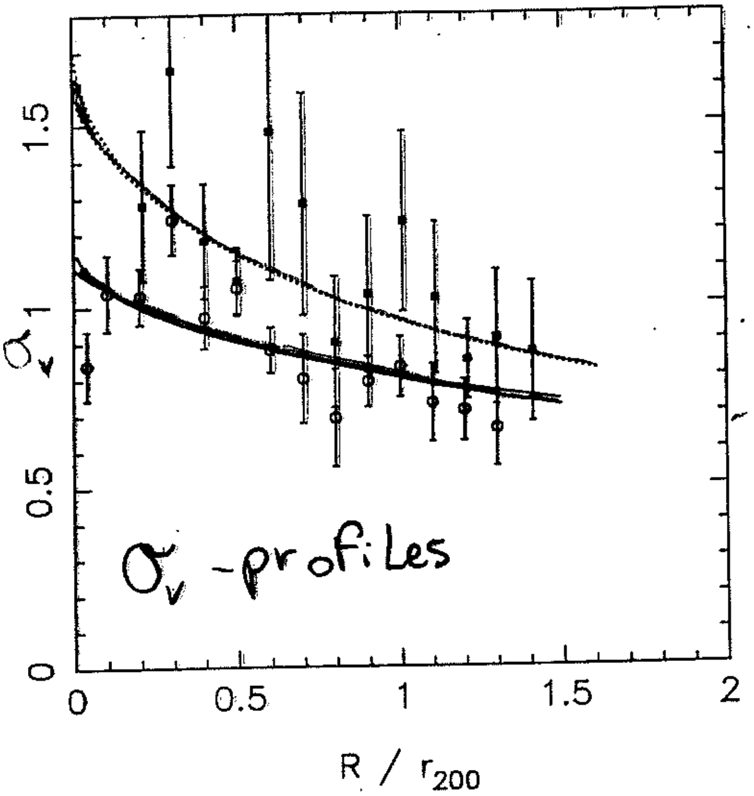
CFR. MASSA DA JEANS
E DA VIRIALE

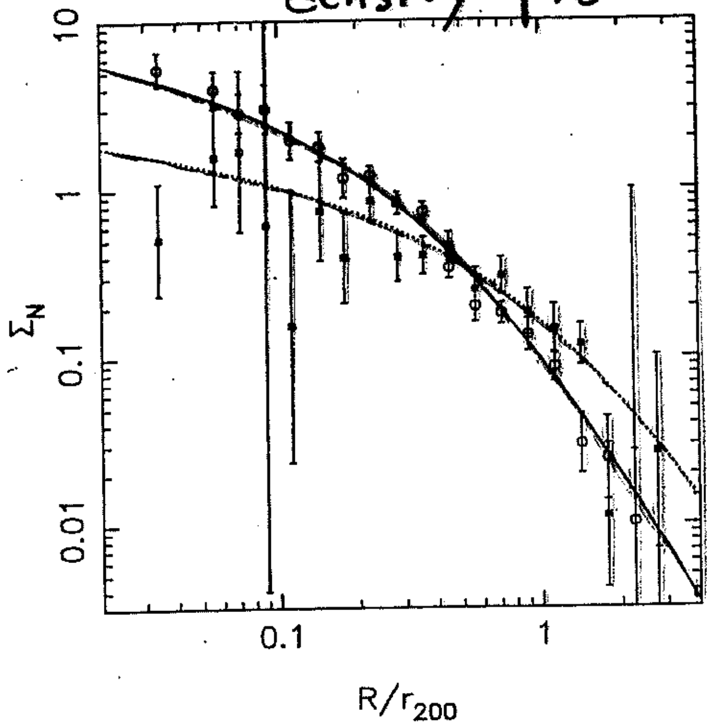
CORREZIONE DEL TERMINE
DI PRESSIONE SUPERFICIALE
(DOVUTO A $\sigma_r(R_{MAX}) \neq 0$)

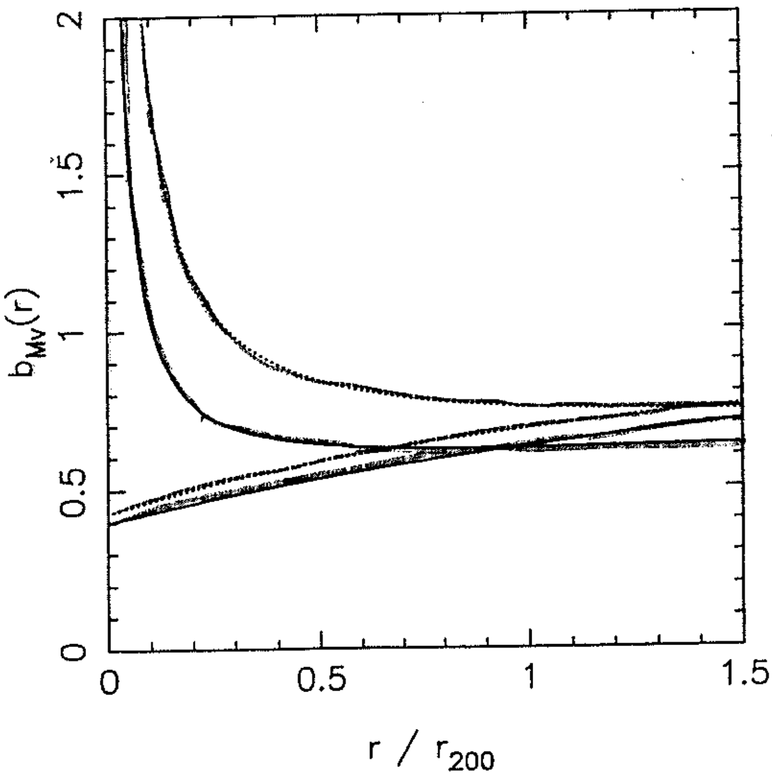
RED / BLUE GALAXIES

CNOC CLUSTERS (CARLBERG ET AL. 1997)

density profiles







DIFFERENZA DA 1 È LA PRESSURE TERM CORRECTION (~20%)

$$\left(\frac{M_{JEANS}}{L(r)} \cdot \frac{\tilde{L}}{\tilde{M}_{VIR}}\right)$$

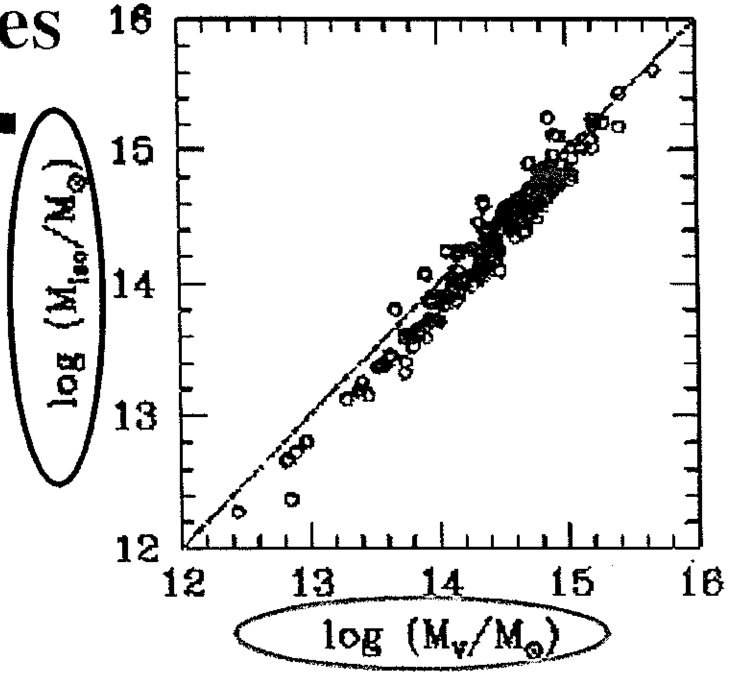
$$M_{VIR}^{BLUE} \sim 3\, M_{VIR}^{RED}$$

BUT

JENS eq. $\Rightarrow$

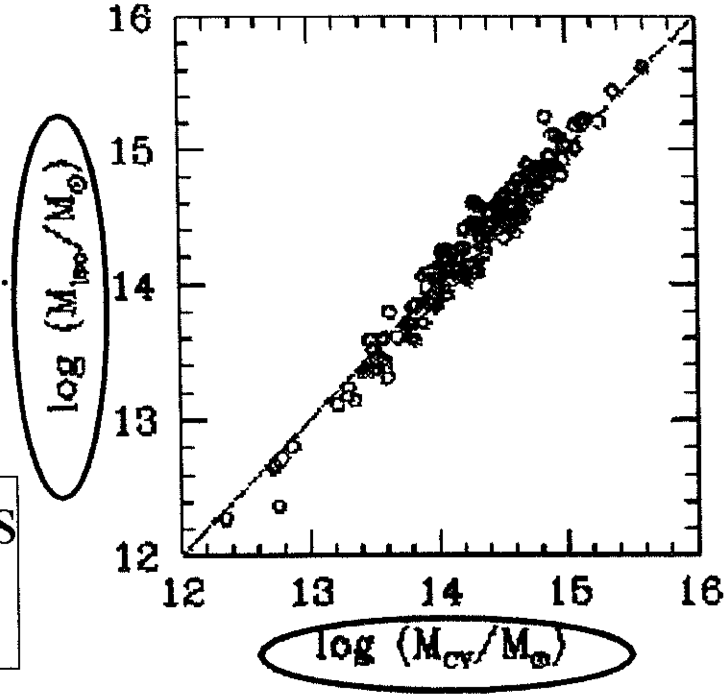
blue galaxies and red galaxies in equilibrium within the same potential

Virial vs. Jeans Mass Estimates



Jeans equation+ flat σ_v–profile
+isotropic orbits
$\Rightarrow \mathbf{M_{iso}(<r)=3\beta_{fit,gal}\sigma_v^2 r/G}$

Median value from the fits: $\beta_{fit,gal}$=0.8.



M_{iso}(<Rvir).
Virial mass.
Virial mass with surface term correction.

M_{iso}(<Rvir) ~Corrected virial mass
⇒Selfconsistency verification.

Teorema del viriale:
Termine di correzione di pressione superficiale
es. Binney-Tremaine, Girardi et al 98, The and White 86
(Carlberg et al 96-98) SPT

$$m\frac{d\phi}{dr} = m\frac{GM(r)}{r^2} = -\frac{d(n\sigma_r^2)}{dr} - \frac{2n}{r}\left(\sigma_r^2 - \sigma_\theta^2\right)$$

$$\times\, 4\pi r^3 \int_0^{r_{max}} \longrightarrow \text{raggio max delle osservazioni}$$

a sinistra:

$$\int_0^{r_{max}} n\frac{d\phi}{dr}4\pi r^3 dr = \left\langle r\frac{d\phi}{dr}\right\rangle_{r_{max}} \cdot \int_0^{r_{max}} n\, 4\pi r^2 dr$$

a destra

$$-\left. n\sigma_r^2 4\pi r^3\right|_0^{r_{max}} + \underbrace{\int_0^{r_{max}} 4\pi r^2 n\,\sigma_r^2 dr - \int_0^{r_{max}} 4\pi r^2 n\left(-2\sigma_r^2 + 2\sigma_\theta^2\right)dr}_{\int_0^{r_{max}} 4\pi r^2 n\,\sigma^2 dr}$$

$\hookrightarrow \sigma(r_{max}) \neq \emptyset$!

$$-n\sigma_r^2(r_{max})4\pi r_{max}^3 + \langle\sigma^2\rangle_{r_{max}}\int_0^{r_{max}} n\,4\pi r^2 dr$$

$$\left\langle r\frac{d\phi}{dr}\right\rangle_{r_{max}} = \frac{-n\sigma_r^2(r_{max})\,4\pi r_{max}^3}{\int_0^{r_{max}} n\,4\pi r^2 dr} + \langle\sigma^2\rangle_{r_{max}}$$

$$\left\langle \cancel{r}\frac{GM(r_{max})F(r)}{r^{\cancel{2}}}\right\rangle_{r_{max}} = GM(r_{max})\left\langle r^{-1}F(r)\right\rangle_{r_{max}}$$

$$M(r_{max}) = \frac{\langle\sigma^2\rangle_{r_{max}}}{G\langle r^{-1}F\rangle_{r_{max}}} - \frac{n\sigma_r^2(r_{max})\,4\pi r_{max}^3}{G\langle r^{-1}F\rangle_{r_{max}}\int_0^{r_{max}} 4\pi r^2 n\,dr}$$

$\hookrightarrow$ M viriale standard

$$M(r_{max}) = M_{V\,STAND}\Bigg(1 - \underbrace{\frac{4\pi r_{max}^3 n(r_{max})}{\int_0^{r_{max}} 4\pi r^2 n\,dr}}_{\text{dipende da profilo distribuz. gals}} \cdot \underbrace{\frac{\sigma_r^2(r_{max})}{\langle\sigma^2\rangle_{r_{max}}}}_{\text{dip. da anisotropia vel. se è isotropo } 1/3}\Bigg) \longrightarrow \text{osserv.}$$

tipicamente
Corr. = 20% di $M_{V\,stand}$. $\times\, R_{max} = R_{200}$

X SURFACE PRESSURE CORRECTION E ANISOTROPIE DI VELOCITÀ

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OPTICAL MASS ESTIMATES OF GALAXY CLUSTERS

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ABSTRACT

We evaluate in a homogeneous way the optical masses of 170 nearby clusters ($z \lesssim 0.15$). The sample includes both data from the literature and the new ESO Nearby Abell Clusters Survey (ENACS) data. On the assumption that mass follows the galaxy distribution, we compute the mass of each cluster by applying the virial theorem to the member galaxies. We constrain the masses of very substructured clusters (about 10% of our clusters) between two limiting values. After appropriate rescaling to the X-ray radii, we compare our optical mass estimates to those derived from X-ray analyses, which we compiled from the literature (for 66 clusters). We find a good overall agreement. This agreement is expected in the framework of two common assumptions: that mass follows the galaxy distribution and that clusters are not far from a situation of dynamical equilibrium, with both gas and galaxies reflecting the same underlying mass distribution. We stress that our study strongly supports the reliability of present cluster mass estimates derived from X-ray analyses and/or (appropriate) optical analyses.

Subject headings: galaxies: clusters: general — galaxies: fundamental parameters — X-rays: galaxies

1. INTRODUCTION

A knowledge of the properties of galaxy clusters plays an important role in the study of large-scale structure formation. In particular, the observational distribution of the abundance of galaxy clusters as a function of their mass places a strong constraint on cosmological models (e.g., Bahcall & Cen 1993; Borgani et al. 1997; Gross et al. 1998; White, Efstathiou, & Frenk 1993a). Moreover, recent studies stress the need for reliable estimates of cluster masses in order to constrain the ratio of the baryonic to the total mass and the consequent value of Ω_0 (e.g., White & Frenk 1991; White et al. 1993b).

Indeed, estimating cluster masses is not an easy task, in spite of the various methods available. Applying the virial theorem to positions and velocities of cluster member galaxies is the oldest method of cluster mass determination (e.g., Zwicky 1933). More recent methods are based on the dynamical analysis of hot X-ray–emitting gas (e.g., Cowie, Henriksen, & Mushotzky 1987; Eyles et al. 1991) and on gravitational lensing of background galaxies (e.g., Grossman & Narayan 1989).

Mass estimates derived from the dynamical analysis of gas or member galaxies based on the Jeans equation or its derivations, such as the virial theorem, assume that clusters are systems in dynamical equilibrium (e.g., Binney & Tremaine 1987). This assumption is not strictly valid; in fact, although clusters are bound galaxy systems, they have collapsed very recently or are just now collapsing, as is suggested by the frequent presence of substructures (e.g., West 1994). However, some analyses suggest that the estimate of optical virial mass is robust against the presence of small substructures (Escalera et al. 1994; Girardi et al. 1997a; see also Bird 1995 for a partially different result), although it is affected by strong substructures (e.g., Pinkney et al. 1996). Similar results are found in studies based on numerical simulations (e.g., Schindler 1996a; Evrard, Metzler, & Navarro 1996; Roettiger, Burns, & Locken 1996) for X-ray masses estimated with the standard β-model approach (Cavaliere & Fusco-Femiano 1976), although some authors have claimed that there is a systematic mass underestimation (e.g., Bartelmann & Steinmetz 1996).

Dynamical analyses based on galaxies have the additional drawback that the mass distribution or (alternatively) the velocity anisotropy of galaxy orbits should be known a priori. Unfortunately, the two quantities cannot be disentangled in the analysis of the observed velocity dispersion profile, but only in the analysis of the whole velocity distribution, which, however, requires a large number of galaxies (on the order of several hundreds; e.g., Dejonghe 1987; Merritt 1988; Merritt & Gebhardt 1994). Without some information on the relative distribution of dark and galaxy components, the virial theorem places only order-of-magnitude constraints on the total mass (e.g., Merritt 1987). The usual approach is to apply the virial theorem assuming that mass is distributed as in the observed galaxies (e.g., Giuricin, Mardirossian, & Mezzetti 1982; Biviano et al. 1993). This assumption is supported by several pieces of evidence from both optical (e.g., Carlberg, Yee, & Ellingson 1997a) and X-ray data (e.g., Watt et al. 1992; Durret et al. 1994; Cirimele, Nesci, & Trevese 1997), as well as from gravitational lensing data, which, however, suggest a smaller core radius (e.g., Narayan & Bartelmann 1997).

The mass estimates derived from gravitational lensing phenomena are completely independent of the cluster dynamical status, but a good knowledge of cluster geometry is required in order to go from the projected mass to the cluster mass (e.g., Fort 1994). Moreover, strong lensing observations give values for the mass contained within very small cluster regions ($\lesssim 100$ kpc), and weak lensing observations are generally more reliable in providing the shape of the internal mass distribution rather than the amount of mass (e.g., Squires & Kaiser 1996).

Up to now, few studies have dealt with wide comparisons between mass estimates obtained by different methods for the same cluster. Wu & Fang (1996, 1997) found that masses derived from gravitational lensing analyses are higher than those derived from X-ray analyses by a factor of 2, but agree

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