ABSTRACT

We study the mass–to–light ratio of galaxy systems from poor groups to rich clusters, and present for the first time a large database for useful comparisons with theoretical predictions. We extend a previous work, where $B_j$ band luminosities and optical virial masses were analyzed for a sample of 89 clusters. Here we also consider a sample of 52 more clusters, 36 poor clusters, 7 rich groups, and two catalogs, of $\sim 500$ groups each, recently identified in the Nearby Optical Galaxy sample by using two different algorithms. We obtain the blue luminosity and virial mass for all systems considered. We devote a large effort to establishing the homogeneity of the resulting values, as well as to considering comparable physical regions, i.e. those included within the virial radius. By analyzing a fiducial, combined sample of 294 systems we find that the mass increases faster than the luminosity: the linear fit gives $M \propto L_B^{1.34\pm0.03}$, with a tendency for a steeper increase in the low–mass range. In agreement with the previous work, our present results are superior owing to the much higher statistical significance and the wider dynamical range covered ($\sim 10^{12}–10^{15}$ $M_{\odot}$). We present a comparison between our results and the theoretical predictions on the relation between $M/L_B$ and halo mass, obtained by combining cosmological numerical simulations and semianalytic modeling of galaxy formation.

Subject headings: galaxies: clusters: general – galaxies: fundamental parameters – cosmology: observations.

1 INTRODUCTION

Since the work by Zwicky (1933), it is well known that the luminous matter associated with galaxies in clusters provides only a small part of the total cluster mass. The relative contribution of the dark matter component is usually specified in terms of the mass–to–light ratio, $M/L$, the total amount of mass relative to the total light within a given scale.

Pioneering analyses showed that $M/L$ increases from the bright luminous parts of galaxies to cluster scales (Blumenthal et al. 1984). Indeed, models of biased galaxy formation, where galaxies formed only in the highest peaks in the initial fluctuation spectrum, naturally predict an increase of $M/L$ with system mass (e.g., Bardeen et al. 1986; Davis et al. 1985). Several mechanisms whereby the efficiency of galaxy formation is biased towards very high density peaks are possible (e.g., Rees 1985). However, only recently has the combination of cosmological N–body simulations and semianalytic modeling of galaxy formation allowed realistic predictions about the $M/L$ of galaxy systems (Kauffmann et al. 1999; Bahcall et al. 2000; Benson et al. 2000; Somerville et al. 2001). Although differing in details, it has been generally found that $M/L$ increases with mass halo from very poor to rich systems, possibly with a flattening on large scales.

As for the observational point of view, the estimate of $M/L$ in galaxy systems is not an easy task. Both mass and luminosity estimates are fraught with several uncertainties. The uncertainties in the luminosity determination are related to corrections for calibration of the photometry (when using inhomogeneous photometric data), background galaxy contamination, and the need to extrapolate the sum of measured luminosities of galaxy members to include faint galaxies and the outer parts of the systems, beyond the region studied (see, e.g., Oemler 1974).

Also the estimate of masses is not an easy task, in spite of the various methods which have been applied (e.g., Narayan & Bartelmann 1996; Schindler 1996; Mellier 1999; Biviano 2001). Masses of galaxy systems are inferred from either X–ray or optical data, under the general hypothesis of dynamical equilibrium. Estimates based on gravitational lensing do not require assumptions about the dynamical status of the system, but a good knowledge of the geometry of the potential well is necessary. Claims for a discrepancy (by a factor of 2–3) between cluster masses obtained with different methods cast doubts about the general reliability of mass estimates (e.g., Wu & Fang 1997). However, recent analyses have shown that, if we avoid cases of bimodal clusters, mass estimates concerning large cluster areas are in general agreement (Allen 1997; Girardi et al. 1998b, hereafter G98; Lewis et al. 1999).

Large collections of observational data concerning galaxies, groups, and clusters suggest that all systems have a constant ratio of $M/L_B \sim 200–300$ $h M_{\odot}/L_{\odot}$ for scales larger than galaxies, so that the total mass of galaxy systems could be roughly accounted for by the total mass of their member galaxies, possibly plus the mass of the hot intracluster gas (Rubin 1993; Bahcall, Lubin, & Dor-
Homogeneous samples, where both masses and luminosities are computed in a consistent way, would be more reliable. Unfortunately, the above observational difficulties prevented us from building a large $M/L$ data base spanning a wide dynamical range. Based on homogeneous optical data, the pioneering work by Dressler (1978) showed no evidence of correlation of $M/L$ values with richness for 12 clusters. More recently, David, Jones, & Forman (1995), who used homogeneous X–ray mass estimates and luminosities from different sources in the literature, showed that $M/L_V$ of seven groups and clusters of galaxies are comparable. Also $M/L_r$ values for the sample of 15 clusters of the Canadian Network for Observational Cosmology (CNOC, Calberg et al. 1996), where masses come from optical virial estimates, are consistent with an universal underlying value.

A slight increase of $M/L$ with mass system was suggested by indirect analyses of the cluster fundamental plane, i.e., the study of the relations between cluster size, internal velocity dispersion, and luminosity (but see Fritsch & Buchert 1999). In fact, assuming the virial–size, internal velocity dispersion, and luminosity (but see plane, i.e., the study of the relations between cluster fundamental plane, i.e., the study of the relations between cluster size, internal velocity dispersion, and luminosity), showed that $M/L_V$ of seven groups and clusters of galaxies are comparable. Also $M/L_r$ values for the sample of 15 clusters of the Canadian Network for Observational Cosmology (CNOC, Calberg et al. 1996), where masses come from optical virial estimates, are consistent with an universal underlying value.

New insights on the behavior of $M/L$ for galaxy systems of different mass would be particularly useful in view of the theoretical predictions recently coming from cosmological N–body simulations combined with semianalytic modeling of galaxy formation. To draw more definitive conclusions about this topic, we extend the work of G00 by increasing the statistics of the data base and doubling the dynamical range, from $\sim 5 \times 10^{13} - 10^{15} h^{-1} M_\odot$ to $\sim 10^{12} - 10^{15} h^{-1} M_\odot$. To this purpose, we consider both clusters analyzed by G98, the poor clusters by Ledlow et al. (1996; hereafter L96), the rich groups by Zabludoff & Mulchaey (1998a; hereafter ZM98), and the groups identified in the NOG sample (Nearby Optical Galaxy, Giuricin et al. 2000).

The paper is organized as follows. We describe the data samples in § 2. We compute the main observational quantities, i.e. virial masses and optical luminosities, for all galaxy systems in § 3. We devote § 4 to the analysis of the relation between mass and luminosity and to the mass–to–light ratio. We discuss our results in § 5, while in § 6 we give a brief summary of our main results and draw our conclusions.

Unless otherwise stated, we give errors at the 68% confidence level (hereafter c.l.)

A Hubble constant of $100 h$ km s$^{-1}$ Mpc$^{-1}$ is used throughout.

## 2 DATA SAMPLES

Table 1 briefly summarizes the samples of galaxy systems in this work. We list: the sample name with the corresponding number of systems, $N_S$, and references for the catalog [Cols. (1), (2), and (3), respectively]; the sub-sample name with the corresponding number of systems, $N_{SS}$ [Cols. (4) and (5), respectively]; the references for galaxy redshift and coordinates used for mass determination [Col. (6)]; the references for galaxy magnitudes used for luminosity determination [Col. (7)]; and a brief description of the sample [Col. (8)]. Detailed comments are given below.
The sample of nearby clusters ($z \leq 0.15$) of G98 is an extension of that of Fadda et al. (1996) and collects clusters having at least 30 galaxies with available redshifts in the field, in order to allow homogeneous and robust estimates of internal velocity dispersion and cluster mass. G00 have already analyzed a subsample of 89 clusters for which galaxy magnitudes are available in the COSMOS catalog (hereafter C-CL sample).

Here we select another 52 clusters (hereafter A-CL sample) for which galaxy magnitudes are available in the Revised APS catalog of POSSI (Pennington et al. 1993). In particular, we avoid the G98 clusters which show two peaks either in the velocity or in the projected galaxy distribution, as well as clusters with uncertain dynamics (cf. § 2 of G98). From the G98 analysis we take for each cluster: the l.o.s. velocity dispersion $\sigma_v$, the cluster center, the virial radius $R_{\text{vir}}$ (there called virialization radius), and the (corrected) virial mass $M$ computed within $R_{\text{vir}}$.

Among A-CLs, 22 systems are in common with C-CLs and will be used to homogenize the photometric data.

### 2.2 Sample of Poor Systems (PS)

The 71 poor galaxy clusters of L96 are a statistically complete sample derived from the catalog of 732 nearby poor clusters of White et al. (1999). The clusters of the original sample were optically selected by covering the entire sky north of $-3^\circ$ declination and are identified as concentrations of 3 or more galaxies with photographic magnitudes brighter than 15.7 (from Zwicky et al.’s 1961-1968 catalogue), possessing a galaxy surface overdensity of 21.5. The subsample of L96 is limited to the galactic latitude range $|b| \geq 30^\circ$ and to the most dense and rich groups, i.e. with 46.4 surface–density enhancement and with at least four Zwicky galaxies. L96 collected new redshifts and computed velocity dispersions for several of these poor clusters.

The sample of ZM98 consists of 12 nearby optically–selected groups from the literature (NED, NASA/IPAC Extragalactic Database) for which there are existing, sometimes serendipitous, pointed PSPC observations of the fields in which the groups lie. As pointed out by the authors, this group sample is not representative of published group catalogs, but is weighted towards X-ray groups. By using multi-fiber spectroscopy, ZM98 extend greatly the number of galaxies with available redshift and present a sample of 1002 galaxy velocities.

Avoiding poor systems with $z \leq 0.01$, more strongly affected by peculiar motions, and those which do not survive our procedure of member selection (cf. § 3.1), we consider 36 poor clusters and 7 rich groups for a total sample of 43 poor systems (hereafter PS) having available magnitudes in COSMOS and/or APS (C-PS and A-PS samples, respectively). In particular, five poor systems have available magnitudes in both photometric catalogs.

From ZM98 we take for each rich group: the group center, and galaxy positions and redshifts, to apply our procedure of member selection (cf. § 3.1). From L96 we take the mean velocity and the center for each poor cluster: we use these data to collect galaxy positions and redshifts within $1.5 \, h^{-1} \text{Mpc}$ from the cluster center by using NED, and then apply our procedure of member selection.

### 2.3 NOG Group Samples (HG and PG)

We use the groups identified by Giuricin et al. (2000) in the NOG sample. This is a complete, distance limited ($cz < 6000 \, \text{km s}^{-1}$) and magnitude limited ($B \leq 14$) sample of $\sim 7000$ optical galaxies, which covers about 2/3 of the sky ($|b| > 20^\circ$), and appears to be quasi-complete in redshift (97%). The authors identified the groups by means of both the hierarchical and the percolation “friend–of–friend” methods: their final catalogs contain 475 and 513 groups, respectively (hereafter HG and PG). From Giuricin et al. (2000) we take the data available for each group’s galaxy positions, redshifts, and corrected total blue magnitudes.

### 3 MASS AND LUMINOSITY ESTIMATES

With the exception of the masses of CLs and luminosities of C-CLs, all other mass and luminosity estimates are obtained in this study. In order to extend the work by G00 throughout this section, a great effort is devoted to computing masses and luminosities in a consistent way so as to obtain a large homogeneous sample of $M/L$ estimates.

In particular, G00 used mass and luminosity computed within the virial radius $R_{\text{vir}}$, which defines, as usual in the context of cold dark matter (CDM) cosmologies, the region where the matter overdensity is $\sim 180$ for a $\Omega_m = 1$ cosmology, or $\sim 350$ for a $\Omega_m = 0.3$ and $\Omega_{\Lambda} = 0.7$ cosmology (which hereafter we use as our reference model in this
study). In this region one can assume a status of dynamical equilibrium and therefore reasonably apply the virial theorem for the mass computation.

In our case, where we deal with systems spanning a large dynamical range, to consider comparable physical regions is particularly useful for mass and luminosity estimation. The great advantage lies both in considering a similar dynamical status (e.g., in the case of variations among galaxy systems, cf. Zabludoff & Mulchaey 1998b) and a comparable galaxy population (in connection with color gradients, e.g., Abraham et al. 1996). Therefore we compute both mass and luminosity within $R_{\text{vir}}$.

3.1 Mass Determination

For poor systems, PCLs, we perform the same procedure already used by G98, in particular with those recipes for poor data samples already introduced by Girardi \\& Mezzetti (2001). Since the procedure was already amply described in these works (cf. also Fadda et al. 1996), here we only outline the main steps.

3.1.1 Member Selection

After having converted all galaxy velocities to galactocentric ones, we perform the selection of member galaxies. First, we apply the one-dimensional algorithm of the adaptive kernel technique by Pisani (1993, see also Appendix A of Girardi et al. 1996) to find the significant peaks in the velocity distribution. The main cluster body is generally identified as the highest significant peak. In some particular cases, where the sampling is particularly poor, we had to choose another peak in order to have a good coincidence (at least within 1000 km s$^{-1}$) with the mean system velocity suggested by L96. All galaxies not belonging to the selected peak are rejected as non cluster members. F96 and G98 required that peaks must be significant at the 99% c.l., but in dealing with poor sampled systems we follow the suggestion by Girardi \\& Mezzetti (2001), considering peaks having smaller significance < 99% (but generally > 95%). We do not consider systems with multipeaked velocity distributions.

Afterwards, we use the combination of position and velocity information to reveal the presence of surviving interlopers by applying the “shifting gapper” (Fadda et al. 1996). We reject galaxies that are too far away in velocity (by $\geq$ 1000 km s$^{-1}$) from the main body of galaxies at a given distance from the system center (within a shifting annulus of 0.4 $h^{-1}$ Mpc or large enough to include 15 galaxies). As for very poor samples with less than 15 members, we reject galaxies that are too far away in velocity from the main body of galaxies of the whole system.

At this point we recompute the system center for rich groups of ZM98 (by using the two-dimensional adaptive kernel method; cf. Pisani et al. 1996; Girardi et al. 1996), while for the poor clusters of L96 we retain the original centers, generally coming from a much larger number of galaxies.

3.1.2 Galaxy Velocity Dispersion

We estimate the “robust” l.o.s. velocity dispersion, $\sigma_v$, by using the biweight and the gapper estimators when the galaxy number is larger or smaller than 15, respectively (cf. ROSTAT routines – see Beers Flynn, \\& Gebhardt 1990), and applying the relativistic correction and the usual correction for velocity errors (Danese, De Zotti, \\& di Tullio 1980). For the poor clusters of L96, where redshifts are taken from NED, we assume a typical velocity error of 100 km s$^{-1}$.

Following Fadda et al. (1996, cf. also Girardi et al. 1996) we analyze the “integral” velocity dispersion profile (hereafter VDP), where the dispersion at a given (projected) radius is evaluated by using all the galaxies within that radius, i.e. $\sigma_v(< R)$. The VDPs make it possible for us to check the robustness of the $\sigma_v$ estimate. In fact, the presence of velocity anisotropy in galaxy orbits can strongly influence the value of $\sigma_v$ computed for the central cluster region, but does not affect the value of the $\sigma_v$ computed for the whole cluster (e.g., Merritt 1988). The VDPs of nearby clusters show strongly increasing or decreasing behaviors in the central cluster regions, but they are flattening out in the external regions, suggesting that in such regions they are no longer affected by velocity anisotropies. Thus, while the $\sigma_v$-values computed for the central cluster region could be a very poor estimate of the depth of cluster potential wells, one can reasonably adopt the $\sigma_v$ value computed by taking all the galaxies within the radius at which the VDP becomes roughly constant.

When the data are good enough, also poor systems show an (asymptotical) flatness in their VDPs (cf. Figure 1). However, some cases show a sharp increase towards the very external regions, suggesting the presence of a neighboring system with a different mean velocity (cf., e.g., A3391 and A3395 in Girardi et al. 1996). Since the radius of our data samples is relatively large this situation is not unexpected. For these systems, we assume that the real system is enclosed within the radius where the VDP sharply increases when there are enough galaxies to detect a region of a flat profile (N79-298, N79-283, N67-336, N45-363) or, otherwise, within the first galaxy useful for computing $\sigma_v$ (S49-142, N67-317).

G98 computed the virial radius from:

$$R_{\text{vir}} = \left[ 2 \cdot \frac{\sigma_v}{(1000 \text{ km s}^{-1})} \right] h^{-1} \text{ Mpc}$$

and we adopt the same definition. Indeed, this is only a first order approximation, but Girardi et al. (1998a) made a recomputation for some choices of cosmological models: they found that, for our reference model ($\Omega_m = 0.3$, $\Omega_\Lambda = 0.7$), the difference is $\sim 10\%$ for $R_{\text{vir}}$, and $\sim 5\%$ for the mass within $R_{\text{vir}}$. Since we are interested in fixing a radius for dealing with consistent physical regions in different systems, rather than with precise cosmological computations, this choice is well suited to our aims.
### 3.1.3 Galaxy Spatial Distribution

In order to estimate the virial mass, one must compute the radius appearing in the virial theorem (Limber & Mathiews 1960), which is, indeed, larger than the harmonic radius by about a factor of two. In particular, since we want to compute the mass within \( R_{\text{vir}} \), only the \( N \) galaxies within \( R_{\text{vir}} \) are considered. Here we use the luminosity-unweighted, projected version of this radius, \( R_{PV} \) (cf. Giuricin, Mardirossian, & Mezzetti 1982; please note that G98 referred to \( R_{PV} \) as “virial radius”):

\[
R_{PV} = N(N-1)/(\Sigma_{i>j} R_{ij}^{-1}),
\]

(2)

where \( R_{ij} \) are the projected mutual galaxy distances.

Unfortunately, for several poor systems the number of galaxies within \( R_{\text{vir}} \) is very small (\( N \leq 6 \)) or the sampled region is smaller than \( R_{\text{vir}} \) (26 systems). In these cases the estimate of \( R_{PV} \) can be recovered in an alternative way from the knowledge of the galaxy surface density profile \( \Sigma(R) \): Girardi et al. (1995) presented this method for the King-like distribution \( \Sigma(R) = \Sigma(0)/(1 + (R/R_c)^2)^{\alpha} \), where \( R_c \) is the core radius and \( \alpha \) is the parameter which describes the galaxy distribution in external regions (cf. the \( \beta \)-profile used in X-ray surface brightness analyses).

The alternative procedure described by Girardi et al. (1995) allows one to compute \( R_{PV} \) at each radius and, in particular, we compute \( R_{PV} \) at \( R_{\text{vir}} \). Here we use the same parameters as the King-like distribution already used by G98: \( \alpha = 0.7 \) and \( R_c/R_{\text{vir}} = 0.05 \). In fact, by using the 17 systems sampled with \( N \leq 10 \) galaxies within \( R_{\text{vir}} \) and the same Maximum Likelihood approach, we fit consistent
values. We find: \( \alpha = 0.64^{+0.07}_{-0.02} \) (median value and 90% errors), which corresponds to a galaxy volume–density of \( \rho \propto r^{-2.4} \) for \( R >> R_C \); and \( R_v/R_{\text{vir}} = 0.03^{+0.03}_{-0.01} \).

### 3.1.4 Virial Mass

Assuming that clusters are spherical, non–rotating systems, and that the internal mass distribution follows galaxy distribution, cluster masses can be computed with the virial theorem (e.g., Limber & Mathiews 1960; The & White 1986) as:

\[
M = M_V - C = \frac{3\pi}{2} \frac{\sigma_v^2 R_P}{G} - C, \tag{3}
\]

where the \( C \) correction takes into account that the system is not fully enclosed within the boundary radius, \( b \), here \( R_{\text{vir}} \). The correction can be written as:

\[
C = M_V \cdot 4\pi b^3 \int_0^b \frac{\rho(b)}{4\pi b^2 \rho dr} \left[ \sigma_v(b)/\sigma(> b) \right]^2, \tag{4}
\]

and requires knowledge of the velocity anisotropy of galaxy orbits. In fact, \( \sigma_v(b) \) is the radial component of the velocity dispersion \( \sigma(b) \), while \( \sigma(> b) \) refers to the integrated velocity dispersion within \( b \); here \( b = R_{\text{vir}} \).

In order to give the \( C \)–correction for each individual cluster, G98 used a profile indicator, \( I_p \), which is the ratio between \( \sigma_v(< 0.2 \times R_{\text{vir}}) \), the l.o.s. velocity dispersion computed by considering the galaxies within the central cluster region of radius \( R = 0.2 \times R_{\text{vir}} \), and the global \( \sigma_v \). According to the values of this parameter, they divided clusters into three classes: “A” clusters with a decreasing profile \( (I_p > 1.16) \), “C” clusters with an increasing profile \( (I_p < 0.97) \), and an intermediate class “B” of clusters with very flat profiles \( (0.97 < I_p < 1.16) \). Each of the three types of profiles can be explained by models with a different kind of velocity anisotropy: fully isotropical (B), with a radial component only in external regions (A), or with a circular component in central regions (C); cf. Figure 3 of G98 and relative comments.

In the same way, we can define 6, 4, and 5 systems belonging to class A, B, and C, respectively, and for each class we use the respective value \( [\sigma_v(R_{\text{vir}})/\sigma(> R_{\text{vir}})]^2 \) and typical galaxy distribution \( \rho(r) \) to determine the \( C \)–corrections. For systems where we cannot define the type of profile we assume isotropical velocities, i.e. the type “B”, already shown to be the most adequate for describing clusters and acceptable also for poor clusters (at the 39% \( \chi^2 \) probability). Figure 2 compares the observational velocity dispersion profile \( \sigma_v(R) \), as computed by combining together the galaxies of all 17 “well–sampled” systems, to the three models with different velocity anisotropy recovered by using the Jeans equation: both the model with isotropical velocity and that with circular velocity anisotropy are acceptable.

The median value of the correction of the sample is 20%, similar to that of G98, and also to that of CNOC clusters (Calberg, Yee, & Ellingson 1997).

Table 2 lists the results of the dynamical analysis: the system name, Col. (1); \( N_f \), the number of galaxies with measured redshift in each cluster field [Col. (2)]; \( N_m \), the number of member galaxies after checking with VDP [Col. (3)] and used to compute \( V \), the mean velocity, [Col. (4)] and \( \sigma_v \), the global l.o.s. velocity dispersion, with the respective bootstrap errors [Col. (5)]: only systems with \( N_m \geq 5 \) are retained in the sample; \( R_{\text{vir}} \), the virial radius which defines the region of dynamical equilibrium [Col. (6)]; \( N \), the number of member galaxies within \( R_{\text{vir}} \) [Col. (7)]; \( R_{PV} \), the projected radius used in the virial theorem and here computed within \( R_{\text{vir}} \), with the respective jacknife error (a 25% error is assumed for radii computed from the alternative theoretical formula; cf. G98) [Col. (8)]; \( T \), the type of velocity dispersion profile [Col. (9)]; \( M \), the virial mass contained within \( R_{\text{vir}} \) after pressure surface term correction with the corresponding errors [Col. (10)]. The percent errors on \( M \) are the same as for \( M_V \), i.e. we take into account the errors on \( \sigma_v \) and \( R_{PV} \) and neglect the uncertainties on \( C \)–correction.

The median percent error on mass is \( \sim 40\% \), but varies with the mass (see also Girardi et al. 1998a), ranging from \( \sim 30\% \) for massive systems, \( M > 5 \times 10^{14} \ M_\odot \), to \( \sim 75\% \) for less massive systems, \( M < 5 \times 10^{13} \ M_\odot \).

Fig. 2.— The (normalized) line–of–sight velocity dispersion, \( \sigma_v(R) \), as a function of the (normalized) projected distance from the system center. The points represent data combined from all systems and binned in equispacial intervals. We give the robust estimates of velocity dispersion and the respective bootstrap errors. We give the results for poor systems (open circles) and for nearby clusters taken from Girardi et al. (1998b, filled circles). The solid, dotted, and dashed lines represent models with different kinds of velocity anisotropy: isotropic, circular in central regions, and radial in external regions, respectively (see text).

Finally, we note that four poor clusters here analyzed were already studied by G98: N34-172/MKW1, N67-312/MKW10, N67-335/MKW4, N67-336/MKW12. The two mass estimates, based on partially different data samples (G98 considered only homogeneous data from specific cluster studies), show fair agreement.
### TABLE 2
Results of Dynamical Analysis

| Name       | $N_f$ | $N_m$ | $V$   | $\sigma_v$ | $R_{vir}$ | $N$   | $R_{pv}$ | $T$   | $M$  |
|------------|-------|-------|-------|------------|-----------|-------|----------|-------|------|
|            | (1)   | (2)   | (3)   | (4)        | (5)       | (6)   | (7)      | (8)   | (9)  | (10) |
| S49-145    | 29    | 10    | 6812  | 371±7      | .74       |       |          |       |      |      |
| S49-142    | 20    | 5     | 6299  | 124±140    | .24       |       |          |       |      |      |
| N45-384    | 26    | 14    | 7833  | 232±55     | .46       |       |          |       |      |      |
| N34-172    | 17    | 9     | 6007  | 302±89     | .60       |       |          |       |      |      |
| N56-393    | 24    | 5     | 6663  | 311±174    | .62       |       |          |       |      |      |
| N79-278    | 40    | 17    | 8983  | 287±359    | .57       |       |          |       |      |      |
| N67-312    | 33    | 16    | 6036  | 131±67     | .26       |       |          |       |      |      |
| N56-371    | 53    | 8     | 8130  | 319±20     | .64       |       |          |       |      |      |
| N79-280    | 17    | 10    | 9390  | 87±101     | .17       |       |          |       |      |      |
| N79-392    | 174   | 12    | 7995  | 172±15     | .34       |       |          |       |      |      |
| N79-298    | 46    | 7     | 4478  | 152±141    | .30       |       |          |       |      |      |
| N79-299B   | 26    | 22    | 6920  | 364±46     | .73       |       |          |       |      |      |
| N67-335    | 40    | 27    | 5922  | 515±104    | 1.03      |       |          |       |      |      |
| N79-299A   | 26    | 22    | 6910  | 391±40     | .78       |       |          |       |      |      |
| N79-283    | 52    | 24    | 7970  | 360±84     | .72       |       |          |       |      |      |
| N79-292    | 116   | 34    | 7290  | 318±76     | .64       |       |          |       |      |      |
| N67-333    | 20    | 10    | 14176 | 489±102    | .98       |       |          |       |      |      |
| N67-323    | 15    | 6     | 9212  | 79±43      | .16       |       |          |       |      |      |
| N67-317    | 35    | 5     | 7021  | 223±233    | .45       |       |          |       |      |      |
| N79-270    | 9      | 5     | 6746  | 130±73     | .26       |       |          |       |      |      |
| N79-296    | 33    | 20    | 6779  | 388±69     | .78       |       |          |       |      |      |
| N67-329    | 13    | 11    | 6842  | 176±94     | .35       |       |          |       |      |      |
| N79-297    | 11    | 5     | 8730  | 206±136    | .41       |       |          |       |      |      |
| N79-276    | 36    | 6     | 11059 | 540±79     | 1.08      |       |          |       |      |      |
| N67-336    | 71    | 25    | 5843  | 270±67     | .54       |       |          |       |      |      |
| N67-325    | 8      | 6     | 5184  | 265±56     | .53       |       |          |       |      |      |
| N67-326    | 146   | 33    | 4532  | 256±26     | .51       |       |          |       |      |      |
| N67-309    | 16    | 6     | 8057  | 340±108    | .68       |       |          |       |      |      |
| N65-394    | 49    | 23    | 8586  | 296±59     | .59       |       |          |       |      |      |
| N65-395    | 27    | 20    | 8137  | 477±82     | .95       |       |          |       |      |      |
| N65-381    | 16    | 10    | 8950  | 259±53     | .52       |       |          |       |      |      |
| N45-381    | 50    | 7     | 11198 | 150±91     | .30       |       |          |       |      |      |
| N45-363    | 26    | 7     | 10995 | 449±146    | .90       |       |          |       |      |      |
| N45-389    | 24    | 22    | 9522  | 656±75     | 1.31      |       |          |       |      |      |
| N34-171    | 13    | 5     | 5484  | 215±29     | .43       |       |          |       |      |      |
| N34-175    | 12    | 6     | 8894  | 550±76     | 1.10      |       |          |       |      |      |
| NGC 533    | 99    | 36    | 5518  | 464±54     | .93       |       |          |       |      |      |
| HCG 42     | 106   | 22    | 3719  | 211±23     | .42       |       |          |       |      |      |
| NGC 4325   | 68    | 18    | 7468  | 265±38     | .53       |       |          |       |      |      |
| HCG 62     | 106   | 46    | 4307  | 396±57     | .79       |       |          |       |      |      |
| NGC 5129   | 85    | 33    | 6938  | 294±33     | .59       |       |          |       |      |      |
| NGC 491    | 104   | 6     | 3987  | 92±76      | .18       |       |          |       |      |      |
| NGC 664    | 67    | 6     | 5489  | 148±90     | .30       |       |          |       |      |      |

*Values in brackets are those computed through the alternative estimate by using the typical galaxy distribution (see text).*

#### 3.2 Luminosity Determination

##### 3.2.1 COSMOS and APS Catalogs

Following G00, we derive from the COSMOS catalogue the magnitudes for 8 poor systems of the PS sample.

The COSMOS catalogue is described by Yentsis et al. (1992), and a part, the Edinburgh–Durban Southern Galaxy Catalogue (EDSG) is well analyzed by Heydon-Dumbleton, Collins, & MacGillivray (1989). The EDSGC is nominally quasi–complete to $B_j = 20$. A more conservative limiting apparent magnitude was suggested by Valotto et al. (1997), who found that galaxy counts follow a uniform law for $B_j < 19.4$. Accordingly, and following G00, we decide to adopt a limiting magnitude of $B_j = 19.4$ for the COSMOS catalog. Within this limit, we adopt a completeness value of 91% for areas containing galaxy systems, suggested as being more appropriate for areas of high surface density (Katgert et al. 1998) and the nominal 95% completeness value for the rest of the catalog (Heydon-
Dumbleton et al. 1989). These levels of incompleteness are assumed for all magnitudes down to $B_j = 19.4$, since Katgert et al. (1998) found that the magnitude distribution of missing galaxies is essentially the same as for sampled galaxies. Moreover, we note that, although COSMOS magnitudes are isophotal magnitudes, the threshold on average being only 8% above the sky (Heydon-Dumbleton, Collins, & MacGillivray 1988) the difference between COSMOS magnitudes and “total” magnitudes becomes significant only at the faint limit (well below our limiting magnitude, cf. Shanks, Stevenson, & Fong 1984).

For each system of C-PS we select galaxies with magnitudes $B_j < 19.4$ within circular regions with a radius equal to $R_{\text{vir}}$ and a center as chosen in § 3.1.1.

Moreover, we take magnitudes for 52 CLs and 40 PSs from the fields which are currently on-line from the APS Revised Catalog of POSS I.

The APS Catalog is the result of scans of glass duplicates of the blue (O) and red (E) plates of the original Palomar Observatory Sky Survey (POSS I) for all 664 fields with $|b| > 20^\circ$. The operation of the Automated Plate Scanner (APS) and the scanning procedures and parameters are described in detail in Pennington et al. (1993). Here we consider $B_{\text{APS}}$ band–magnitude, corresponding to the (O) Sky Survey plates, which is an isophotal magnitude within the level of surface brightness of $\mu \sim 26.5$ mag per square arcsec. Comparisons with available photometry in the RC3 and for fainter galaxies at the North Galactic Pole find that APS–derived integrated galaxy magnitudes show no systematic photometric errors and a typical rms scatter of 0.2 to 0.3 magnitudes (Odewahn & Aldering 1995). Several checks suggest that the catalog is quasi–complete for $B_{\text{APS}} < 19–20$ mag (Odewahn et al. 1993; Odewahn & Aldering 1995). We assume a completeness of 85% down to 19.4 $B_{\text{APS}}$ as recovered by Odewahn & Aldering (1995) from a comparison with a previous photometric catalog of Coma. In particular, we assume the same level of incompleteness for all magnitudes down to $B_j = 19.4$; this seems true at least for $B_{\text{APS}} > 15$ (cf. Figure 11 by Odewahn et al. 1993).

For each system of A-CL and A-PS we select galaxies with magnitudes $B_{\text{APS}} < 19.4$ within circular regions with a radius equal to $R_{\text{vir}}$ and a center as chosen in § 3.1.1 for poor systems, or computed by G00 for clusters. Since the APS catalog is still in progress, before including a system in our study we have checked by visual inspection that the photometric data fully cover the selected system region.

Fig. 3.— Comparison of magnitudes from COSMOS and APS catalogs for the galaxies of the 27 systems having both photometries available. The faint lines represent the result of the (bisecting) fitting of $B_j$ vs. $B_{\text{APS}}$. 

8
3.2.2 Magnitude Conversion and Correction

In order to homogenize the photometry coming from the two catalogs, as well as for comparison with results by G00, we convert $B_{\text{APS}}$ magnitudes into the $B_j$ band. We consider the 27 systems for which both photometries are available: 22 A-CLs in common with C-CLs of G00, and five PSs. On the base of similar positions, with a maximum distance of 0.1′, we select 4845 system galaxies having magnitudes in both catalogs (note that for this analysis we consider somewhat larger areas). We fit $B_j$ vs. $B_{\text{APS}}$ magnitudes by using the unweighted bisecting procedure (Isobe et al. 1990) for each of the 27 systems; cf. Figure 3 where we show $B_{\text{APS}} - B_j$ vs. $B_{\text{APS}}$ magnitudes for the sake of clarity.

We verify that slopes (and intercepts) of all straight lines can be derived from only one parent value, according to the Homogeneity test (or Variance–ratio test, cf. e.g., Guest 1961), and combine together data of all 27 systems. Figure 4 shows the cumulative relation between the two magnitude bands and the corresponding quadratic fit (via the MINUIT subroutine of CERN Libraries):

$$B_{\text{APS}} - B_j = 0.23 + 0.19 \cdot B_{\text{APS}} - 1.02 \cdot 10^2 \cdot B_{\text{APS}}^2,$$

performed by using the 1021 galaxies with $B_{\text{APS}} < 18$ mag in order to avoid the bias on the difference $(B_{\text{APS}} - B_j)$ caused by the limit in $B_j$.

![Figure 4](image)

Fig. 4.— The relationship between COSMOS and APS magnitudes obtained by combining data for all 27 systems shown in Figure 3. The solid line represents the best quadratic fit, which is performed on the data with $B_{\text{APS}} < 18$ mag to avoid the bias on the difference $(B_{\text{APS}} - B_j)$ caused by the limit in $B_j$, as shown by the dashed line.

After having homogeneized all magnitudes to COSMOS $B_j$, following G00 we apply the correction of Lumsden et al. (1997) to convert COSMOS $B_j$ magnitudes to the CCD–based magnitude scale. This correction is consistent with our choice to use the luminosity function and counts by Lumsden et al. (1997). Finally, we correct each galaxy magnitude for (1) Galactic absorption by assuming the absorption in the blue band as given by de Vaucouleurs et al. (1991) in the region of each system, and (2) $K$-dimming by assuming that all galaxies lie at the average system redshift (Colless 1989). The correction for internal galactic absorption will be taken into account at the end of the procedure to estimate luminosities.

3.2.3 Luminosities from COSMOS and APS

For all C-PSs, A-PSs and A-CLs we compute total luminosities within $R_{\text{vir}}$ following the procedure already outlined for C-CLs by G00 who used COSMOS. Having already homogeneized the original APS magnitudes to the $B_j$ band, the whole procedure is the same except for the value of the magnitude incompleteness in the catalogs (cf. point 2 below). Here we give a short summary of the procedure.

1) We compute observed system luminosities, $L_{B_j,\text{obs}}$, obtained by summing the individual absolute luminosities of all galaxies and assuming $B_{1,\odot} = 5.33$ (i.e., $B_{\odot} = 5.48$ and using the conversion to $B_j$ by Kron 1978).

2) For samples from the COSMOS (or APS) catalog we correct for 91% (or 85%) incompleteness, obtaining $L_{B_j,\text{compl}} = L_{B_j,\text{obs}}/0.91$. (or $L_{B_j,\text{compl}} = L_{B_j,\text{obs}}/0.85$), and the same correction is also applied to number counts.

3) We subtract the average fore/background luminosity obtained from the mean field $B_j$ counts by Lumsden et al. (1997) using the EDSGC (cf. their Figure 2, corrected for 95% completeness): $L_{B_j,\text{corr}} = L_{B_j,\text{compl}} - L_{B_j,\text{mean field}}$. We correct counts in a similar way. The median correction is 29%.

4) We include the luminosity of faint galaxies below the magnitude completeness limit $L_{B_j,\text{extr}} = L_{B_j,\text{corr}} + L_{B_j,\text{faint}}$, where $L_{B_j,\text{faint}}$ is obtained by extrapolating the usual Schechter (1976) form for the cluster luminosity function (with $M_{B_j} = -20.16$ for the characteristic magnitude and $\alpha = -1.22$ for the slope as determined by Lumsden et al. 1997), normalized by using the observed (corrected) galaxy number counts for $-21 \leq M_{B_j} \leq -18$ (cf. eqs. 1 and 2 of G00). The median correction is 5%.

5) The final luminosity estimate of galaxy systems, $L_{B_j}$, takes into account the internal galactic absorption by adopting a correction of $\Delta B_j = 0.1$ mag. On account of this correction, the luminosity increases by about 10%.

$L_{B_j,\text{c,COSMOS}}$ and $L_{B_j,\text{c,APS}}$ denote luminosities computed for the two catalogs.

The above method for the fore/background correction does not take into account the local field–to–field count variations, which lead to random errors. Since this correction is the largest one in our procedure, it is worthwhile considering an alternative procedure, too. Following G00, we also consider the method recently used by Rauzy, Adami, & Mazure (1998) to take into account the very local field, i.e. the presence of a nearby group along the system l.o.s.. This method is based on the idea that having redshifts for all galaxies would allow an unambiguous determination of the membership and thus the solution of the fore/background correction. Rauzy et al. suggested correcting cluster luminosity (and counts) by assuming that
the fraction of members of the examined photometric sample corresponds, for luminosity and number, to that computed on a corresponding sample of galaxies all having redshift \( L_{B_j,corr} = L_{B_j,obs} \times f_L \) and \( N_{corr} = N_{obs} \times f_N \). The drawback of this method is obviously that the estimated member fraction computed in the redshift sample depends on the magnitude limit and the extension of the sampled region. Here we use the redshift samples analyzed in § 3.1 for poor systems and those analyzed by G98 for clusters in order to compute \( f_N \) and \( f_L \) within \( R_{vir} \). The fraction \( f_N \) is directly recovered by comparing the number of member galaxies with those in the field. As for clusters, following G00, we compute \( f_L \) when original redshift samples have available magnitudes, or assume that \( f_L = f_N \) when luminosities are not directly available (since \( f_L \sim f_N \)). As for poor systems, we compute \( f_L \) after assigning to galaxies of redshift samples the corresponding magnitudes taken from the photometric samples (here \( f_L > f_N \) for a typical factor of 30%); when less than five galaxies are available we use the median values \( f_L = 0.8 \) and \( f_N = 0.6 \) as computed on all better sampled poor systems. \( L_{B_j,COSMOS} \) and \( L_{B_j,APS} \) denote our alternative luminosity estimates.

Table 3 gives the results of luminosity computation, reporting the results of G00 too, for both clusters and poor systems (CL+PS sample, 162 systems), which make up a very homogeneous sample for both mass and luminosity estimates. We list: the system name [Col. (1)]; the adopted system center [Col. (2)]; \( R_{vir} \), the virial radius [Col. (3)]; \( N_{APS} \), the number of galaxies within \( R_{vir} \), used to compute \( L_{B_j,APS} \) and \( L_{B_j,APS} \), the two alternative APS luminosities based on two procedures for the fore/background correction [Cols. (4), and (5), respectively]; \( N_{COSMOS} \), the number of galaxies within \( R_{vir} \), used to compute \( L_{B_j,COSMOS} \) and \( L_{B_j,COSMOS} \), the two alternative COSMOS luminosities [Cols. (6), and (7), respectively].

### Table 3: Luminosity Estimates

| Name     | Center \( \alpha(2000) - \delta(2000) \) | \( R_{vir} \) h\(^{-1}\) Mpc | \( N_{APS} \) | \( L_{B_j,APS} \) \( \times 10^{11} h^{-2} L_{\odot} \) | \( N_{COSMOS} \) | \( L_{B_j,COSMOS} \) \( \times 10^{11} h^{-2} L_{\odot} \) |
|----------|------------------------------------------|-----------------------------|--------------|-----------------------------------------------|----------------|-----------------------------------------------|
| A85      | 004140.6 - 091833                       | 1.94                        | 462          | 26.75, 26.93                                  | 403            | 20.55, 23.41                                  |
| A119     | 005617.9 - 011528                       | 1.36                        | 280          | 11.36, 14.99                                  | 370            | 13.78, 17.48                                  |
| A193     | 012505.4 + 084157                       | 1.45                        | 200          | 6.64, 10.29                                   | -              | -                                             |
| A194     | 012552.6 - 012008                       | 0.68                        | 150          | 1.73, 2.35                                    | 218            | 2.50, 3.03                                    |
| A229     | 013914.5 - 033803                       | 1.01                        | 35           | 5.66, 7.41                                    | 50             | 6.80, 8.15                                    |
| A256     | 014804.5 - 035429                       | 1.09                        | 56           | 9.98, 7.42                                    | 85             | 10.00, 7.61                                   |
| A262     | 015246.7 + 360856                       | 1.05                        | 1307         | 15.12, 14.12                                  | -              | -                                             |
| A295     | 020211.8 - 010603                       | 0.72                        | -            | -                                             | 137            | 5.94, 5.81                                    |
| A400     | 025740.7 + 060048                       | 1.20                        | 351          | 6.03, 6.61                                    | -              | -                                             |
| A420     | 030916.8 - 113226                       | 0.72                        | 25           | 1.33, 1.66                                    | 45             | 2.73, 2.41                                    |
| A458     | 034605.4 - 242040                       | 1.47                        | -            | -                                             | 114            | 12.44, 17.82                                  |
| A496     | 043318.1 - 131703                       | 1.37                        | 323          | 5.38, 8.81                                    | 526            | 7.68, 11.09                                   |
| A514     | 044830.1 - 203330                       | 1.76                        | 214          | 33.19, 33.26                                  | 294            | 11.72, 16.10                                  |
| A524     | 045743.2 - 194345                       | 0.50                        | 27           | 3.50, 1.73                                    | 33             | 2.20, 1.19                                    |
| A978     | 102028.5 - 063050                       | 1.07                        | 165          | 8.60, 9.72                                    | 161            | 5.51, 7.18                                    |
| A999     | 102325.4 + 124058                       | 0.56                        | 61           | 3.71, 3.12                                    | -              | -                                             |
| A1060    | 103631.2 - 272935                       | 1.22                        | -            | -                                             | 3678           | 8.80, 11.75                                   |
| A1069    | 103937.0 - 083121                       | 0.72                        | 67           | 7.98, 5.60                                    | 72             | 6.25, 4.59                                    |
| A1142    | 110154.8 + 101835                       | 0.97                        | 133          | 3.32, 4.43                                    | -              | -                                             |
| A1146    | 110116.4 - 224113                       | 1.86                        | -            | -                                             | 148            | 38.51, 43.15                                  |
| A1185    | 111044.4 + 284145                       | 1.07                        | 380          | 6.20, 7.68                                    | -              | -                                             |
| A1228    | 112151.2 + 342201                       | 0.34                        | 35           | 2.17, 1.47                                    | -              | -                                             |
| A1314    | 113428.0 + 409243                       | 0.55                        | 97           | 4.27, 4.56                                    | -              | -                                             |
| A1631    | 125258.2 - 152111                       | 1.40                        | 357          | 18.95, 12.49                                  | 511            | 22.25, 14.21                                  |
| A1644    | 125723.3 - 172448                       | 1.52                        | 328          | 11.92, 13.15                                  | 524            | 17.91, 19.97                                  |
| A1656    | 125937.2 + 275712                       | 1.64                        | 1136         | 21.36, 26.80                                  | -              | -                                             |
| A1795    | 134849.3 + 263347                       | 1.67                        | 239          | 14.08, 19.52                                  | -              | -                                             |
| A1809    | 135256.0 + 050760                       | 1.53                        | 144          | 11.09, 18.77                                  | -              | -                                             |
| A1983    | 145258.1 + 164129                       | 0.99                        | 233          | 5.97, 7.44                                    | -              | -                                             |
| A1991    | 145432.6 + 183735                       | 1.26                        | 158          | 7.55, 10.84                                   | -              | -                                             |
| Name       | Center       | $R_{vir}$ | $N_{APS}$ | $L_{B_j,APS}^2$ | $N_{COSMOS}$ | $L_{B_j,COSMOS}^{a,b}$ |
|------------|--------------|-----------|-----------|-----------------|-------------|------------------------|
| (1)        | (2)          | (3)       | (4)       | (5)             | (6)         | (7)                    |
| A2191      | 145432.6 + 183735 | 1.26      | 158       | 7.55, 10.84     | -            | -                      |
| A2029      | 151056.7 + 054500 | 2.33      | 504       | 49.67, 65.10    | -            | -                      |
| A2040      | 151246.4 + 072517 | .92       | 158       | 8.01, 7.87      | -            | -                      |
| A2048      | 151516.9 + 042229 | 1.33      | 109       | 15.05, 15.90    | -            | -                      |
| A2079      | 152745.1 + 285508 | 1.34      | 172       | 12.12, 13.89    | -            | -                      |
| A2092      | 153323.2 + 310856 | 1.07      | 106       | 7.01, 6.77      | -            | -                      |
| A2107      | 153941.1 + 214843 | 1.24      | 242       | 7.43, 9.53      | -            | -                      |
| A2124      | 154447.2 + 360440 | 1.76      | 286       | 31.60, 40.53    | -            | -                      |
| A2142      | 155819.8 + 271435 | 2.26      | 275       | 29.36, 44.31    | -            | -                      |
| A2151      | 160510.5 + 174522 | 1.50      | 626       | 15.44, 18.97    | -            | -                      |
| A2197      | 162946.7 + 405036 | 1.22      | 546       | 11.48, 15.02    | -            | -                      |
| A2199      | 162843.0 + 390343 | 1.60      | 797       | 19.75, 25.61    | -            | -                      |
| A2353      | 213422.3 − 013507 | 1.19      | 36        | 32.84, 36.90    | 47           | 6.65, 11.41            |
| A2362      | 213901.3 − 141911 | .66       | 54        | 3.62, 4.09      | 55           | 1.56, 2.30             |
| A2401      | 215821.1 − 200557 | .79       | 165       | 11.68, 11.38    | 132          | 5.65, 6.26             |
| A2426      | 221411.9 − 101103 | .66       | 71        | 12.95, 4.01     | 62           | 6.77, 2.36             |
| A2500      | 225351.8 − 253103 | .95       | -         | -              | -            | -                      |
| A2554      | 231212.7 − 213050 | 1.68      | -         | -              | -            | -                      |
| A2569      | 231757.8 − 124635 | .98       | -         | -              | -            | -                      |
| A2589      | 232401.4 + 164834 | .94       | 106       | 2.90, 4.18      | -            | -                      |
| A2634      | 233828.4 + 270133 | 1.40      | 507       | 20.90, 24.40    | -            | -                      |
| A2644      | 234035.7 − 000350 | .36       | -         | -              | -            | -                      |
| A2670      | 235414.6 − 102505 | 1.70      | 201       | 14.42, 18.53    | 245          | 12.33, 17.24           |
| A2715      | 000245.2 − 349332 | .93       | -         | -              | -            | -                      |
| A2717      | 000310.8 − 355557 | 1.08      | -         | -              | -            | -                      |
| A2721      | 000607.9 − 344302 | 1.61      | -         | -              | -            | -                      |
| A2734      | 001126.6 − 285018 | 1.26      | -         | -              | -            | -                      |
| A2755      | 001736.9 − 351059 | 1.54      | -         | -              | -            | -                      |
| A2798      | 003733.1 − 283205 | 1.42      | 37        | 10.87, 6.10    | 108          | 20.84, 10.48           |
| A2799      | 003723.1 − 390750 | .84       | -         | -              | -            | -                      |
| A2800      | 003804.2 − 250610 | .81       | 42        | 2.55, 3.42     | 70           | 3.53, 4.29             |
| A2877      | 010948.3 − 455702 | 1.77      | -         | -              | -            | -                      |
| A2911      | 012604.0 − 375609 | 1.09      | -         | -              | -            | -                      |
| A3093      | 031057.5 − 472426 | .88       | -         | -              | -            | -                      |
| A3094      | 031140.7 − 265908 | 1.31      | -         | -              | -            | -                      |
| A3111      | 031738.6 − 454656 | .32       | -         | -              | -            | -                      |
| A3122      | 032210.7 − 411905 | 1.55      | -         | -              | -            | -                      |
| A3126      | 032833.0 − 554241 | 2.11      | -         | -              | -            | -                      |
| A3128      | 033052.6 − 523023 | 1.58      | -         | -              | -            | -                      |
| A3142      | 033644.0 − 394616 | 1.47      | -         | -              | -            | -                      |
| A3151      | 034034.4 − 284043 | .47       | -         | -              | -            | -                      |
| A3158      | 034259.7 − 533759 | 1.95      | -         | -              | -            | -                      |
| A3194      | 035908.8 − 301044 | 1.61      | -         | -              | -            | -                      |
| A3223      | 040809.7 − 310248 | 1.29      | -         | -              | -            | -                      |
| A3266      | 043046.8 − 613408 | 2.21      | -         | -              | -            | -                      |
| A3334      | 051749.1 − 583325 | 1.39      | -         | -              | -            | -                      |
| A3354      | 053442.5 − 284046 | .72       | -         | -              | -            | -                      |
| A3360      | 054007.3 − 432358 | 1.67      | -         | -              | -            | -                      |
| A3376      | 060215.5 − 395625 | 1.38      | -         | -              | -            | -                      |
| A3381      | 060957.0 − 333320 | .59       | -         | -              | -            | -                      |
| A3391      | 062617.6 − 534143 | 1.33      | -         | -              | -            | -                      |
| A3395      | 062735.6 − 542629 | 1.70      | -         | -              | -            | -                      |
| A3528N     | 125426.7 − 290017 | .92       | 229       | 14.14, 8.85    | -            | -                      |
| Name     | Center  | $R_{vir}$ | $N_{APS}$ | $L_{Bj,APS}^a$ | $N_{COSMOS}$ | $L_{Bj,COSMOS}^{ab}$ |
|----------|---------|-----------|-----------|---------------|--------------|-----------------|
|          | (1)     | (2)       | (3)       | (4)           | (5)          | (6)             |
| A3532    | 125715.3 − 302105 | 1.48 | - | - | 463 | 18.92, 17.32 |
| A3556    | 132418.2 − 314220 | 1.28 | - | - | 409 | 16.22, 15.02 |
| A3558    | 132755.5 − 312921 | 1.95 | - | - | 1115 | 50.30, 55.51 |
| A3559    | 133011.5 − 293400 | 0.91 | 186 | 9.10, 9.60 | 215 | 9.52, 10.32 |
| A3571    | 134720.8 − 325210 | 2.09 | - | - | 1746 | 35.97, 45.65 |
| A3574    | 134849.3 − 302735 | 0.98 | - | - | 1303 | 8.56, 9.25 |
| A3651    | 195226.3 − 550815 | 1.25 | - | - | 348 | 21.34, 19.65 |
| A3667    | 201226.5 − 564840 | 1.94 | - | - | 882 | 40.78, 40.10 |
| A3693    | 203420.5 − 343311 | 0.96 | - | - | 89 | 8.31, 4.59 |
| A3695    | 203445.0 − 354809 | 1.56 | - | - | 214 | 20.65, 26.62 |
| A3705    | 204210.2 − 351215 | 1.75 | - | - | 327 | 29.61, 32.44 |
| A3733    | 210315.2 − 280232 | 1.22 | 342 | 10.34, 12.89 | 301 | 5.30, 8.27 |
| A3744    | 210723.8 − 252558 | 1.02 | - | - | 340 | 6.55, 7.76 |
| A3809    | 214715.8 − 435523 | 0.96 | - | - | 162 | 5.78, 7.14 |
| A3822    | 215414.8 − 575103 | 1.62 | - | - | 545 | 36.26, 33.83 |
| A3825    | 215819.6 − 601828 | 1.40 | - | - | 298 | 16.96, 16.56 |
| A3879    | 222759.3 − 685547 | 0.80 | - | - | 81 | 4.86, 5.15 |
| A3880    | 222751.7 − 303419 | 1.65 | - | - | 365 | 14.66, 19.75 |
| A3921    | 225003.3 − 642351 | 0.98 | - | - | 117 | 12.05, 13.37 |
| A4008    | 233020.5 − 391538 | 0.85 | - | - | 126 | 4.71, 5.34 |
| A4010    | 233132.1 − 363010 | 1.25 | - | - | 102 | 8.67, 10.56 |
| A4053    | 235424.6 − 274115 | 1.23 | - | - | 136 | 6.16, 4.60 |
| A4067    | 235856.9 − 603730 | 1.00 | - | - | 84 | 8.11, 8.74 |
| S84      | 004925.3 − 290951 | 0.66 | - | - | 50 | 6.81, 5.08 |
| S373     | 033003.9 − 351343 | 0.62 | - | - | 4150 | 1.28, 3.68 |
| S463     | 042911.7 − 553013 | 1.22 | - | - | 416 | 15.80, 16.22 |
| S721     | 130604.4 − 373704 | 1.38 | - | - | 463 | 11.36, 12.25 |
| S753     | 140316.0 − 340318 | 1.07 | - | - | 1653 | 5.10, 5.65 |
| S805     | 185246.3 − 631441 | 1.08 | - | - | 2133 | 6.28, 7.59 |
| S987     | 220154.8 − 222433 | 1.35 | - | - | 206 | 21.45, 25.42 |
| S1157/C67| 235139.8 − 342714 | 1.16 | - | - | 191 | 8.87, 5.36 |
| AWM4     | 160455.3 + 235627 | 0.24 | 26 | 1.62, .75 | - | - |
| CL2335-26| 233753.1 + 271047 | 1.20 | 51 | 58.34, 51.83 | - | - |
| DC0003-50| 000604.0 − 503842 | 0.70 | - | - | 146 | 3.17, 3.96 |
| Eridanus | 034014.6 − 183725 | 0.53 | - | - | 1536 | .52, .96 |
| MKW1     | 100044.2 − 025741 | 0.45 | - | - | 185 | 1.51, 1.82 |
| MKW6A    | 141439.7 + 030753 | 0.55 | 80 | 1.38, 2.04 | - | - |
| S49-145  | 020732.49 + 020814 | 0.74 | - | - | 279 | 3.47, (3.68) |
| S49-142  | 032044.7 − 010215 | 0.24 | 21 | .41, (.41) | 16 | .21, (.26) |
| N45-384  | 092751.8 + 295956 | 0.46 | 149 | 1.57, .90 | - | - |
| N34-172  | 100322.1 − 025727 | 0.60 | 158 | 1.05, 1.43 | - | - |
| N56-393  | 101352.0 + 384007 | 0.62 | 116 | 1.50, (1.87) | - | - |
| N79-278  | 113754.4 + 215823 | 0.57 | 63 | 1.24, 1.60 | - | - |
| N67-312  | 114204.6 + 101820 | 0.26 | 53 | .75, (.71) | - | - |
| N56-371  | 114503.5 − 013938 | 0.64 | 162 | 1.61, (1.95) | 246 | 1.90, (2.21) |
| N79-280  | 114618.5 + 330919 | 0.17 | 25 | 1.07, (0.89) | - | - |
| N56-392  | 114938.9 − 033135 | 0.34 | 31 | .73, .84 | 65 | 1.42, 1.36 |
| N79-298  | 115752.3 + 251018 | 0.30 | 71 | .35, (.42) | - | - |
| N79-299B | 120409.5 + 201318 | 0.73 | 234 | 3.13, 3.00 | - | - |
| N67-335  | 120421.7 + 015019 | 1.03 | 490 | 1.41, 1.60 | - | - |
| N79-299A | 120551.2 + 203219 | 0.78 | 200 | 2.77, 2.86 | - | - |
Figure 5 compares the luminosities derived from the COSMOS catalog with those derived from the APS catalog for the 27 systems having both photometrics available. For both the two alternative estimates (panels a and b) the fitted straight lines in the logarithmic plane are consistent with the one–to–one relation within 1σ (using the unweighted bisecting fit; cf. Isobe et al. 1990). This fair agreement supports the homogeneity of our luminosity estimates, although recovered from two different photometric catalogs, and justify their combination. When both APS and COSMOS luminosities are available, we consider their average.

Figure 6 compares the two alternative luminosity estimates $L_{Bj,c}$ and $L_{Bj,f}$ for all 119 CLs and those 22 PSs for which we compute individual member fractions. The (bisecting) fit is consistent with the one–to–one relation, within 2σ, indicating that any systematic bias connected to the fore/background correction should not seriously pollute our analysis. More particularly, Figure 6 shows no systematic overestimate of $L_{Bj,c}$ with respect to $L_{Bj,f}$, as expected when subtracting the mean field luminosity density from cluster regions, when clusters are selected as overdensities in a projected galaxy distribution. This is due to two main reasons. First, systematic foreground/background contamination for nearby clusters is small (e.g. only $\sim 10\%$ for ENACS, Katgert et al. 1996); second, in this study we exclude, a priori, clusters showing two significant peaks in the velocity distribution, which are the most contaminated clusters (cf. SS 2.1 and 3.1.1). The comparison in Figure 6 suggests that the majority of clusters has $L_{Bj,f} > L_{Bj,c}$, although for a small amount ($L_{Bj,f}/L_{Bj,c} = 1.1$, median value), probably because that the member fractions we determine in the redshift samples are slightly larger than the appropriate ones for the (deeper) magnitude samples. The distribution of the scatter is not symmetric with respect the one–to–one relation, thus suggesting competition between two different sources of errors. This supports the use, in our final results, of the average of the two estimates.

As for the error estimates, the scatter in the $L_{Bj,c} - L_{Bj,f}$ relation ($\sim 25\%$) provides an estimate of the random errors due to the variations of local field, i.e. to the

\begin{table}[h]
\centering
\caption{Continued}
\begin{tabular}{lcccccc}
\hline
Name & Center & $R_{vir}$ & $N_{APS}$ & $L_{Bj,APS}^{a}$ & $N_{COSMOS}$ & $L_{Bj,COSMOS}^{a,b}$ \\
& $\alpha(2000) - \delta(2000)$ & $h^{-1}$ Mpc & & $10^{11} h^{-2} L_{Bj,\odot}$ & & $10^{11} h^{-2} L_{Bj,\odot}$ \\
(1) & (2) & (3) & (4) & (5) & (6) & (7) \\
\hline
N79-283 & 121954.8 + 282521 & .72 & 183 & 6.99, 2.09 & - & - \\
N79-292 & 122414.7 + 092024 & .64 & 80 & .36, .43 & - & - \\
N67-333 & 130425.3 + 075454 & .98 & 110 & 2.63, 2.49 & - & - \\
N67-323 & 130526.5 + 533536 & .16 & 11 & .48, (.42) & - & - \\
N67-317 & 131349.0 + 065709 & .45 & 64 & .42, (.63) & - & - \\
N79-270 & 131719.3 + 203711 & .26 & 26 & .41, (.43) & - & - \\
N79-296 & 132922.3 + 114731 & .78 & 289 & 2.72, 2.08 & - & - \\
N67-329 & 133236.4 + 072036 & .35 & 39 & .76, (.81) & - & - \\
N79-297 & 135524.7 + 250320 & .41 & 65 & 1.75, (1.67) & - & - \\
N79-276 & 135622.3 + 283123 & 1.08 & 206 & 1.92, 1.78 & - & - \\
N67-336 & 140304.0 + 092635 & .54 & 159 & 2.99, 2.91 & - & - \\
N67-325 & 140958.5 + 172515 & .53 & 199 & 1.76, (2.00) & - & - \\
N67-326 & 142814.1 + 255038 & .51 & 199 & .67, (.97) & - & - \\
N79-309 & 142831.6 + 112238 & .68 & 119 & 1.68, (2.08) & - & - \\
N56-394 & 143400.9 + 034533 & .59 & 109 & 1.41, 1.73 & - & - \\
N56-395 & 144043.2 + 032712 & .95 & 302 & 1.96, 3.06 & - & - \\
N56-381 & 144700.4 + 113529 & .52 & 62 & .31, (.64) & - & - \\
N45-381 & 151311.6 + 042850 & .30 & 41 & 1.60, (1.40) & - & - \\
N45-363 & 155746.9 + 161267 & .90 & 178 & 4.52, 2.67 & - & - \\
N45-389 & 161739.2 + 350545 & 1.31 & 408 & 6.46, 9.40 & - & - \\
N34-171 & 164135.4 + 675021 & .43 & 97 & .35, (.57) & - & - \\
N34-175 & 171521.4 + 572434 & 1.10 & 976 & 12.18, (12.11) & - & - \\
NGC 533 & 012529.9 + 014537 & .93 & 311 & 1.33, 2.71 & 507 & 1.65, 2.83 \\
HCG 42 & 100018.6 - 193960 & .42 & - & - & 554 & 2.29, 2.40 \\
NGC 4325 & 122304.6 + 103352 & .53 & 57 & .44, .76 & - & - \\
HCG 62 & 125305.1 - 091247 & .79 & 449 & 2.04, 2.79 & 978 & 5.93, 5.59 \\
NGC 5129 & 132425.2 + 354555 & .59 & 129 & 1.79, 2.27 & - & - \\
NGC 491 & 012162.7 - 340358 & .18 & - & - & 51 & .34, (.32) \\
NGC 664 & 014314.4 + 041319 & .30 & 27 & .23, (.32) & - & - \\
\hline
\end{tabular}
\footnotesize{\textsuperscript{a} Both alternative estimates of luminosity are given ($L_{Bj,c}$, $L_{Bj,f}$). Values between brackets are $L_{Bj,f}$, which are not based on individual member fraction estimates, but on median values.}
\footnotesize{\textsuperscript{b} We report values computed by G00 for clusters (C-CL sample), too.}
\end{table}
procedure adopted, while the scatter in the COSMOS–APS comparison ($\sim 40\%$ and $\sim 30\%$ in the two cases) also gives an idea of the random errors connected with the photometry of the catalogs. By adding in the quadrature the two sources of errors, we assume that the error on each individual luminosity is $\lesssim 50\%$.

Fig. 5.— Comparison between the luminosities derived from the APS catalog with those derived from the COSMOS catalog for the 27 galaxy systems with both photometries available, and for both the two alternative estimates of the fore/background correction: by using the mean counts (top–panel) or the member fraction (bottom–panel). The solid lines represent the (bisecting) fitting to be compared to the one–to–one relation (the faint line).

3.3 Mass and Luminosity for NOG Groups

Here we compute mass and luminosity for each group of NOG group catalogs, PG and HG.

The observational determination of group $M/L$ encounters several additional problems. These problems arise in the estimate of mass and are mainly due to the poor number of group members and to the uncertainties in the dynamical stage. In fact, although group cores are close to virialization or virialized (ZM98; Zabludoff & Mulchaey 1998b), the sampling area of groups identified in three–dimensional galaxy catalogs is well outside their likely virialized region (e.g., Girardi & Giuricin 2000, hereafter GG00; Carlberg et al. 2001a). Also older works indicated that, by considering their whole sampled region, these groups cannot be considered virialized systems, but rather described as being in a phase of collapse (e.g., Giuricin et al. 1988; Diaferio, Geller, & Ferrari 1993; Mamon 1994).

The small number of galaxies prevents us from applying refined analyses such as those used for clusters and well–sampled groups, e.g. the member selection or the analysis of velocity dispersion profiles (cf. G98 and reference therein; ZM98; Mahdavi et al. 1999). Above all, the small number of galaxies prevent us from working in smaller, quasi virialized, group regions.

Therefore, for computing group masses we could not apply the procedure used in § 3.1, but we rather use the procedure recently adopted by GG00. Here we summarize the main steps of this procedure.

First of all, we do not perform any procedure of member selection, but we rely on the group membership as assigned by Giuricin et al. (2000). The comparison of the results coming from the two catalogs of groups identified

Fig. 6.— Comparison between the two alternative luminosity estimates based on the two different fore/background corrections: by using the mean counts ($L_{B,\text{c}}$) or the member fraction ($L_{B,\text{f}}$). Circles and crosses indicate clusters and poor systems, respectively. The solid line represents the (bisecting) fitting to be compared to the one–to–one relation (the faint line).
in the same galaxy catalog, but with two different member assignments, will allow us to check a posteriori the effect of the membership procedure.

Then we compute the l.o.s. velocity dispersion, $\sigma_v$, and the (projected) radius used in the virial theorem, $R_{PV}$, in the same way as performed in §3.1; in particular, for each galaxy we assume a typical velocity error of 30 km s$^{-1}$. The corresponding virial mass is $M_V = 3\pi \sigma_v^2 R_{PV} / (2G)$. When the correction for velocity errors leads to a negative value of $\sigma_v$, $\sigma_v$ and mass are considered null.

To take into account the dynamical state of groups we use the method proposed by Giuricin et al. (1988). This method is based on the classical model of spherical collapse where the initial density fluctuation grows, lagging behind the cosmic expansion when it breaks away from the Hubble flow, and begins to collapse, and the authors used the results of very simple numerical simulations of galaxy systems (Giuricin et al. 1984; the limits of this model are discussed in §7.1 of GG00). Using the above method, the value of $A$, which is needed to recover corrected masses as $M_{VC} = (1/2A)M_V$, can be inferred from the estimate of the presently observed crossing time. In particular, the precise value of $A$ depends on the background cosmology: for our reference model we obtain a typical correction of 0% and 30% for PGs and HGs, respectively (cf. GG00 for other examples).

As for the luminosity computation, we gain a great advantage with respect to poor systems in §3.2. In fact, the NOG catalog is already homogeneized for photometry; the total blue magnitudes, $B$, are already corrected (for Galactic absorption, K–dimming, and internal absorption); and the known membership avoids the problem of fore/background contamination. Taking into account these differences, we apply a procedure similar to that outlined in §3.2.3, i.e.: we compute observed group luminosities, $L_{B,obs}$, (assuming $B_0 = 5.48$), which here refer to the whole sampled region; we correct for 97% NOG incompleteness, obtaining $L_{B,comp}$; we include the luminosity of faint galaxies below the magnitude completeness limit to obtain total luminosity $L_{B,tot}$, with $M_L = -19.97$ for the characteristic magnitude and $\alpha = -1.16$ for the slope (Giuricin et al. 2000). The median correction for faint galaxies is less than 1%.

For the two NOG catalogs, PG and HG, as well as some subsamples: PG5 and HG5, PG7 and HG7, i.e. groups having at least 5 and 7 members respectively, we give median values (and 90% c.l. error bands) for interesting physical quantities. Table 4 lists the sample name [Col. (1)]; $N_G$, the number of groups [Col. (2)]; and the median values for: $N_m$, the number of member galaxies [Col. (2)]; $R_{max}$, the group size which is the projected distance of the most distant galaxy from the group center, here computed as the bieweight center [Col. (4)]; $\sigma_v$, the l.o.s. velocity dispersion [Col. (5)]; $R_{PV}$, the projected radius used in the virial theorem [Col. (6)]; $M_V$ and $M_{VC}$, the virial mass, before and after the correction for the dynamical status [Cols. (7) and (8)]; $L_{B,tot}$, the blue luminosity [Cols. (9)]. Both mass and luminosity refer to the whole sampled region.

| Cat. | $N_G$ | $N_m$ | $R_{max}$ | $\sigma_v$ | $R_{PV}$ | $M_V$ | $M_{VC}$ | $L_{B,tot}$ |
|------|-------|-------|-----------|-----------|---------|-------|---------|------------|
|      |       |       | h$^{-1}$ Mpc | km s$^{-1}$ | h$^{-1}$ Mpc |       |         | h$^{-1}$ Mpc | 10$^{13}$ h$^{-1}$ M$\odot$ | 10$^{13}$ h$^{-1}$ M$\odot$ | 10$^{11}$ h$^{-2}$ L$\odot$ |
| (1)  | (2)   | (3)   | (4)       | (5)       | (6)     | (7)   | (8)     | (9)        |
| PG   | 513   | 4     | 0.46$^{+0.04}_{-0.04}$ | 132$^{+9}_{-9}$ | 0.49$^{+0.04}_{-0.04}$ | 0.81$^{+0.14}_{-0.14}$ | 0.85$^{+0.22}_{-0.22}$ | 0.52$^{+0.04}_{-0.04}$ |
| PG5  | 208   | 7     | 0.60$^{+0.06}_{-0.06}$ | 164$^{+22}_{-22}$ | 0.53$^{+0.04}_{-0.04}$ | 1.49$^{+0.43}_{-0.43}$ | 1.47$^{+0.23}_{-0.23}$ | 0.82$^{+0.08}_{-0.08}$ |
| PG7  | 112   | 10    | 0.76$^{+0.09}_{-0.09}$ | 199$^{+19}_{-19}$ | 0.56$^{+0.04}_{-0.04}$ | 2.44$^{+0.62}_{-0.62}$ | 2.57$^{+0.68}_{-0.68}$ | 1.15$^{+0.14}_{-0.14}$ |
| HG   | 475   | 4     | 0.58$^{+0.03}_{-0.03}$ | 84$^{+6}_{-6}$ | 0.60$^{+0.05}_{-0.05}$ | 0.43$^{+0.12}_{-0.12}$ | 0.53$^{+0.09}_{-0.09}$ | 0.52$^{+0.06}_{-0.06}$ |
| HG5  | 190   | 7     | 0.81$^{+0.07}_{-0.07}$ | 106$^{+8}_{-8}$ | 0.66$^{+0.06}_{-0.06}$ | 0.78$^{+0.12}_{-0.12}$ | 1.05$^{+0.27}_{-0.27}$ | 0.92$^{+0.16}_{-0.16}$ |
| HG7  | 103   | 10    | 0.98$^{+0.13}_{-0.13}$ | 120$^{+11}_{-11}$ | 0.71$^{+0.08}_{-0.08}$ | 1.22$^{+0.33}_{-0.33}$ | 1.57$^{+0.48}_{-0.48}$ | 1.23$^{+0.28}_{-0.28}$ |

Typical mass errors are very large and vary with group mass: e.g., we find a median mass error of $\sim 130\%$ on the whole catalogs, and only $\sim 70\%$ for groups with at least five members. Both mass and luminosity could have large systematic errors connected to the algorithm of identification: for instance the typical mass of PG and HG differs for a $60\%$, while the luminosity seems enough robust.

3.4 NOG Groups vs Other Galaxy Systems

As for a reliable comparison with clusters analyzed by G00, and other galaxy systems analyzed in §3.1 and 3.2, we should rescale both group mass and luminosity to the region within $R_{vir}$. The paucity of data does not allow us to make an individual correction: we apply a mean correction to all groups by using the procedure outlined by G00.

PGs and HGs are identified by using a number density contrast ($\delta_n/\rho_g = 80$) and a luminosity density contrast ($\delta_L/\rho_g = 45$), respectively, which are comparable to the matter density contrast, $\delta/\rho$, since the biasing factor $b = (\delta_n/\rho_g)/ (\delta_L/\rho)$ is roughly one (e.g., from $b = 1/\sigma_8$ and $\sigma_8$ value from Eke et al. 1996; Girardi et al. 1998a). These values of $\delta_L/\rho$ for PG and HG groups are much smaller than the values of $\sim 350$ expected within the virialized region (e.g., Eke et al. 1996).

After assuming that groups have a common radial profile (Fasano et al. 1993), we can roughly estimate the number fraction of members contained in the virialized region. For each of the two catalogs, Figure 7 plots the cumulative distributions of the projected galaxy distances from the group.
center, combining together data of all groups. To combine the galaxies of all groups we divide each galaxy distance by the projected radius, $R_{PV}$, of its group and then we normalize to the mean $<R_{PV}/R_{\text{max}}>$ of the catalog. From Figure 7 one can infer the fraction of the number of galaxies, i.e., the fraction of group luminosity and mass if galaxy number distribution traces luminosity and mass, contained within each radius. We are interested in determining the radius, and the corresponding number fraction, for which one obtains a density enhancement which is large enough to reach the density contrast expected in the virialized region. In the case of PG, the virialization density is obtained within a radius smaller by $\sim 55\%$, which contains $\sim 73\%$ fewer galaxies; in fact the density in these central regions is $0.73/(0.55^3) \times 80 = 4.4 \times 80 \sim 350$. In the case of HG, similar arguments show that the virialization density is obtained within a radius smaller by $\sim 42\%$, which contains $\sim 57\%$ fewer galaxies. The direct application of $R_{\text{vir}}$ definition (eq. 1) would give similar small virialization radii: e.g., for PG groups the median value of $\sigma_v \sim 132 \text{ km s}^{-1}$ corresponds to a value of $R_{\text{vir}} = 0.26 h^{-1} \text{ Mpc}$ to be compared with the sampling area of groups $R_{\text{max}} = 0.46 h^{-1} \text{ Mpc}$, i.e. $\sim 56\%$ smaller (cf. also Carlberg et al. 2001a for CNOC2 groups).

Moreover, when comparing results in the $B$ band with those in the $B_1$ band, we assume that $(L_{B_1}/L_{B_1})/(L_B/L_{B,80}) = 1.1$ in agreement with the relation $B_1 - B = 0.28(B - V)$ of Blair & Gilmore 1982 (see also Metcalfe, Fong, & Shanks 1995; Maddox, Efstathiou, & Sutherland 1990), where we take $(B_1 - B)_{80} = 0.15$ and a mean value of $(B - V) = 0.9$ mag for cluster members.

Finally, we attempt a comparison of the results for those systems catalogued both as NOG groups and as clusters or poor systems (CL+PS). We identify 13 groups for PG and 12 for HG: A194/PG72/HG78, A262/PG102/HG113, A3574/PG753/HG725, Eridanus/PG202/HG207, S373/PG201/HG208, S753/PG770/HG752, S805/PG929/HG898, N67-312/PG581/HG554, N79-298/PG605/HG581, N67-336/PG776/HG753, N67-325/PG787/HG766, N67-326/PG809, N34-171/PG896, HCG62/HG646. Both mass and luminosity of NOG groups correlate with the corresponding CL+PS values, but there is a large scatter. As for PGs, masses are comparable and mass–to–light ratios are slightly larger: $M_{PG}/M_{CL+PS} = 0.91(0.70 - 1.95)$ and $(M/L)_{PG}/(M/L)_{CL+PS} = 1.36(0.78 - 1.71)$, median values with $90\%$ c.l. error bands. As for HGs, masses are smaller and mass–to–light ratios comparable: $M_{HG}/M_{CL+PS} = 0.48(0.35 - 0.63)$ and $(M/L)_{HG}/(M/L)_{CL+PS} = 0.87(0.44 - 1.58)$. However, the sample is so small and sparse that this comparison is not useful for understanding which catalog is the more consistent with the treatment of other galaxy systems.

3.5 The Combined Sample

Our comparison between groups and other systems does not enable us to express a preference to one or the other of the two NOG catalogs (cf. above section). Indeed, both algorithms present known problems. It has been suggested that the drawback of percolation methods is the inclusion in the catalogs of possible non–physical systems, like a long galaxy filament aligned close to the l.o.s., which could give large mass estimates, while the drawback of hierarchical methods is the splitting of galaxy clusters into various subunits, which give small mass estimates (e.g., Gourguilhon et al. 1992; Giuricin et al. 2000). Therefore we choose to consider only common groups, i.e. those groups which are identified by both the algorithms (cf. cross–identifications of Tables 5 and 7 of Giuricin et al. 2000), averaging the corresponding estimates of physical quantities. Avoiding PGs which are split into two or more HGs and, viceversa, groups with null mass, as well as groups which are already present in the CL+PS sample, we obtain 296 groups.

Moreover, the physical reality of the very poor detected groups has often been discussed in the literature. In particular, the efficiency of the percolation algorithm has been repeatedly checked in the literature, showing that an appreciable fraction of the poorer groups, those with $N_m < 5$ members, is false (i.e. unbound density fluctuations), whereas the richer groups almost always correspond to real
systems (e.g., Ramella, Geller, & Huchra 1989; Ramella et al. 1995; Mahdavi et al. 1997; Nolthenius, Klypin, & Primack 1997; Diaferio et al. 1999). Therefore, among the 296 common groups we consider the 132 groups having more than five members (hereafter GROUP sample). By combining GROUPs with other systems we obtain a fiducial combined sample of 294 systems (CL+PS+GROUP).

| Name | $M/L_{BH}$ | $M/L_{BH}$ | $M/L_{BH}$ | $M/L_{BH}$ | $M/L_{BH}$ |
|------|------------|------------|------------|------------|------------|
| A85  | 14.99      | 448        | 14.18      | 98         | 14.58      |
| A194 | 13.78      | 274        | 14.30      | 315        | 14.19      |
| A262 | 14.12      | 99         | 13.89      | 145        | 14.40      |
| A420 | 13.88      | 413        | 14.74      | 401        | 14.50      |
| A514 | 14.91      | 376        | 13.30      | 103        | 14.37      |
| A999 | 13.49      | 100        | 14.28      | 204        | 13.88      |
| A1142| 14.29      | 552        | 14.87      | 199        | 14.02      |
| A1228| 12.79      | 37         | 13.49      | 78         | 14.70      |
| A1644| 14.65      | 325        | 14.70      | 227        | 14.77      |
| A1809| 14.66      | 338        | 14.22      | 271        | 14.27      |
| A2029| 14.83      | 131        | 14.24      | 243        | 14.40      |
| A2079| 14.67      | 391        | 14.12      | 212        | 14.42      |
| A2124| 14.84      | 210        | 15.25      | 533        | 14.75      |
| A2197| 14.55      | 296        | 14.76      | 277        | 14.31      |
| A2362| 13.79      | 236        | 13.98      | 121        | 13.68      |
| A2500| 14.01      | 340        | 14.78      | 261        | 14.30      |
| A2589| 13.89      | 239        | 14.63      | 210        | 12.87      |
| A2670| 14.74      | 391        | 14.23      | 361        | 14.17      |
| A2721| 14.74      | 257        | 14.53      | 579        | 14.82      |
| A2798| 14.28      | 172        | 14.07      | 285        | 13.98      |
| A2877| 14.69      | 394        | 14.20      | 200        | 13.91      |
| A3094| 14.67      | 450        | 12.71      | 28         | 14.70      |
| A3126| 14.89      | 491        | 14.85      | 380        | 14.72      |
| A3151| 13.29      | 76         | 14.97      | 454        | 14.87      |
| A3223| 14.51      | 355        | 15.07      | 480        | 14.58      |
| A3354| 13.76      | 94         | 14.96      | 768        | 14.56      |
| A3381| 13.57      | 124        | 14.56      | 244        | 14.76      |
| A3528n| 13.99     | 94         | 14.51      | 198        | 14.54      |
| A3558| 15.06      | 240        | 14.10      | 145        | 14.91      |
| A3574| 14.15      | 175        | 14.59      | 210        | 15.07      |
| A3693| 13.93      | 146        | 14.59      | 180        | 14.88      |
| A3733| 14.46      | 346        | 14.10      | 192        | 14.21      |
| A3822| 14.62      | 132        | 14.59      | 255        | 13.83      |
| A3880| 14.76      | 371        | 14.31      | 175        | 14.02      |
| A4010| 14.43      | 305        | 14.31      | 421        | 14.03      |
| AW1M4| 12.34      | 20         | 14.51      | 498        | 14.60      |
| DC0003-50| 13.75  | 174        | 13.60      | 597        | 13.22      |
| MK66A | 13.42    | 169       | 13.58      | 70         | 13.49      |
| S463 | 14.30      | 137        | 14.49      | 290        | 14.12      |
| S805 | 14.06      | 184        | 14.51      | 151        | 13.82      |
| S49-142| 12.37     | 81         | 13.21      | 144        | 13.55      |
| N56-393| 13.59    | 254        | 13.28      | 149        | 12.46      |
| N56-371| 13.62    | 242        | 11.93      | 10         | 12.57      |
| N79-298| 12.66    | 130        | 13.67      | 167        | 14.06      |
| N79-299A| 13.80   | 247        | 13.79      | 150        | 13.47      |
| Name            | $\log \left( \frac{M}{M_\odot} \right)$ | $\log \left( \frac{M/L_B}{M_\odot} \right)$ | Name            | $\log \left( \frac{M}{M_\odot} \right)$ | $\log \left( \frac{M/L_B}{M_\odot} \right)$ |
|-----------------|------------------------------------------|---------------------------------------------|-----------------|------------------------------------------|---------------------------------------------|
| N67-333         | 13.73, 229                               |                                             | N67-323         | 13.51, 16                                |                                             |
| N67-270         | 12.45, 75                                 |                                             | N79-296         | 14.31, 1215                              |                                             |
| N67-297         | 13.05, 73                                 |                                             | N56-381         | 12.85, 100                              |                                             |
| N67-325         | 13.38, 141                                |                                             | N56-394         | 13.44, 369                               |                                             |
| N56-394         | 13.74, 384                                |                                             | N56-395         | 14.16, 633                               |                                             |
| N45-381         | 12.64, 32                                 |                                             | N45-363         | 14.07, 359                               |                                             |
| N34-171         | 13.11, 311                                |                                             | N34-175         | 14.18, 136                               |                                             |
| HCG 42          | 13.12, 62                                 |                                             | NGC 4325        | 13.49, 565                               |                                             |
| NGC 5129        | 13.62, 228                                |                                             | NGC 491         | 12.00, 34                                |                                             |
| HG3             | 12.74, 53                                 |                                             | HG11            | 13.52, 645                               |                                             |
| HG49            | 12.74, 53                                 |                                             | HG57            | 12.53, 32                                |                                             |
| HG83            | 12.37, 52                                 |                                             | HG73            | 13.72, 263                               |                                             |
| HG109           | 12.67, 59                                 |                                             | HG120           | 12.95, 127                               |                                             |
| HG138           | 11.34, 4                                  |                                             | HG158           | 11.83, 21                                |                                             |
| HG167           | 12.57, 59                                 |                                             | HG175           | 12.59, 72                                |                                             |
| HG185           | 13.23, 631                                |                                             | HG187           | 12.87, 125                               |                                             |
| HG201           | 12.46, 98                                 |                                             | HG212           | 13.41, 211                               |                                             |
| HG223           | 11.69, 29                                 |                                             | HG226           | 13.11, 190                               |                                             |
| HG234           | 12.77, 30                                 |                                             | HG246           | 12.85, 89                                |                                             |
| HG246           | 12.94, 84                                 |                                             | HG261           | 13.28, 188                               |                                             |
| HG311           | 12.68, 109                                |                                             | HG322           | 11.93, 53                                |                                             |
| HG333           | 11.82, 67                                 |                                             | HG348           | 13.81, 608                               |                                             |
| HG349           | 12.46, 16                                 |                                             | HG361           | 12.38, 75                                |                                             |
| HG402           | 12.36, 65                                 |                                             | HG421           | 12.34, 30                                |                                             |
| HG439           | 12.44, 283                                |                                             | HG454           | 12.13, 83                                |                                             |
| HG473           | 14.18, 450                                |                                             | HG507           | 12.84, 137                               |                                             |
| HG491           | 12.10, 167                                |                                             | HG500           | 12.54, 132                               |                                             |
| HG511           | 12.79, 111                                |                                             | HG507           | 12.79, 111                               |                                             |
| HG546           | 13.03, 828                                |                                             | HG545           | 13.48, 184                               |                                             |
| HG557           | 13.29, 168                                |                                             | HG545           | 13.27, 140                               |                                             |
| HG574           | 13.39, 176                                |                                             | HG595           | 12.49, 122                               |                                             |
| HG576           | 11.73, 9                                  |                                             | HG594           | 12.92, 167                               |                                             |
| HG601           | 12.27, 24                                 |                                             | HG602           | 13.13, 390                               |                                             |
| HG574           | 13.15, 189                                |                                             | HG607           | 13.47, 582                               |                                             |
| HG611           | 13.09, 147                                |                                             | HG610           | 13.21, 296                               |                                             |
| HG617           | 12.20, 161                                |                                             | HG619           | 13.75, 753                               |                                             |
| HG623           | 12.27, 57                                 |                                             | HG626           | 12.37, 36                                |                                             |
| HG636           | 13.22, 329                                |                                             | HG647           | 12.92, 316                               |                                             |
| HG639           | 11.10, 29                                 |                                             | HG641           | 12.54, 108                               |                                             |
| HG680           | 12.15, 28                                 |                                             | HG690           | 12.59, 156                               |                                             |
| HG703           | 12.05, 25                                 |                                             | HG704           | 13.02, 514                               |                                             |
| HG712           | 11.85, 26                                 |                                             | HG718           | 12.81, 610                               |                                             |
| HG731           | 13.02, 75                                 |                                             | HG737           | 12.81, 117                               |                                             |
| HG743           | 12.44, 66                                 |                                             | HG745           | 13.41, 301                               |                                             |
| HG759           | 12.37, 119                                |                                             | HG806           | 12.89, 133                               |                                             |
| HG806           | 13.02, 124                                |                                             | HG806           | 12.82, 110                               |                                             |
| HG868           | 12.25, 12                                 |                                             | HG872           | 12.49, 55                                |                                             |
| HG910           | 13.74, 293                                |                                             | HG910           | 13.95, 306                               |                                             |
| HG926           | 13.78, 315                                |                                             | HG939           | 13.15, 105                               |                                             |
| HG949           | 13.51, 282                                |                                             | HG959           | 13.02, 148                               |                                             |
| HG1008          | 12.60, 63                                 |                                             | HG1017          | 12.75, 276                               |                                             |
| HG1060          | 12.31, 35                                 |                                             | HG1057          | 13.55, 481                               |                                             |
| HG1062          | 13.35, 197                                |                                             | HG1071          | 13.02, 180                               |                                             |
RESULTS

We computed the values of the mass-to-light ratio for all systems. As for clusters and poor systems, we average COSMOS and APS luminosities when both are available, and then we average the two alternative luminosity estimates, $L_{B,c}$ and $L_{B,f}$, to obtain a single value for each system. In particular, for clusters we consider values coming from G00, too. In Table 5 we list the values of $M$ and $M/L$ for all 294 systems of the combined sample.

Table 6 summarizes our results, listing the median values of $M$ and $M/L$, and 90% c.l., for all the samples we consider. The general feeling is that $M/L_B$ increases with system mass (cf. Figure 8).

For a more quantitative analysis we avoid of fitting the behavior of $M/L$ vs. $M$ or $L$ because $M/L$ is defined as a function of $M$ and $L$, and therefore that would mean working with correlated quantities (cf. Mezzetti, Giuricin, & Mardirossian 1982; Girardi et al. 1996). Rather, we directly examine the $M$–$L$ relation.

![Fig. 8.— Behavior of mass-to-light ratio vs. cluster mass for the sample of clusters (CL), poor systems (PS), percolation and hierarchical NOG groups of different richness (PG and HG, respectively). Circles are median values with 90% c.l. error bars.](image)

![Fig. 9.— Relation between mass and luminosity for the combined sample of clusters (CL, circles) and poor systems (PS, crosses). Heavy lines represent the linear fits: dashed lines give the direct and the inverse fits, while the solid line gives the bisecting line. The faint line is the $M \propto L_{B,j}$ relation.](image)

First, we consider together clusters and poor systems, analyzing a combined sample (CL+PS) of 162 systems. Figure 9 shows the $M$ vs $L_B$ relation. As the errors are comparable, we fit the regression line into the logarithmic

TABLE 6

| Sample | $N_S$ | $M_{10^{13}h^{-1}M_\odot}$ | $M/L_{B,c}$ | $M/L_{B,f}$ | $M/L_B$ |
|--------|-------|--------------------------|-------------|-------------|---------|
|        |       | (1)                      | (2)         | (3)         | (4)     |
| A-CL   | 52    | 29.32$^{+6.89}_{-4.71}$  | 262$^{+45}_{-54}$ | 238$^{+75}_{-51}$ |
| C-CL$^a$ | 89    | 23.39$^{+4.51}_{-7.23}$  | 276$^{+31}_{-32}$ | 253$^{+34}_{-32}$ |
| CL     | 119   | 24.90$^{+5.87}_{-1.74}$  | 270$^{+30}_{-29}$ | 245$^{+10}_{-32}$ |
| PS     | 43    | 3.09$^{+4.12}_{-1.47}$   | 223$^{+62}_{-80}$ | 222$^{+29}_{-86}$ |
| PG     | 513   | 0.55$^{+0.15}_{-0.10}$   | 173$^{+31}_{-37}$ |
| PG5    | 208   | 1.00$^{+0.15}_{-0.22}$   | 197$^{+38}_{-26}$ |
| PG7    | 112   | 1.67$^{+0.38}_{-0.44}$   | 230$^{+38}_{-37}$ |
| HG     | 475   | 0.34$^{+0.10}_{-0.06}$   | 106$^{+16}_{-16}$ |
| HG5    | 190   | 0.68$^{+0.11}_{-0.18}$   | 123$^{+15}_{-21}$ |
| HG7    | 103   | 1.92$^{+0.31}_{-0.30}$   | 131$^{+25}_{-22}$ |
| GROUP  | 132   | 0.63$^{+0.15}_{-0.15}$   | 122$^{+15}_{-20}$ |

$^a$ We report here the values obtained by G00 for clusters by using COSMOS.
plane by using the unweighted bisecting fit (cf. Isobe et al. 1990):

\[
\frac{M}{M_\odot} = 10^c \cdot \left( \frac{L_{B,j}}{L_{B,j,\odot}} \right)^d .
\]

(6)

We obtain \( c = -1.476 \pm 0.756 \) and \( d = 1.321 \pm 0.063 \). Similar results are obtained by considering \( L_{B,j,c} \) and \( L_{B,j,f} \) separately, i.e. \( d = 1.312 \pm 0.07 \) and \( d = 1.293 \pm 0.056 \), respectively, both larger than one at more than the 3\( \sigma \) level.

Then we extend our analysis to NOG groups. Figure 10 combines results for all NOG groups with those for the CL+PS systems. Both NOG catalogs turn out to show a continuity with other systems, although PGs seem to have larger \( M/L \) ratios.

The analysis of our fiducial, combined sample of 294 systems (CL+PS+GROUP), which considers only groups common to both PG and HG catalogs with at least five members, gives:

\[
\frac{M}{M_\odot} = 10^{-1.596 \pm 0.381} \cdot \left( \frac{L_B}{L_{B,\odot}} \right)^{1.338 \pm 0.033} .
\]

(7)

Similar results are obtained if we consider also all common groups \( (d = 1.349 \pm 0.028 \) for a combined sample of 458 systems), or those with at least seven members \( (d = 1.309 \pm 0.036 \) for a combined sample of 231 systems).

![Fig. 10. Relation between mass and luminosity for groups and other systems.](image)

![Fig. 11. Relation between mass and luminosity for our combined sample of clusters, poor systems, and NOG groups.](image)

Fig. 11.— Relation between mass and luminosity for our combined sample of clusters, poor systems, and NOG groups. Heavy lines represent the linear fits: dashed lines give the direct and the inverse fits, while the solid line gives the bisecting line. The faint solid line is the \( M \propto L_B \) relation. The two faint dotted lines represent the two quadratic fits obtained by minimizing the scatter on one or the other variable.

Although the above straight line approach can be very useful to show that mass increases faster than luminosity, it might not be adequate to describe the \( M-L \) relation in such a wide dynamical range, from poor groups to very rich clusters. We also attempt a quadratic fit for the two extreme situations; minimizing the scatter on \( M \)-axis we obtain:

\[
\lg(M/M_\odot) = -17.04 + 4.26 \cdot \lg(L_B/L_{B,\odot}) - 0.14 \cdot \lg(L_B/L_{B,\odot})^2,
\]

(8)

and minimizing the scatter on \( L \)-axis we obtain:

\[
\lg(L_B/L_{B,\odot}) = 17.16 - 1.61 \cdot \lg(M/M_\odot) + 0.09 \cdot \lg(M/M_\odot)^2.
\]

(9)

The first quadratic fit very closely resembles the direct linear fit, while the second one shows a more pronounced change in the slope of the \( M-L \) relation; both fits show a
steeper slope in the low–mass range (cf. Figure 11). The above results are obtained by imposing on the dependent variable the same percent errors as masses. Other fits with fixed errors (e.g., of 50% or 80%) give different numerical results but with the same qualitative behavior. Only by having a better knowledge of error on group quantities could we arrive at more conclusive results. In particular, although we have not found any statistical confirmation of this, we suspect that in the case of groups the errors on mass could be larger than the nominal statistical ones, being due to spurious groups and/or interlopers, and thus larger (in percent terms) than the errors on luminosity. This possibility could explain the visual impression for a left vertical selection boundary in the plots of $M$ vs. $L$.

5 DISCUSSION

5.1 Comparison with Previous Results

Our estimate of $M/L$ (A–CL) for clusters is fully consistent with that obtained by G00 (C–CL); we refer to G00 for other useful discussions about clusters. As for poor systems, recent studies give values of $M/L_B = 188–254 h M_\odot/L_\odot$ for groups with $\sigma_v = 164–274$ km s$^{-1}$ (Ramella, Pisani, & Geller 1997; Tucker et al. 2000; Carlberg et al. 2001a; Hoekstra et al. 2001a). These results are roughly consistent with richer NOG groups, PG5 and PG7, which have comparable $\sigma_v$ (cf. Table 4), while the whole NOG group catalogs, which describe the local Universe very deeply, are, as expected, characterized by less massive systems, with smaller $M/L$.

As for the $M–L$ relation, analyzing 89 clusters with homogeneous mass and luminosity estimates, G00 found that mass has a slight but significant tendency to increase faster than the luminosity, $M \propto L_B^{1.2–1.3}$, where mass and luminosity are computed within the virial radius. Although this result agrees with those indirectly recovered by fundamental plane analyses (Schaeffer et al. 1993; Adami et al. 1998a), there is a general absence of direct evidence for a correlation between $M/L$ and cluster properties (e.g., Dressler 1978; David et al. 1995; Carlberg et al. 1996; Fritsh & Buchert 1999; but see Adami et al. 1998b). G00 pointed out the need for a rather large sample spanning a large dynamical range and homogeneous analysis to detect such a small effect.

Here, with respect to G00, we consider a sample three times larger and covering a wider dynamical range (two times larger in logarithmic scale). Our results are fully consistent with those obtained by G00, but with a stronger statistical significance ($\sim 10\sigma$ vs. $\sim 3\sigma$, according to face values). Interestingly, these results have found support in some independent recent studies. As for groups identified in CNOC2, Carlberg et al. (2001a) find evidence that $M/L$ increases with increasing group velocity dispersion, and Hoekstra et al. (2001a) have noted that the typical group $M/L$ is smaller than that of CNOC clusters (Carlberg et al. 1996). However, the issue is far from being clear: e.g., Hradecky et al. (2000) have recently claimed that $M/L$ is roughly independent of system mass (but, indeed, the seven points in their Figure 5 could also allow an increase of $M/L$).

New insights could come from a very different approach, i.e. from preliminary results of the correlation between the red galaxy distribution and the dark matter distribution as measured by the lensing signal (Hoekstra et al. 2001b; Wilson, Kaiser, & Luppino 2001). Pioneering results support the hypothesis that red light traces mass on scales from 0.2 $h^{-1}$ Mpc to very large scales and it is probable that in the future it will be possible to make a comparison with dynamical results.

5.2 Reliability and Caveats of Observational $M/L$

As for the robustness of our results, several tests for luminosity estimates were computed by G00 in their cluster analysis (cf. their § 6.3). In particular, they showed the small effect of changing the analytical form and/or the parameters of the luminosity function in the extrapolation to faint galaxies. Here, this correction is very small for groups and poor systems, which are very close and so very deeply sampled.

Indeed, as for luminosity estimates, the most important correction concerns the foreground/background problem, and, in fact, following G00, we use two alternative corrections, leading to two alternative luminosity estimates ($L_{B_1,c}$ and $L_{B_1,f}$ in § 3.2).

In dealing with poor, possibly spiral rich, galaxy systems, it is worthwhile discussing the correction applied for the internal reddening of galaxies, although this is often neglected in analyses of the $M/L$ ratio for galaxy systems (e.g., Hradecky et al. 2000). In this study, following G00, we adopt a mean correction of $A_{B_1} = 0.1$ mag for clusters: this is a compromise between the mean correction of $A_B \sim 0.3$ mag for galaxies of the Third Reference Catalogue and the value of $A_B = 0$ mag for early–type galaxies (de Vaucouleurs et al. 1991). As for loose groups of NOG, where the fraction of early galaxies is comparable to that of the field ($f_e \sim 0.2$), the adopted magnitudes are already corrected for internal absorption (Paturel et al. 1997, cf. also Bottinelli et al. 1995). The recent study by Tully et al. (1998) on global extinction agrees with corrections suggested by de Vaucouleurs et al. (1991) and Bottinelli et al. (1995): they find negligible extinction in lenticulars and $A_B \sim 1.8$ in highly inclined spirals (cf. with $A_B \sim 1.5–1.67$ by de Vaucouleurs et al. 1991 and Bottinelli et al. 1995). Indeed, some specific studies of highly inclined spiral galaxies could suggest higher extinction values, finding $A_B = 2–3$ mag in the center and then a rapid drop with radius (cf. Jansen et al. 1994, see also Kuchinski et al. 1998). Even alternating that we are underestimating the internal extinction of spirals by a factor of two, the group $M/L$ is presently overestimated at most by a factor of $\sim 30\%$ and the slope of the $M–L$ relation is presently slightly underestimated (e.g., we would obtain $M \propto L_B^4$ by applying a 30\% correction to NOG group luminosities).

Finally, as for the robustness of our luminosity estimates, we go well beyond G00 results on one particular
point. In fact, while G00 results are strongly based on the COSMOS catalog, we have shown that luminosities coming from two different catalogs (COSMOS and APS) are really comparable, suggesting that no systematic effect, connected to a particular catalog, pollutes our results.

The most important systematic uncertainty concerns mass estimates, since our application of the virial theorem assumes that, within each system, mass distribution follows galaxy distribution. For clusters this assumption is supported by several independent analyses using optical and X-ray data, as well as gravitational lensing phenomena (e.g., Durret et al. 1994; Narayan & Bartelmann 1996; Carlberg, Yee, & Ellingson 1997; Cirimele, Nesci, & Trevese 1997), but we must recognize that the issue is far from being clear for poor systems. The absence of luminosity segregation of galaxies in the velocity space (Giuricin et al. 1982; Pisani et al. 1992) suggests that the effect of dynamical friction in slowing down galaxies with respect to dark matter is very poor. However, analyzing CNO C2 groups, Carlberg et al. (2001a) have recently shown that light might be much more concentrated than mass. If that also galaxy number distribution is more concentrated than mass, our virial mass estimates for very poor systems, similar to that of clusters. Instead, no trace of color gradients has been found for less massive groups (Carlberg et al. 2001b). In our case, the fraction of early galaxies in NOG groups is comparable with that of the field, being 0.2. To be compared to 0.5–0.75 in clusters, e.g. Oemler 1974). This could mean that NOG groups are different from clusters in their morphological content or that they are similar, but we are looking at the the combined effect of color gradients and a sampling area that is very large with respect to clusters (~2 × Rvir). Whatever the reality is, one needs to apply a correction to pass from blue to infrared luminosities.

Assuming (B − H) ∼ 3.75 and ∼ 3.0 for early type and late type galaxies, respectively (Fioc & Rocca-Volmerange 1999), as well as (B − H)⊙ ∼ 2.1 (Wamsteker 1981), we find that L∗ H = 4.6L∗ B for luminosity of early–type galaxies and L∗ H = 2.3L∗ B for luminosity of late type galaxies. Then, when assuming that typical blue galaxy luminosities in clusters are roughly comparable for early and late type galaxies (e.g. Sandage, Binggeli, & Tammann 1985; Andreon 1998) and that the early galaxy fraction goes from 0.75 to 0.2 for spiral–poor clusters and groups, respectively, we obtain L H ∼ 4.0LB and L H ∼ 2.8LB for clusters and groups, respectively. Therefore, we expect that M/LH for groups (GROUP sample) will still be lower than for clusters (CL sample, cf. Table 6) by ∼ 40%, compared with a factor two difference in M/LB.

5.3 Comparison with Theoretical Results

The assumption that M/L within galaxy clusters is typical of the Universe as a whole leads to an estimate of the matter density parameter Ωm, i.e. Ωm = (M/L) · ρL/ρc, where ρc is the critical density, and ρL is the typical luminosity density of the Universe, as generally determined on field galaxies (Oort’s method, e.g. Bahcall et al. 1995; Carlberg et al. 1996; G00). However, both assumptions that luminosity is conserved when field galaxies fall into a cluster and that galaxy formation is the same in all environments are questionable. Recently, the combination of cosmological numerical simulations and semianalytic modeling of galaxy formation have faced the question of
galaxy–systems $M/L$ in a more realistic way (e.g., Kauffmann et al. 1999; Bahcall et al. 2000; Benson et al. 2000; Somerville et al. 2001). Here we attempt a comparison with the theoretical results.

Figure 12 compares our observational results with the theoretical predictions of Kauffmann et al. (1999) and Benson et al. (2000), who both recovered the behavior of $M/L_B$ vs. halo mass of galaxy systems in the framework of cold dark matter (CDM) models for two alternative cosmologies: a low–density model with $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$ ($\Lambda$CDM), and a high–density model with $\Omega_m = 1$ and shape parameter $\Gamma = 0.21$ ($\tau$CDM).

The $\Omega_m = 1$ cosmology is reported here for the sake of completeness. Also without taking into account the small–mass range, where we should recompute the mass of NOG groups for this kind of model, $\Omega_m = 1$ cosmology is clearly rejected according to the our observational results.

However, the preferred value of $\Omega_m$ is not obvious, since the model with $\Omega_m = 0.3$ by Kauffmann et al. fits the data well, while the results of Benson et al. suggest a smaller value. Indeed, the predicted value of $M/L$ shows large differences among the predictions of different authors and can vary considerably in many theoretical details, e.g. the correction of dust extinction (cf. Somerville et al. 2001). Besides normalization, also the whole behavior of $M/L$ can be very useful in constraining theoretical results: e.g., the results obtained by Kauffmann et al. reproduce the steepness of the observational increase of $M/L$ with halo mass, while the results by Benson et al. show a flatter behavior.

Finally, we discuss the very recent results by Marinoni and Hudson (2001), who derive the behavior of $M/L$ by using the analytical approach of Press & Schechter (1974) and the observational luminosity function for galaxy systems: their prediction for the $\Lambda$CDM model agrees well with our findings in the $10^{13}$–$10^{14} h^{-1} M_\odot$ range, but they obtain a steeper slope in the high–mass range, and an slope inversion in the low–mass range.

6 SUMMARY AND CONCLUSIONS

We analyze the mass–to–light ratios of galaxy systems from poor groups to rich clusters by considering virial mass estimates and blue band luminosities.

We extend the previous work of G00, where they computed $B_j$ band luminosities derived from the COSMOS catalog (Yentis et al. 1992) for a sample of 89 galaxy clusters, with virial mass homogeneously estimated by G98.

In this study we consider another 52 clusters having virial masses estimated by G98, a sample of 36 poor clusters proposed by L96, and a sample of 7 rich groups well analyzed by ZM98. For each poor system we select member galaxies and compute virial mass as performed by G98. For all systems we compute $B_j$–band luminosity by using both the APS catalog (Pennington et al. 1993) and the COSMOS catalog with the same procedure as that adopted by G00. Both mass and luminosity for each object are computed within the virial radius, in order to consider comparable physical regions for systems of different mass. The advantage of this procedure lies in the fact that one can compare regions with similar dynamical status and galaxy populations. By also taking into account the results of G00, we obtain a sample of 162 galaxy systems having homogeneous mass and luminosity estimates.

To extend our data base, we consider the two group catalogs identified in the NOG catalog by Giuricin et al. (2000), based on two different group identification algorithms, a percolation one and a hierarchical one ($\sim 500$ groups for each catalog). We compute mass and blue band luminosity for each group, homogeneizing our results to

Fig. 12.— Comparison between the observational behavior of mass–to–light of galaxy systems and the theoretical predictions of Kauffmann et al. (1999, top panel) and Benson et al. (2000, bottom panel); see text. When plotting Kauffmann et al.’s results we assume a closure value for the Universe $M/L_B[Universe] = 1350 h M_\odot/L_\odot$ (from the luminosity density $\rho_l \sim 2 \times 10^8 h L_\odot Mpc^{-3}$ by Efstathiou, Ellis, & Peterson 1988). For comparison, Benson et al. quoted a mean value of $M/L_B = 1440 h M_\odot/L_\odot$ in their simulation as a whole in the $\tau$CDM cosmology. Points represent individual data for our combined sample, while circles show median values with 90% c.l. error bands.
those of other systems as much as possible; in particular, we rescale mass and luminosity to the central, possibly virialized, group region.

To avoid possible spurious groups, we consider the sub-sample of 132 NOG groups identified in both catalogs and having at least five members. We combine these groups with clusters and poor systems to obtain a fiducial combined sample of 294 systems spanning a very large dynamical range ($\sim 10^{12}-10^{15.5} h^{-1} M_\odot$).

We find that mass increases faster than luminosity. By using the bisecting unweighted procedure, the analysis of the combined sample gives:

$$\frac{M}{M_\odot} = 10^{-1.596 \pm 0.381} \left( \frac{L_B}{L_B,\odot} \right)^{1.338 \pm 0.033}.$$  (10)

Consistent results are recovered by using the more homogeneous subsample, which contains only 162 clusters and poor systems. This result agrees with that reported by G98, confirming the effect at a higher statistical significance (there the effect was detected at the $\sim 3\sigma$ level).

When analyzing the combined sample with a quadratic fitting relation, we find a tendency for a steeper slope in the low-mass range.

Finally, we compare our observational results with the theoretical predictions with the behavior of $M/L_B$ vs. halo mass, in particular to the behavior recently predicted by the combination of cosmological numerical simulations and semianalytic modeling of galaxy formation. We find a very good agreement with the result by Kauffmann et al. (1999) for a CDM model with $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$. This demonstrates that the study of the mass-to-light ratio scaling for galaxy systems represents a useful tool for constraining models of galaxy formation.

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REFERENCES

Abraham, R. G., et al. 1996, ApJ, 471, 694
Adam, C., Mazure, A., Biviano, A., Katgert, P., & Rhee, G. 1998a, A&A, 331, 493
Adam, C., Mazure, A., Katgert, P., & Biviano, A. 1998b, A&A, 336, 98
Andreon, S. 1998, A&A, 336, 98
Allen, S. W. 1997, MNRAS, 296, 392
Bahcall, N. A., Lubin, L. M., & Dorman, V. 1995, ApJ, 447, L81
Baleggi, M. L. et al. 2001, preprint astro-ph/0110326
Bardeen, J. M., Bond, J. R., Kaiser, N., & Szalay, A. S. 1986, ApJ, 304, 15
Beers, T. C., Flynn, K., & Gebhardt, K. 1990, AJ, 100, 32
Benson, A. J., Cole, S., Frenk, C. S., Baugh, C. M., & Lacey, C. G. 2000, MNRAS, 311, 793
Biviano, A. 2001, in Tracing Cosmic Evolution with Galaxy Clusters, eds. S. Borgani, M. Mezzetti, & R. Valdarnini (ASP Conf. Ser.), in press
Blair, F. W., Jones, L. R., Wake, D. A., Collins, C. A., Burke, D. J., Nichol, R. C., & Romer, A. K. 2001, preprint astro-ph/0111169
Blumenthal, G. R., Faber, S. M., Primack, J. R., & Rees, M. J. 1984, Nature, 311, 517
Bottinelli, L., Gouguenheim, L., Patr绿le, G., & Terlevich, P. 1995, A&A, 296, 64
Carlberg, R. G., Yee, H. K. C., & Ellingson, E. 1997 , ApJ, 478, 462
Carlberg, R. G., Yee, H. K. C., Ellingson, E., Abraham, R., Gravel, P., Morris, S., & Pritchett, C. J., et al. 1996, ApJ, 462, 32
Carlberg, R. G., et al. 2001a, ApJ, 552, 427
Carlberg, R. G., et al. 2001b, ApJ, in press, preprint astro-ph/0110326
Cirimele, G., Nesci, R., & Trevese, D. 1997, ApJ, 475, 11
Colless, M. 1989, MNRAS, 237, 799
Danese, L., De Zotti, C., & di Tullio, G. 1980, A&A, 82, 322
David, L. P., Jones, C., & Forman, W. 1995, ApJ, 445, 578
Davis, M., Efstathiou, G, Frenk, C. S., & White, S. D. M. 1985, ApJ, 292, 371
de Vaucouleurs, G., de Vaucouleurs, A., Corwin, H. G., Buta, R. J., Paturel, G. & Fouqué, P. 1991, “3rd Reference Catalogue of Bright Galaxies”, 9th version.
Diaferio, A., Kauffmann, G., Colberg, J. M., White, S. D. M. 1999, MNRAS, 307, 557
Diaferio, A., Ramella, M., Geller, M. J., Ferrari, A. 1993, AJ, 105, 2035
Dressler, A. 1978, ApJ, 226, 55
Dressler, A. 1980, ApJ, 236, 351
Durret, F., Gerbal, D., Lachize-Rey, M., Lima-Nieto G., & Sada, R. 1994, A&A, 287, 733
Efstathiou, G., Ellis, R. S., & Peterson, B.A., 1988, MNRAS, 232, 431
Eke, V. R., Cole, S., & Frenk, C. S. 1996, MNRAS, 282, 263
Fadda, D., Girardi, M., Giuricin, G., Marderossian, F., & Mezzetti, M. 1996, ApJ, 473, 670
Fairley, B. W., Jones, L. R., Wake, D. A., Collins, C. A., Burke, D. J., Nichol, R. C., & Romer, A. K. 2001, preprint astro-ph/0111169
Fasano, G., Pisani, A., Vio, R., & Girardi, M. 1993, ApJ, 416, 546
Fioc, M., & Rocca-Volmerange, B. 1999, A&A, 351, 869
Fritsch, C., & Buchert, T. 1999, A&A, 344, 749
Gavazzi, G., Pierini, D., & Boselli, A. 1996, A&A, 312, 397
Girardi, M., Biviano, A., Giuricin, G., Marderossian, F., & Mezzetti, M. 1995, ApJ, 438, 527
Girardi, M., Borgani, S., Giuricin, G., Marderossian, F., & Mezzetti, M. 2000, ApJ, 530, 62 (G00)
Girardi, M., Fadda, D., Giuricin, G., Marderossian, F., & Mezzetti, M., & Biviano, A. 1996, ApJ, 457, 61
Girardi, M., & Giuricin, G. 2000, ApJ, 540, 45 (GG00)
