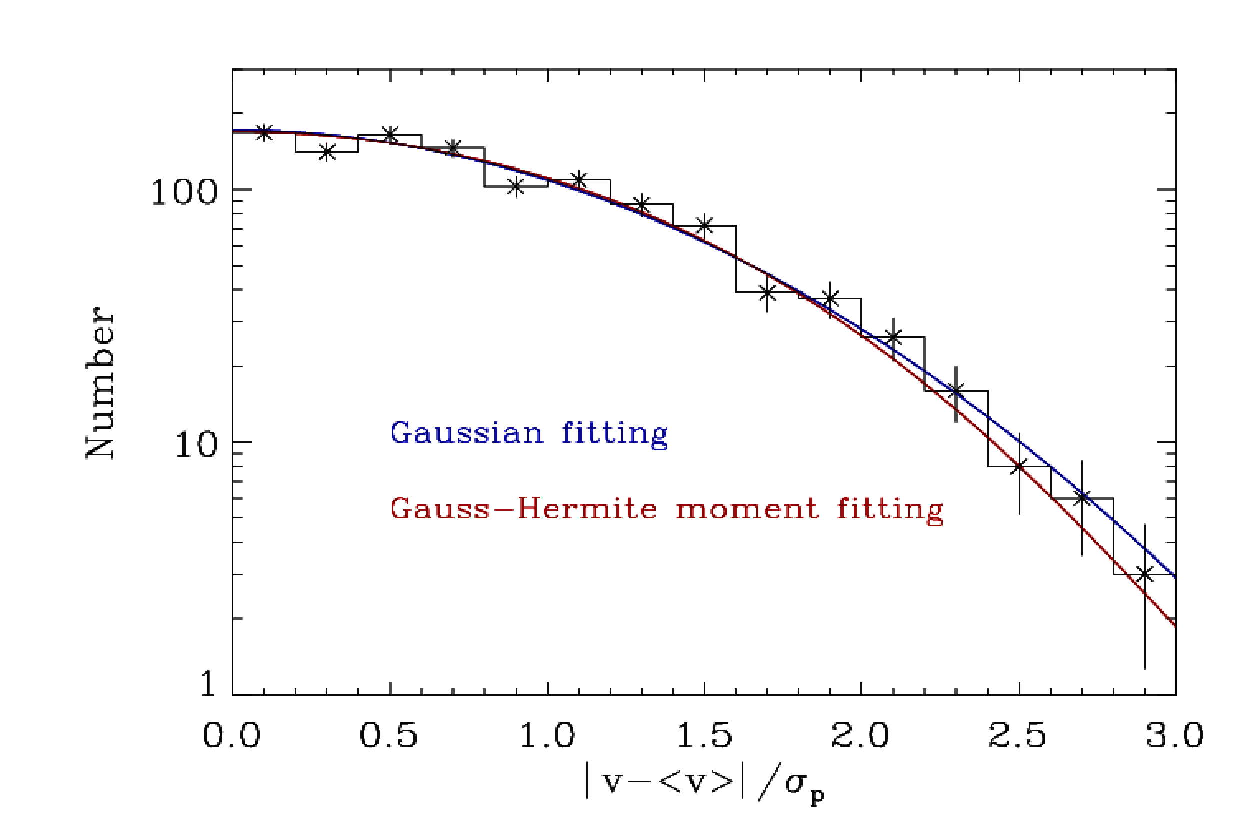
- *Use directly the raw data to determine M(<r) – no model*

- *Use several tracers to break the M(<r) – β(r) degeneracy:*

- *Very bright galaxies (cD-like)*
- *E+S0*
- *early-type spirals*
- *late-type spirals + Irr*
- *galaxies in substructures*

M(<r) for clusters from the ENACS

Start with the dominant cluster population: 1129 E+S0

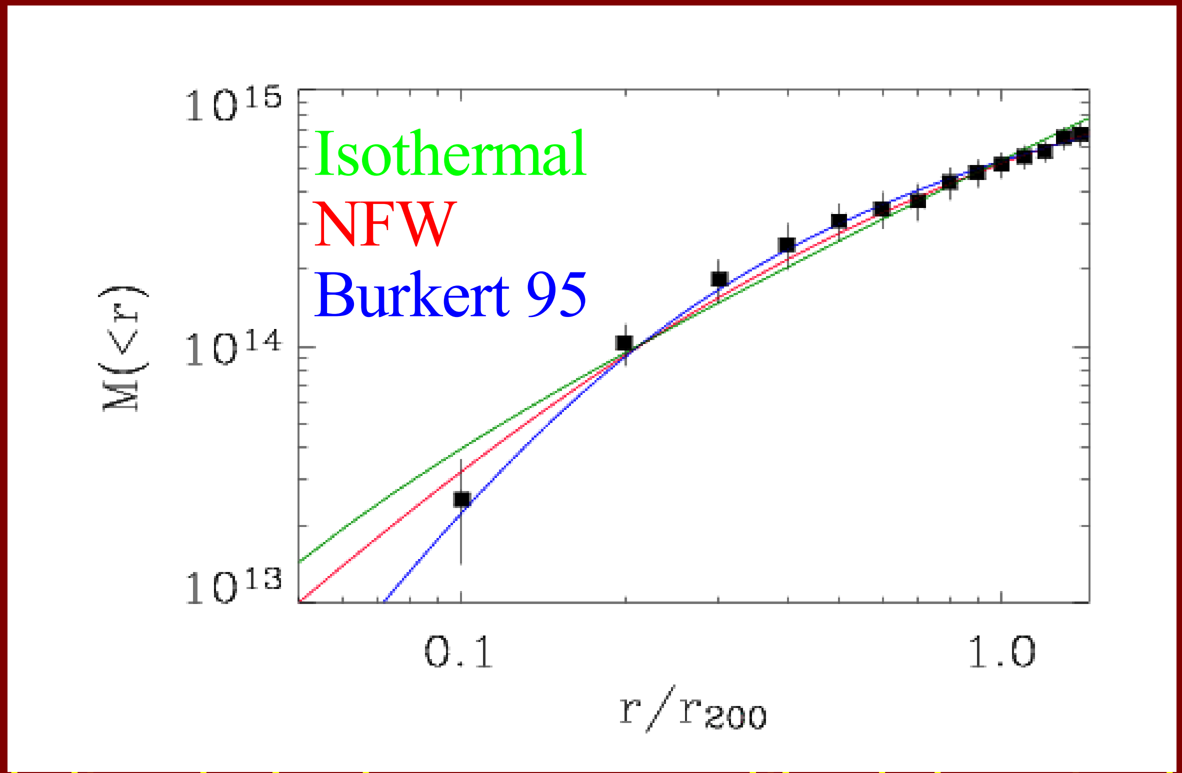


-0.6 $\leqslant\beta\leqslant$0.1 from the analysis of the velocity distribution

➡Isotropic orbits assumed!

M(<r) for clusters from the ENACS

M(<r) solution for the E+S0 population:



First direct cluster mass profile determination:

$\rho(r) \propto r^{-2.4\pm0.4}$ at $r=r_{200}$

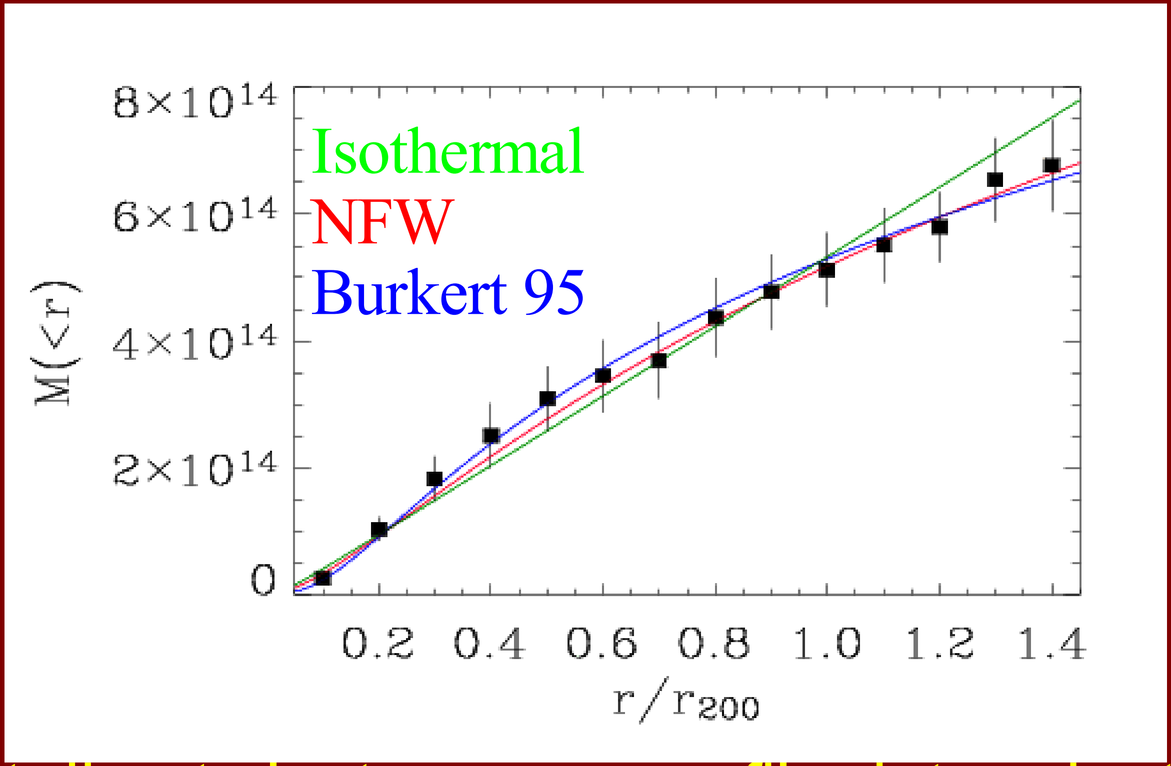
Fitting models:

NFW $c=4\pm2$, Burkert 95 $r_{core}=0.15\ r_{200}$

Isothermal ruled out

M(<r) for clusters from the ENACS

M(<r) solution for the E+S0 population:



First direct cluster mass profile determination:

$\rho(r) \propto r^{-2.4\pm0.4}$ at $r=r_{200}$

Fitting models:

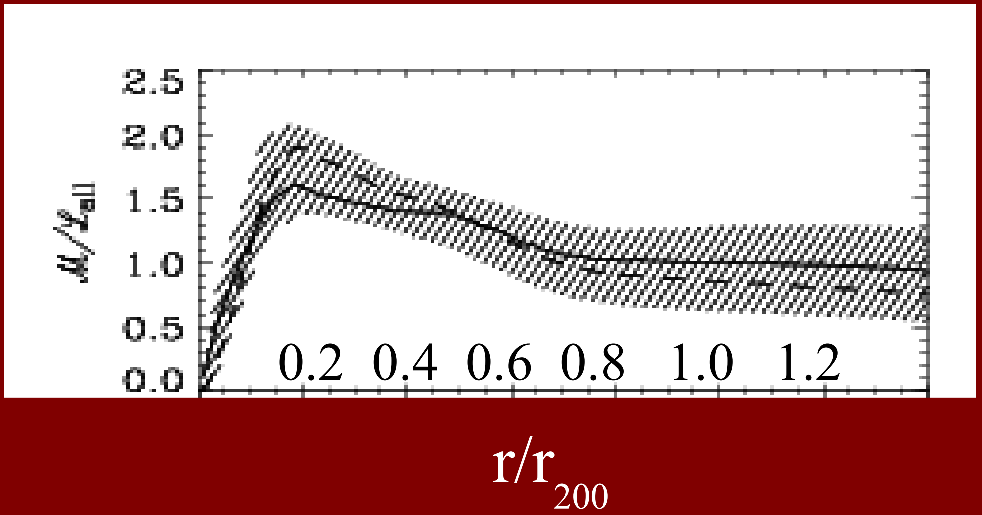
NFW $c=4\pm2$, Burkert 95 $r_{core}=0.15\ r_{200}$

Isothermal ruled out

M(<r) for clusters from the ENACS

Mass-to-light density profile ratio ρ(r)/l(r)

- Excess of light relative to mass both near r~0 and at large r

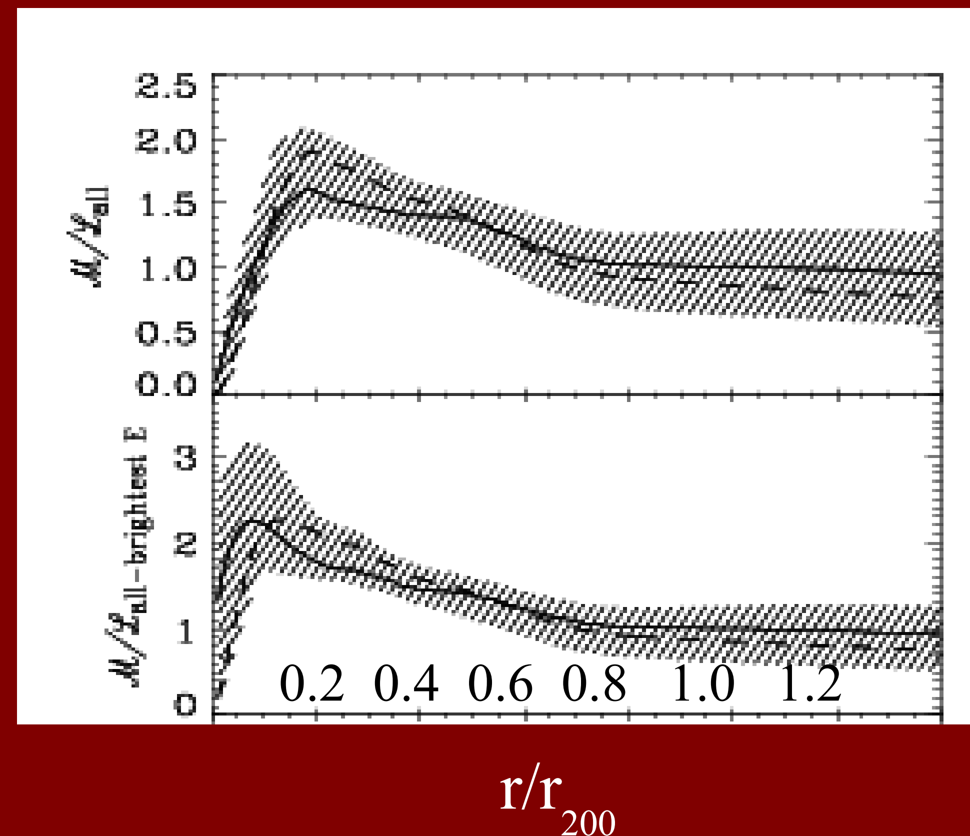


M(<r) for clusters from the ENACS

Mass-to-light density profile ratio $\rho(r)/l(r)$

- Excess of light relative to mass both near r~0 and at large r

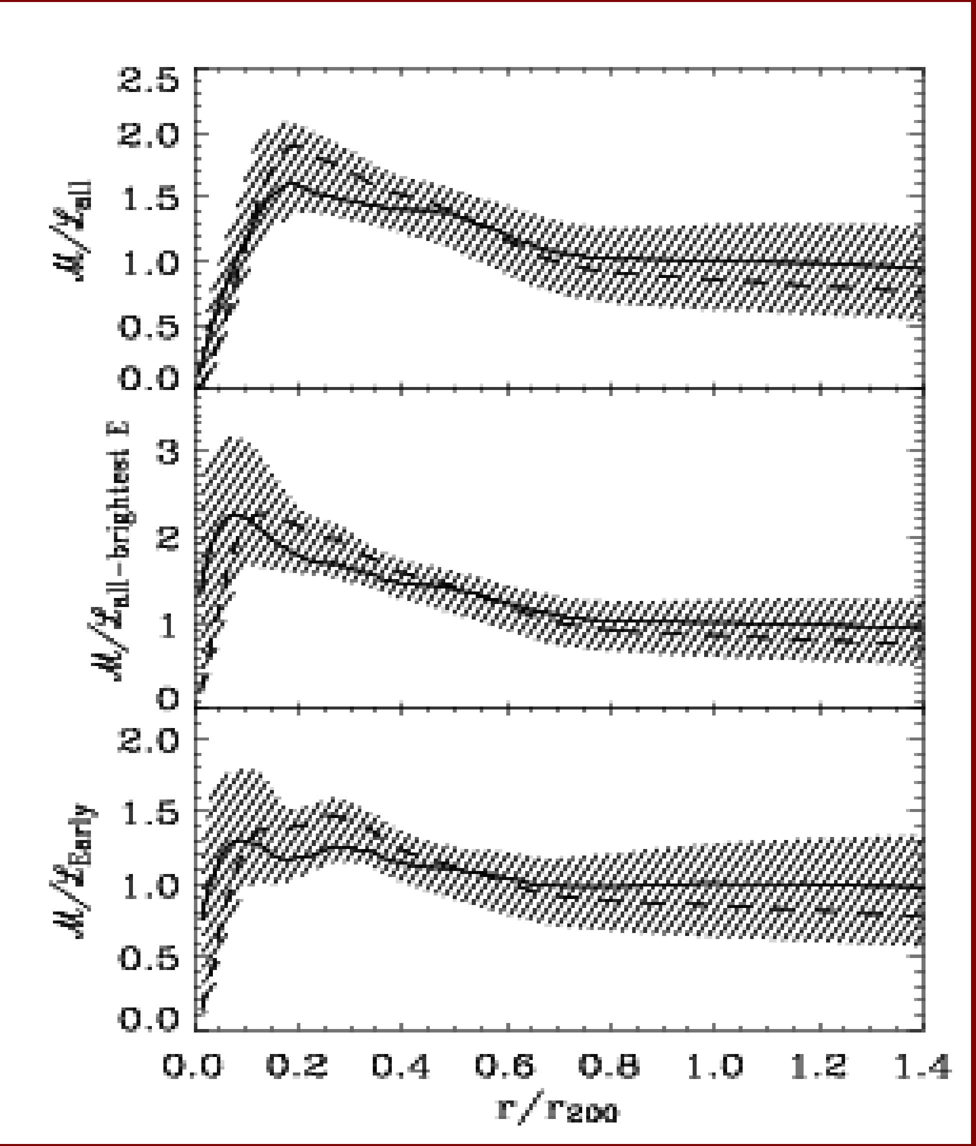
- Excess at r~0 due to cD



M(<r) for clusters from the ENACS

Mass-to-light density profile ratio $\rho(r)/l(r)$

- Excess of light relative to mass both near r~0 and at large r
- Excess at r~0 due to cD
- Excess at large r due to late-type galaxies

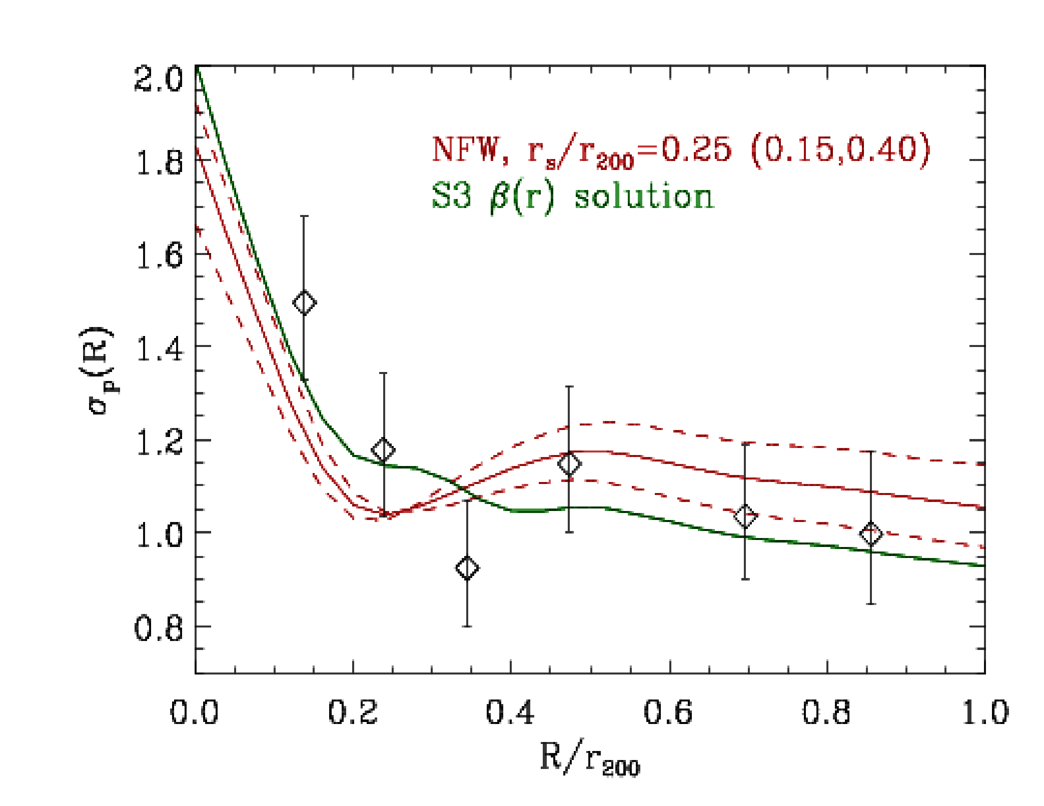


M(<r) for clusters from the ENACS

E+S0 M(<r) confirmed using other cluster galaxy populations

Given M(<r) solve
Jeans eq.s for $\beta(r)$

(see Binney & Mamon 82,
Merrifield & Kent 90,
Solanes & Salvador-Solé 90,
Dejonghe & Merritt 92)

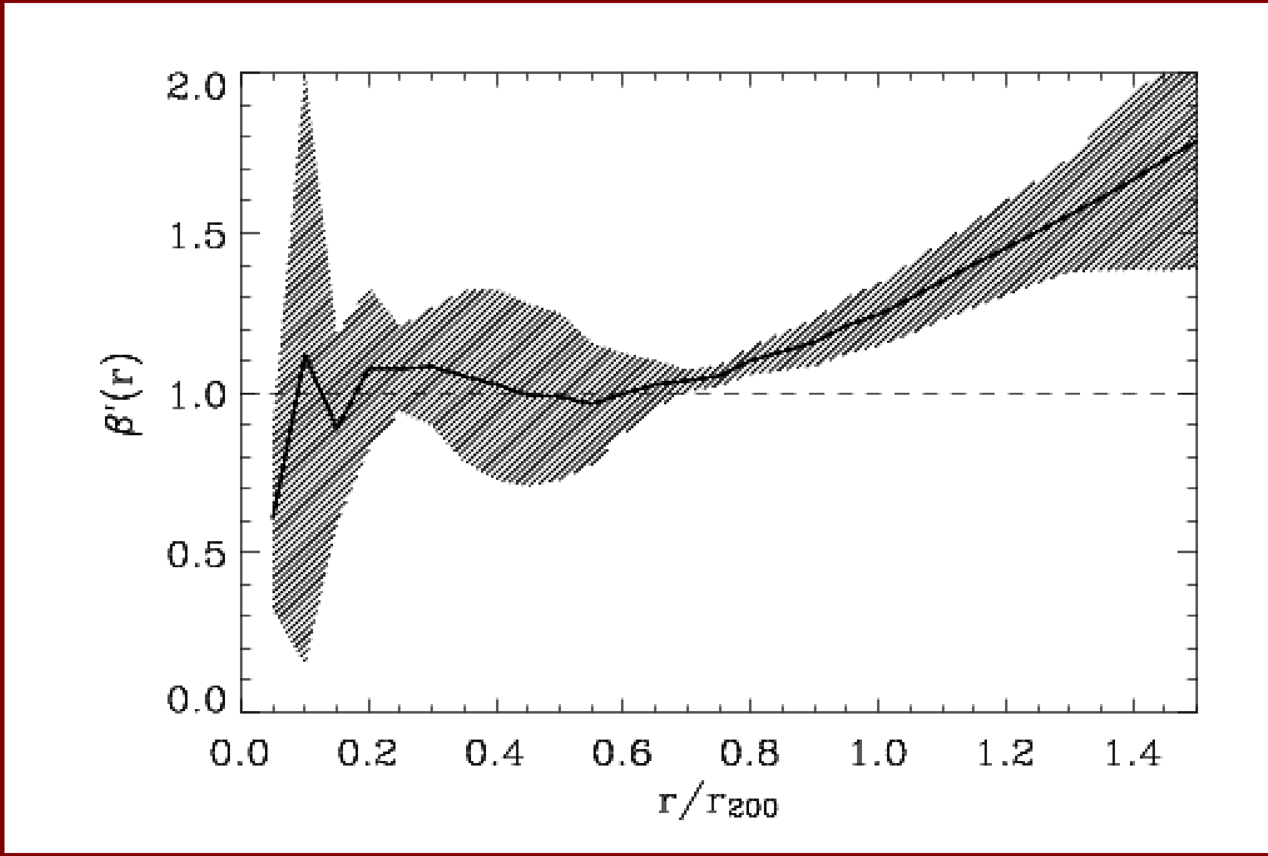


Early spirals in equilibrium within the same grav. potential traced by E+S0, with nearly isotropic orbits

M(<r) for clusters from the ENACS

Late spirals & galaxies in substructures
also in equilibrium within the grav. potential
traced by E+S0, but with non-isotropic orbits:

$\beta' \equiv (\sigma_r/\sigma_t)$

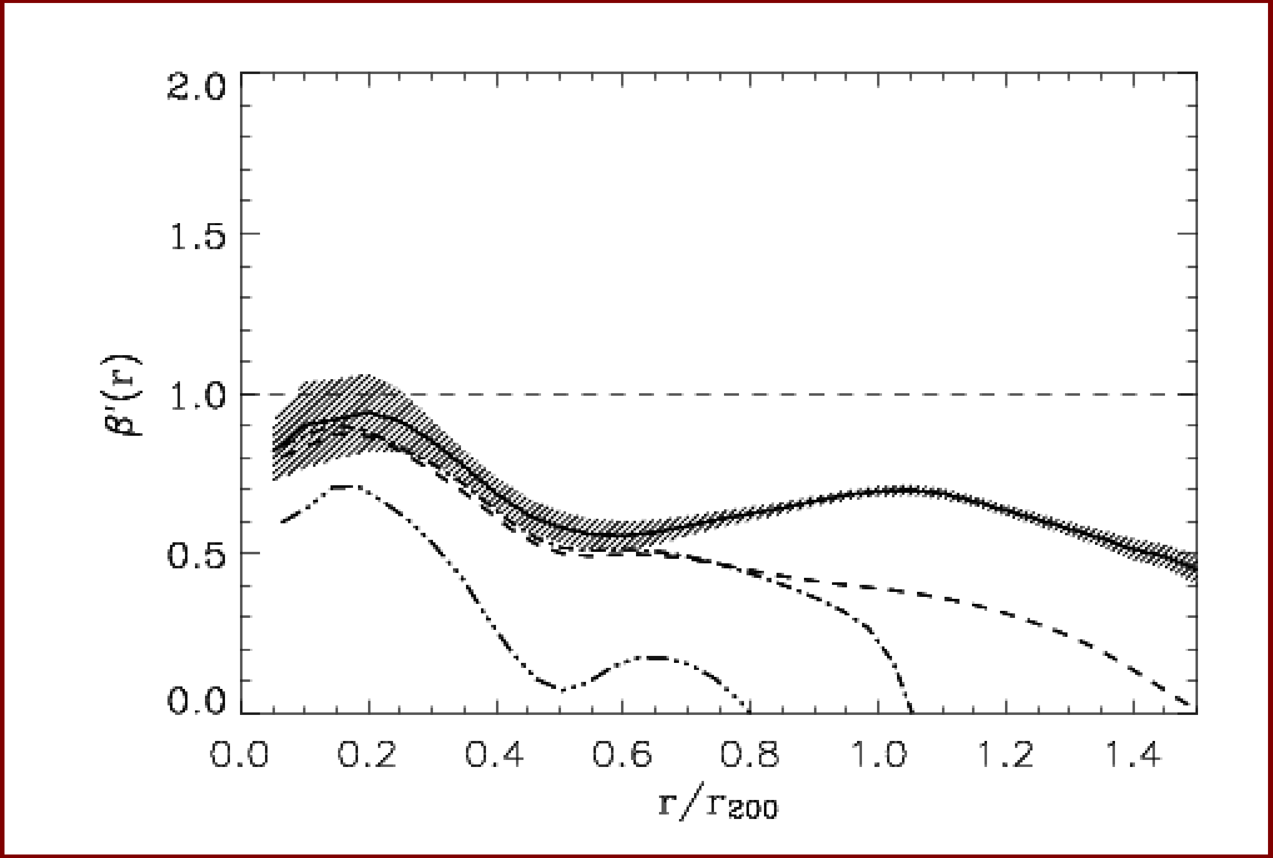


Late-spirals: increasing radial anisotropy with increasing radius

M(<r) for clusters from the ENACS

Late spirals & galaxies in substructures
also in equilibrium within the grav. potential
traced by E+S0, but with non-isotropic orbits:

$\beta' \equiv (\sigma_r / \sigma_t)$



Galaxies in substructures: tangential orbits

M(<r) for clusters from the ENACS

Biviano & Salucci 05 (work in progress):

Determine the DARK MATTER,
not the TOTAL MATTER profile

M(<r) for clusters from the ENACS

Biviano & Salucci 05 (work in progress):

Determine the DARK MATTER,
not the TOTAL MATTER profile

- *Convert galaxies luminosities into baryonic masses (Borriello, Salucci & Danese 03; Persic & Salucci 99)*

M(<r) for clusters from the ENACS

Biviano & Salucci 05 (work in progress):

Determine the DARK MATTER, not the TOTAL MATTER profile

- *Convert galaxies luminosities into baryonic masses (Borriello, Salucci & Danese 03; Persic & Salucci 99)*
- *Estimate the Intra-cluster gas baryonic mass profile using the clusters sample of Reiprich & Boehringer 02*

M(<r) for clusters from the ENACS

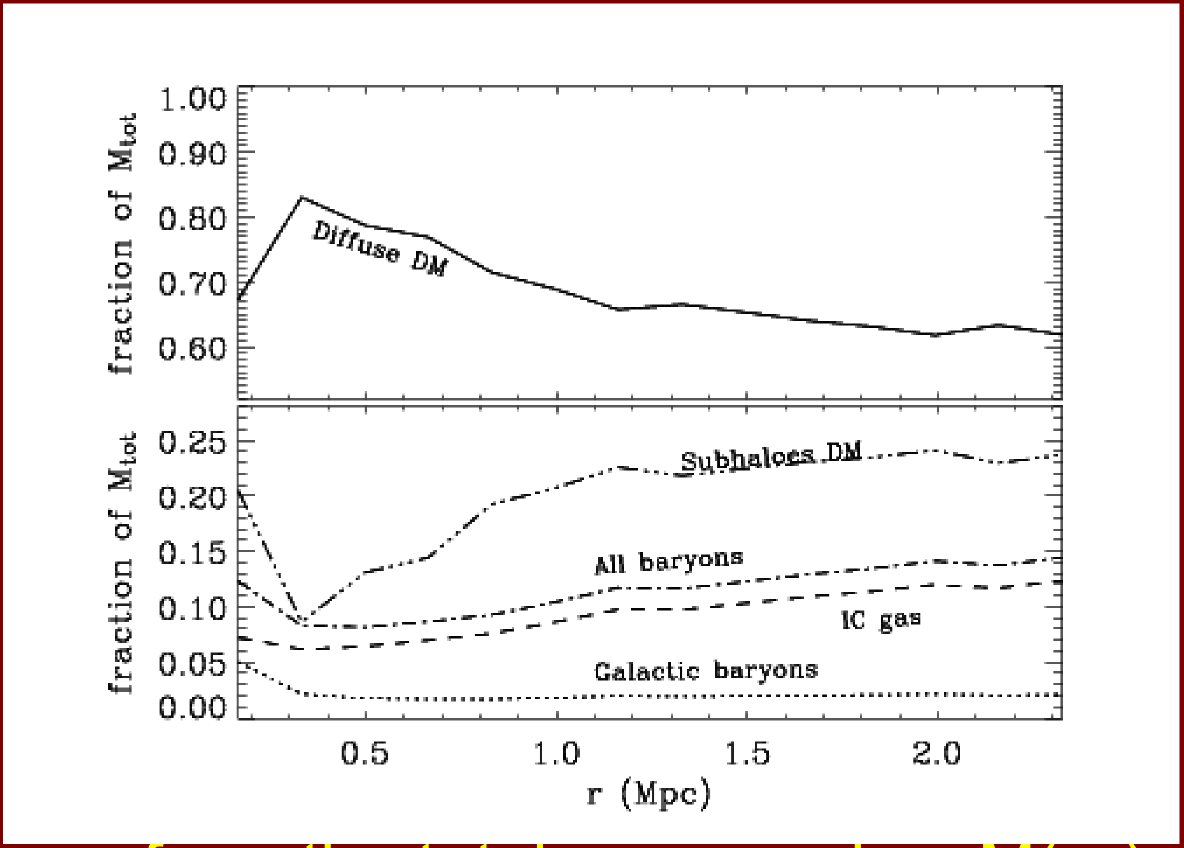
Biviano & Salucci 05 (work in progress):

Determine the DARK MATTER, not the TOTAL MATTER profile

- *Convert galaxies luminosities into baryonic masses (Borriello, Salucci & Danese 03; Persic & Salucci 99)*
- *Estimate the Intra-cluster gas baryonic mass profile using the clusters sample of Reiprich & Boehringer 02*
- *Determine the Dark Matter profile in subhaloes from galaxy luminosities (Shankar, Salucci & Danese 05) by also accounting for halo stripping and overlapping*

M(<r) for clusters from the ENACS

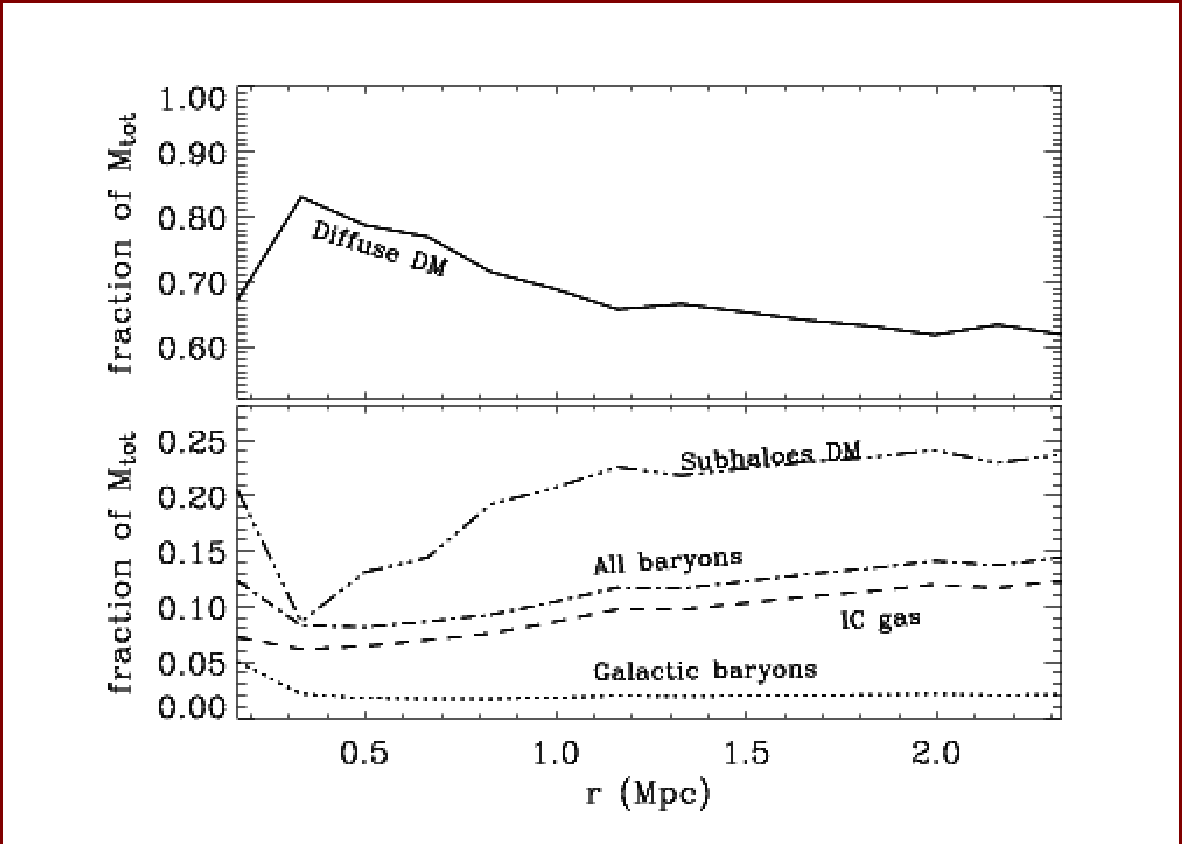
Fractions of total mass in galactic and gas baryons and in dark matter subhaloes



• Subtracting the baryons from the total mass makes M(<r)

M(<r) for clusters from the ENACS

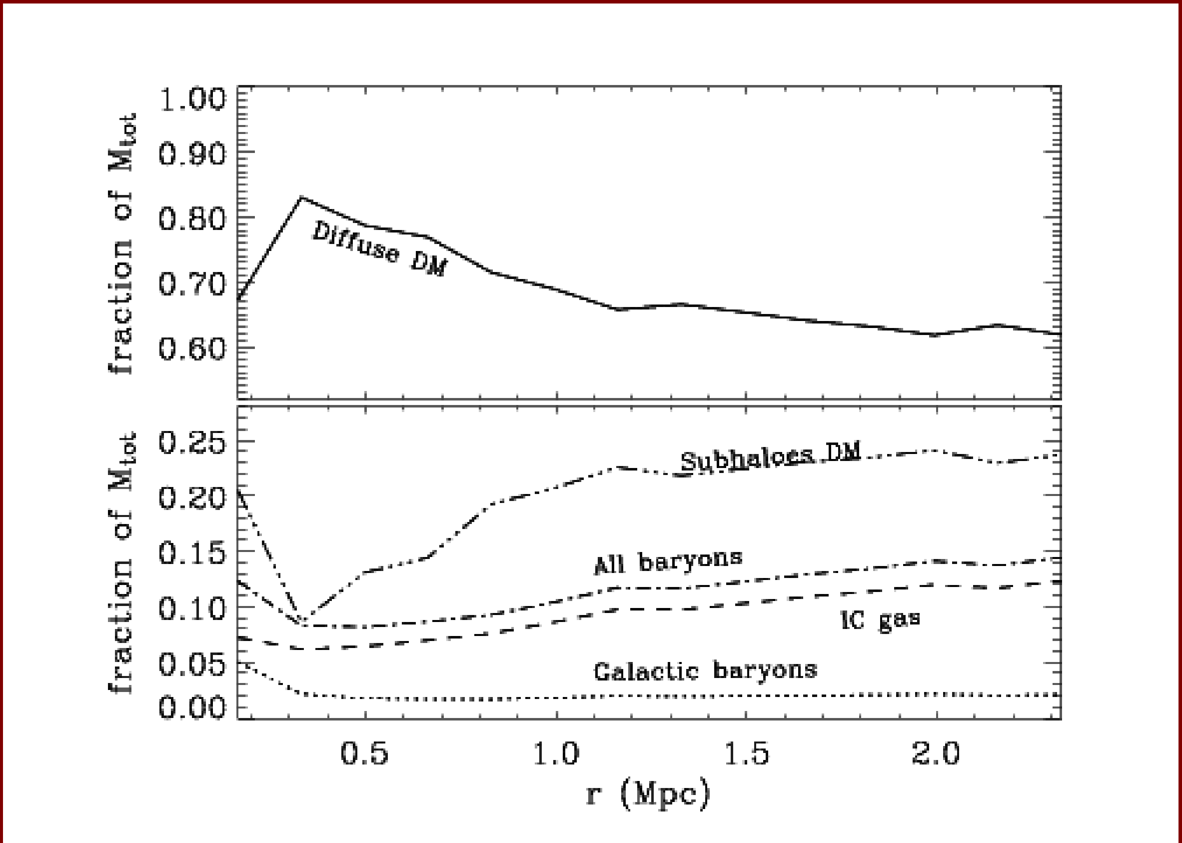
Fractions of total mass in galactic and gas baryons and in dark matter subhaloes



- Subtracting the baryons from the total mass makes M(<r) more concentrated (NFW c=5$\pm$2, Burkert 95 r_c=0.13 r_{200})

M(<r) for clusters from the ENACS

Fractions of total mass in galactic and gas baryons and in dark matter subhaloes

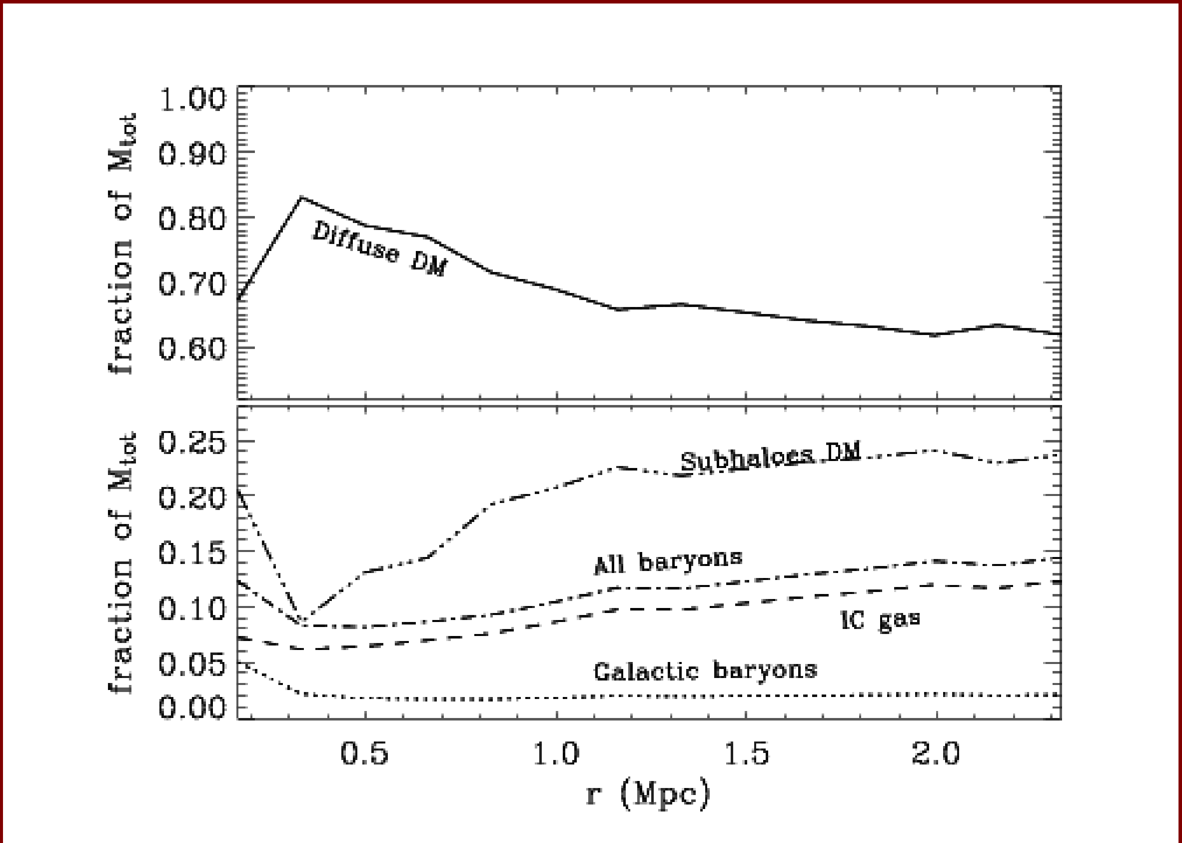


- Subtracting the baryons from the total mass makes M(<r) more concentrated (NFW c=5±2, Burkert 95 r_c=0.13 r_{200})
- Subtracting also the Dark Matter subhaloes makes M(<r) even more concentrated (NFW c=8±2, Burkert 95 r_c=0.09 r_{200})

Both the NFW and the Burkert 95 models are still acceptable

M(<r) for clusters from the ENACS

Fractions of total mass in galactic and gas baryons and in dark matter subhaloes



- Subtracting the baryons from the total mass makes M(<r) more concentrated (NFW c=5±2, Burkert 95 r_c=0.13 r_{200})
- Subtracting also the Dark Matter subhaloes makes M(<r) even more concentrated (NFW c=8±2, Burkert 95 r_c=0.09 r_{200})

Both the NFW and the Burkert 95 models are still acceptable

Summary & perspectives

Results summary

1) Mass density profile of galaxy clusters $\rho(r) \propto r^{-\xi}$:

poor constraints near r=0 : $-2 \leqslant \xi \leqslant 0$

better constraints at large r: $-4 \leqslant \xi \leqslant -3$

→NFW and Hernquist OK, isothermal ruled out

If $\xi=0$ near r=0, core radius is small, $r(\rho=\rho_0/2)<0.1\ r_{200}$

Results summary

2) Mass-to-light profile of galaxy clusters, $(\rho/\nu)(r)$:

M/L~constant within r_{200},
decreases at larger radii

DM more concentrated than baryonic matter
and than DM subhaloes (except for the cD contribution)

Early-type galaxies trace the total matter distribution

Results summary

3) Orbits of galaxies in galaxy clusters:

Early-type galaxies on isotropic orbits

Early-type *spirals* on nearly isotropic orbits

Late-type spirals (and Irr) on radial orbits, $\beta(r)$ ⬆ with r ⬆

Galaxies in substructures on tangential orbits

Results summary

4) Evolution of cluster dynamics with z:

ENACS & CAIRNS vs. CNOC:
No evolution seen from z~0 to z~0.3-0.6
(see also Girardi & Mezzetti 01)

5) Dynamics of less massive systems (groups):

Controversial results

Perspectives

Extend the dynamical analysis to lower mass systems:

Group Evolution Multiwavelength Study (Osmond & Ponman 04):
T_X available: set the scaling lengths for groups stacking

Perspectives

Extend the dynamical analysis to lower mass systems:

Group Evolution Multiwavelength Study (Osmond & Ponman 04):
T_X available: set the scaling lengths for groups stacking

Enlarge the sample:

Sloan Digital Sky Survey, >14000 member gal.s
in 335 poor and rich galaxy systems (Goto 05)

Perspectives

Extend the dynamical analysis to lower mass systems:

Group Evolution Multiwavelength Study (Osmond & Ponman 04):
T_X available: set the scaling lengths for groups stacking

Enlarge the sample:

Sloan Digital Sky Survey, >14000 member gal.s
in 335 poor and rich galaxy systems (Goto 05)

Extend the dynamical analysis to higher-z systems:

Need more z>0.5 clusters with >100 redshifts
(e.g. De Marco et al. 05, Girardi et al. 05)

Thank you
for your attention!

Jeans analysis:

Models vs. raw data... what is best?

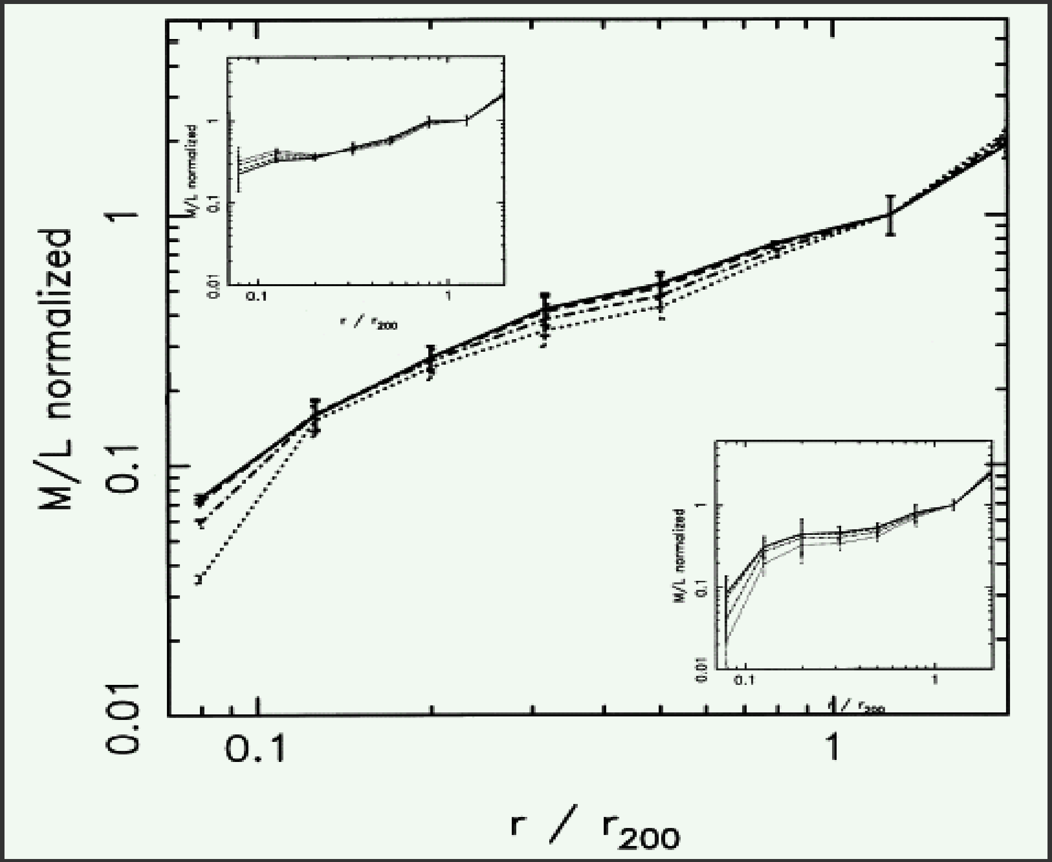
- Models vs. raw data:
  models are easier to integrate and differentiate,
  but $M(<r)$ *solution somewhat forced a-priori*

Practical problems

- <u>Asphericity</u> – Not a real pbm (van der Marel et al. 00)
  Less of a pbm in stacked cl (Sanchis, Łokas & Mamon 04)
  More serious for distant cls? (Plionis et al. 02)

Stacked Groups

Carlberg et al. 01: *CNOC2*
~800 member galaxies
in ~200 group, z=0.1-0.55
Jeans method



ν(r) steeper than NFW at r~0
and $\nu(r) \propto r^{-2.5}$ at large r
L.o.s. vel.disp. profile ~ flat
and $\beta \approx 0$

⇒ Cored ρ(r) and $\rho(r) \propto r^{-1.75}$ at large r ⇒ M/L increasing with r

Not a general consensus about the GROUPS M(<r)!