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THE OBSERVATIONAL MASS FUNCTION OF LOOSE GALAXY GROUPS

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ABSTRACT

We analyze the three catalogs of nearby loose groups compiled by A. M. Garcia. She identified groups in a magnitude–limited redshift galaxy catalog, which covers about $\sim\frac{2}{3}$ of sky within $cz = 5500$ km s^{-1}, using two methods, a percolation method and a hierarchical method. The free parameters of the group-selection algorithms were tuned to obtain similar catalogs of groups. The author also proposed a third catalog of groups, defined as a combination of the two. Each catalog contains almost 500 groups. In agreement with previous works on earlier catalogs, we find that groups can be described as collapsing systems. Their sampled size is in general considerably larger than their expected virialized region. We compute the virial masses and correct them by taking into account the young dynamical status of these groups. We estimate corrected group masses, M, for two reference cosmological models, a flat one with a matter density parameter $\Omega_0 = 1$ and an open one with $\Omega_0 = 0.2$. We calculate the mass function for each of the three catalogs. We find that the amplitude of the mass function is not very sensitive to the choice of the group-identification algorithm. The number density of groups with $M > 9 \times 10^{12}\ h^{-1}\ M_{\odot}$, which is the adopted limit of sample completeness, ranges in the interval 1.3–1.9 $\times 10^{-3}\ h^3$ Mpc^{-3} for $\Omega_0 = 1$, and it is about a factor of 15% lower for $\Omega_0 = 0.2$. The mass functions of the hierarchical and combined catalogs have essentially the same shape, while the mass function of the percolation catalog shows a flattening toward large masses. However, the difference decreases if we do not consider the most massive groups, for which reliable results come from galaxy cluster studies. After having estimated the mass contained within the central, presumably virialized, regions of groups by adopting a reduction in mass of $\sim$30%–40%, we make a comparison with the results from the virial analysis of nearby rich clusters. All three group mass functions turn out to be a smooth extrapolation of the cluster mass function at $M < 4 \times 10^{14}\ h^{-1}\ M_{\odot}$, which is the completeness limit of the cluster sample. The resulting optical virial mass function of galaxy systems, which extends over 2 orders of magnitude, is fitted to a Schechter expression with a slope of $\sim$1.5 and a characteristic mass of $M_* \sim 3 \times 10^{14}\ h^{-1}\ M_{\odot}$. We also verify that our group mass function agrees reasonably well with the Press-Schechter predictions of models which at large masses describe the virial mass function of clusters.

Subject headings: cosmology: observations — cosmology: theory — galaxies: clusters: general — large-scale structure of universe

1. INTRODUCTION

Most galaxies in the local universe belong to loose galaxy groups. Groups seem to be the natural continuation of galaxy clusters at smaller mass scales. Indeed, there is a continuity of properties from rich clusters to poor clusters to groups (e.g., Ramella, Geller, & Huchra 1989; Burns et al. 1996; Mulchaey & Zabludoff 1998; Ramella et al. 1999; Girardi, Boschin, & da Costa 2000).

Zabludoff & Mulchaey (1998) used multifiber spectroscopy to obtain velocities for a large number of group members (i.e., 280 galaxies for a total of 12 groups), and Mahdavi et al. (1999) measured several hundred redshifts to obtain a sample of 20 groups, each one having , on average, 30 galaxies. For these well–sampled groups, Zabludoff & Mulchaey (1998) and Mahdavi et al. (1999) performed refined analyses, i.e., rejection of interlopers, study of the internal galaxy distribution and velocity dispersion profiles, and separation of different galaxy populations (for recent relevant results on rich and poor clusters, see, e.g., Biviano et al. 1997; Carlberg et al. 1996, 1997b; den Hartog & Katgert 1996; Dressler et al. 1999; Girardi et al. 1996, 1998b; Mohr et al. 1996; Koranyi & Geller 2000).

However, all these analyses are so far restricted to a limited number of groups, since they require a strong observational effort. Therefore, to analyze group dynamical properties in a statistical sense, one must resort to wide group catalogs in which groups are extracted from three–dimensional galaxy catalogs and typically contain $\lesssim 5$ member galaxies (e.g., Huchra & Geller 1982; Tully 1987; Ramella et al. 1999).

Here, we focus our attention on the determination of the group mass function from wide catalogs of nearby loose groups. The observational determination of the group mass function is plagued by several problems. Some of these concern the estimate of mass and are mainly due to the small number of group members and to uncertainties in the dynamical stage. In fact, although group cores are virialized or close to virialization (Zabludoff & Mulchaey 1998), the size of groups identified in three–dimensional galaxy catalogs, i.e., $\sim$0.5–1 h^{-1} Mpc, is appreciably greater than their expected virialized region, i.e., $\sim$0.2–0.4 h^{-1} Mpc for systems with a line-of-sight velocity dispersion of 100–200 km s^{-1} (according to the relations found for galaxy clusters; e.g., Carlberg, Yee, & Ellingson 1997a; Girardi et al. 1998b). Indeed, there is a strong indication that these groups are not virialized systems over the whole sampled region, but rather can be described as being in a phase of collapse (e.g., Giuricin et al. 1988; Mamon 1994; Diaferio et al. 1993). Therefore, usual estimates of velocity dispersion and virial mass are not easily connected to physical quantities such as group potential and mass.

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The small number of data and the uncertainties on dynamical status prevent the use of refined methods to reject interlopers in each individual group (e.g., Zabludoff & Mulchaey 1998; Mahdavi et al. 1999). Instead, one must rely on member galaxies as assigned by the group-selection algorithm, while checking a posteriori the presence of spurious groups in a statistical sense (e.g., Ramella, Pisani, & Geller 1997; Diaferio et al. 1999). Indeed, the results could depend on the choice of the group-selection algorithm and its free parameter (e.g., Pisani et al. 1992, hereafter P92; Ramella et al. 1997). For instance, Frederic's (1995b) analysis of cosmological N-body simulations suggested that the estimated median mass depends on the algorithm and that the resulting bias is sensitive to the depth of the galaxy survey. However, even the analysis of simulated groups is not an easy task and, indeed, the results on mass can depend on the treatment of halos (see Frederic 1995b).

A further uncertainty is connected to cosmic variance. In fact, group catalogs are recovered from local galaxy catalogs, which may not be fair samples of the universe.

In view of these difficulties, few statistical distributions of group dynamical properties are available in the literature, and they are often discrepant. The cumulative distributions of internal velocity dispersion, as computed by Moore, Frenk, & White (1993) and by Zabludoff et al. (1993), are strongly discrepant (the number densities of groups with line-of-sight velocity dispersion larger than 200 km s^{-1} differ by a factor of 100; see Fig. 6 of Fadda et al. 1996 for a comparison). Moreover, analyzing nearby groups ($cz \leq 2000$ km s^{-1}) of three different group catalogs, P92 found a significant dependence of the distribution of mass and other dynamical group parameters on the group-identification algorithm.

The availability of new group catalogs has prompted us to derive a new group mass function, and its connection to the recent determination of the optical virial mass function of nearby rich galaxy clusters (Girardi et al. 1998a, hereafter G98) also deserves to be investigated.

The work by Garcia (1993, hereafter G93), who constructed two group catalogs using two different identification algorithms (percolation and hierarchical) and proposed a third catalog that is a combination of the two, represents a good database for examining the effect of identification algorithms. So far, the G93 catalogs are the largest catalogs of groups currently published. They are largely superior to those analyzed by P92, in both the number of groups (450–500 groups for each of the three catalogs) and the encompassed volumes ($\sim\frac{2}{3}$ of sky, $cz \leq 5500$ km s^{-1}). Moreover, these group catalogs were selected from the same parent galaxy sample, thus allowing us to better investigate the effects due to differences in the selection algorithm. Furthermore, the improved statistics in the high-mass range (less than 10 groups analyzed by P92 have masses larger than 10^{14} h^{-1} $M_{\odot}$) permits an interesting comparison with cluster mass function and a determination of the virial mass function over an unprecedentedly large range of masses.

In § 2 we briefly describe the data. In § 3 we calculate group masses. In §§ 4 and 5 we compute the group mass function and verify its stability, respectively. In § 6 we compare the results for groups and clusters, recovering the mass function of galaxy systems for a mass range that extends over 2 orders of magnitude. In § 7 we give our discussions. In § 8 we summarize our results and draw our conclusions.

Throughout the paper, errors are given at the 68% confidence level, and the Hubble constant is $H_0 = 100\,h$ Mpc^{-1} km s^{-1}.

2. DATA SAMPLE

We analyze the loose group catalogs constructed by G93. These groups were identified using galaxies (within $cz = 5500$ km s^{-1}) belonging to the subsample of the Lyon-Meudon Extragalactic Database, which is nearly complete down to the limiting apparent magnitude $B_0 = 14$, the total blue magnitude corrected for Galactic absorption, internal absorption, and K dimming. G93 used two methods in group construction: a percolation method (hereafter P, derived from the friends-of-friends method presented by Huchra & Geller 1982) and a hierarchical method (hereafter H, derived from that of Tully 1980, 1987). Each method gives one catalog. The P and H catalogs contain 453 and 498 groups of at least three members, respectively. In particular, G93 tuned the free parameters of the methods so as to obtain the best compromise between the stability of group membership and the similarity of the two group catalogs (Garcia, Morenas, & Paturel 1992).

Then G93 combined the two catalogs in order to obtain the final catalog (hereafter the G catalog, 485 groups), defined as the catalog containing only the groups found in part in both catalogs. For these final groups, only the galaxies in common were kept as group members. If some groups of a catalog (in most cases the P catalog) turned out to be divided into two or more groups in the other catalog (in most cases the H catalog), the smallest systems were kept for the final catalog.

In our work, as already suggested by the author, we do not consider galaxies added afterward (flagged by " + ") that have no known magnitude or that do not fully satisfy the selection criteria. We refer to the original paper for more details on group catalogs.

We exclude from our analysis groups with $cz \leq 500$ km s^{-1}, because when the velocity becomes low, its random component dominates and the velocity is no longer a reliable indication of the distance.

The samples we analyze consist of 446, 490, and 476 groups (P, H, and G groups, respectively).

3. COMPUTING GROUP MASSES

The virial mass of a relaxed galaxy system is computed as $M_{\mathrm{vir}} = \sigma^2 R_V/G$, where R_V is the virial radius of the system and σ is the velocity dispersion of member galaxies (Limber & Mathews 1960). Other usual mass estimators, e.g., the projected and the median mass estimators (Bahcall & Tremaine 1981; Heisler, Tremaine, & Bahcall 1985) give similar results, as shown by P92 (cf. also Perea, del Olmo, & Moles 1990). A more serious problem arises from the fact that one must assume that, within each group, mass distribution follows galaxy distribution (e.g., Merritt 1987). This assumption is shown to be reliable enough for galaxy clusters from optical, X-ray, and gravitational lensing analyses (see Girardi et al. 1998b; Lewis et al. 1999 and references therein) and, for likeness, the same assumption can be made for galaxy groups.

We compute the above virial parameters from the observed projected positions in the sky and the line-of-sight velocities of the member galaxies. In fact, for a spherical system, the parameters R_V and σ are linked to their observational counterparts as $\sigma = \sqrt{3}\sigma_v$ and $R_V = (\pi/2)R_{PV} = (\pi/2)N_m(N_m - 1)/\Sigma_{i>j} R_{ij}^{-1}$, where σ_v is the line-of-sight velocity dispersion, R_{PV} is the projected virial radius, N_m is the number of group members, and R_{ij} are the galaxy projected distances. In particular, we estimate the "robust" velocity dispersion by using the biweight estimator for rich groups (member number $N_m \geq 15$) and the gapper estimator for poorer groups (ROSTAT routines by Beers, Flynn, & Gebhardt 1990). Beers et al. (1990) have shown the superiority of their techniques in terms of efficiency and stability when treating systems with a small number of members (cf. also Girardi et al. 1993). In our case (see also Mahdavi et al. 1999), we verify that the distributions of robust and traditional estimates of velocity dispersion are not different according to the Kolmogorov-Smirnov (KS) test (e.g., Ledermann 1982). We apply the relativistic correction and the usual correction for velocity errors (Danese, De Zotti, & di Tullio 1980). In particular, for each galaxy we assume a typical velocity error of 30 km s^{-1}, based on the average of errors estimated in the RC3 catalog from optical and radio spectroscopy (de Vaucouleurs et al. 1991).

Note that our estimates of the virial parameters do not require any luminosity-weighting procedure. Indeed, it was shown that the values of the virial masses are largely insensitive to different weighting procedures (e.g., Giuricin, Mardirossian, & Mezzetti 1982; P92), in agreement with evidence of velocity equipartition (e.g., Giuricin et al. 1982).

In order 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 the spherical collapse, in which the initial density fluctuation grows, lagging behind the cosmic expansion when it breaks away from the Hubble flow, and begins to collapse; then a relaxation process sets in (e.g., Gott & Rees 1975). The time evolution curves $A(t)$, which is the ratio between the absolute values of the kinetic and potential energies, given by the dynamical model, are the starting point for the determination of the evolutionary stage. The evolution curve used by Giuricin et al. (1988) has been derived from numerical simulations of systems composed of 15 point masses with a Schechter-type mass function (Giuricin et al. 1984; the limits of this model are discussed in § 7.1)

According to the above method, the value of A, which is needed to recover corrected masses as $M = (1/2A)(\sigma^2 R_V/G)$, can be inferred from the estimate of the present observed virial crossing time, $t_{cr} = (3/5)^{3/2} R_V/\sigma$. One can also derive the value of τ, which is the elapsed time since fluctuations started growing (here in units of the crossing time at the virialization, t_{cr}^v). In particular, the precise values of A and τ depend on the background cosmology. Here, we estimate corrected group masses for two reference cosmological models, a flat one with $\Omega_0 = 1$ for the matter density parameter, and an open one with $\Omega_0 = 0.2$ (cf. also P92).

For each catalog, in Table 1 we give the number of groups (col. [2]) and median group properties: the mean redshift (col. [3]); the line-of-sight velocity dispersion, σ_v (col. [4]); the projected virial radius, R_{PV} (col. [5]); the crossing time, t_{cr} (col. [6]); the virial mass, M_{vir} (col. [7]); and the value of τ and the corrected virial mass, M, for the $\Omega_0 = 0.2$ model (cols. [8] and [9], respectively) and for the $\Omega_0 = 1$ model (cols. [10] and [11], respectively).

From the values of τ ($<2\pi$), we infer that most groups are in the phase of collapse and not yet virialized, in agreement with previous analyses of earlier catalogs (e.g., Giuricin et al. 1988; P92). Moreover, P groups turn out to be more evolved than H groups. The resulting estimate of the corrected mass is larger than the virial mass by a factor of 20%–60%, depending on the group catalog and the assumed background cosmology. Since for each of the three catalogs t_{cr} does not correlate with M_{vir}, one could apply the same percent correction to M_{vir} of all groups to obtain corrected masses (as inferred from Table 1, e.g., multiplying by $12.7/8.4 = 1.41$ in the case of G groups and $\Omega_0 = 1$). The mass distribution resulting from the application of an average correction is indistinguishable (according to the KS test) from the application of individual corrections for each group.

The distribution of corrected group masses is only slightly dependent on the cosmological environment; in fact, the two mass distributions computed for $\Omega_0 = 0.2$ and $\Omega_0 = 1$ do not differ significantly (according to the KS test). Therefore, hereafter, if not explicitly said, we consider the $\Omega_0 = 1$ case only.

4. GROUP MASS FUNCTION

In order to compute a reliable group mass function, MF, we avoid strongly obscured regions by considering only groups with Galactic latitude $|b| \geq 20°$ (i.e., within a solid angle of $\omega = 8.27$ sr). We consider 409, 381, and 344 G, H, and P groups, respectively.

To obtain the true spatial number density, the selection effects of the galaxy catalog, which is magnitude-limited, must be taken into account. Following Moore et al. (1993), we weight each group by using the magnitude of its third-brightest galaxy, which allows the inclusion of the group itself in the catalog. We weight each group by $w = 1/\Gamma_{max}$, where Γ_{max} is the maximum volume, within the catalog velocity cutoff, out to which the group can be seen:

$$\Gamma_{max} = \left(\frac{\omega}{3}\right)\left\{(v_{lim} H_0^{-1})^3\left[1 - \frac{3}{2}\left(1 + q_0\right)\frac{v_{lim}}{c}\right] - (500 H_0^{-1})^3\left[1 - \frac{3}{2}\left(1 + q_0\right)\frac{500}{c}\right]\right\}, \quad (1)$$

where v_{lim} is the smaller of 5500 km s^{-1} and the maximum recession velocity at which the third-brightest galaxy in the

TABLE 1

GROUP PROPERTIES

Catalog (1)	N (2)	z (3)	σ_v (km s^{-1}) (4)	R_{PV} (h^{-1} Mpc) (5)	$H_0 t_{cr}$ (6)	M_{vir} (h^{-1} $M_\odot$) (7)	$\tau_{0.2}$ (t_{cr}^v) (8)	$M_{0.2}$ (h^{-1} $M_\odot$) (9)	τ_1 (t_{cr}^v) (10)	M_1 (h^{-1} $M_\odot$) (11)
G	476	0.0097	118	0.59	0.23	8.4E12	5.43	10.7E12	5.22	12.7E12
H	490	0.0096	108	0.62	0.26	6.6E12	5.32	9.8E12	5.11	11.8E12
P	446	0.0095	151	0.62	0.20	14.8E12	5.51	18.1E12	5.31	20.3E12

group would be brighter than the magnitude limit; c is the speed of light, and q_0 is the deceleration parameter.

By plotting the weights versus group masses (Fig. 1, *left*), we note that groups generally lie in a well–defined region of the w-M plane, with the exception of a few groups that fall very far away from the other points. Therefore, in order to avoid problems of instability in the resulting MF, for a few groups we recompute the weights according to the following procedure. In each mass range (of a unity in logarithmic scale), we compute the mean and s.d. of log w and substitute the values that are three s.d. away from the mean with the corresponding mean values. We change the value of weights for three, four, and three groups in the G, H, and P catalogs, respectively (Fig. 1, *right*).

Then, since the parent galaxy sample was found to have a redshift incompleteness of $\sim 10\%$ (Marinoni et al. 1999), the resulting group densities are enhanced by the same factor. This is a rough correction. As discussed in § 5, a more refined correction that takes into account the number of group members would give similar results.

The comparison between different catalogs is shown in Figure 2. In the low–mass range, the three MFs show large fluctuations (well over the estimated Poissonian errors) and a tendency toward flattening, which suggests problems of incompleteness. Our results for $M \gtrsim 9 \times 10^{12}\ h^{-1}\ M_\odot$, which we assume as our completeness limit, come from 230, 207, and 214 groups for the G, H, and P catalogs, respectively. The determination of global group number density is quite stable, since the density of groups with $M > 9 \times 10^{12}\ h^{-1}\ M_\odot$ is 1.4, 1.3, and $1.9 \times 10^{-3}\ (h^{-1}\ \mathrm{Mpc})^{-3}$ for the G, H, and P catalogs, respectively.

However, Figure 2 shows that the P catalog gives a flatter MF than the G and H catalogs. In fact, according to the KS test, the MF of P groups strongly differs from that of G and H groups (at a confidence level greater than 98%), while there is no difference between the G and H groups. However, the difference becomes smaller if we exclude large masses and, for instance, we do not find any significant difference if we exclude $M > 4 \times 10^{14}\ h^{-1}\ M_\odot$, a range in which reliable results come from cluster analysis.

In the case of the $\Omega_0 = 0.2$ model we find similar results, except for the fact that, since estimated masses are smaller, the density of groups with $M > 9 \times 10^{12}\ h^{-1}\ M_\odot$ is somewhat lower than in the $\Omega_0 = 1$ case, i.e., 1.2, 1.0, and

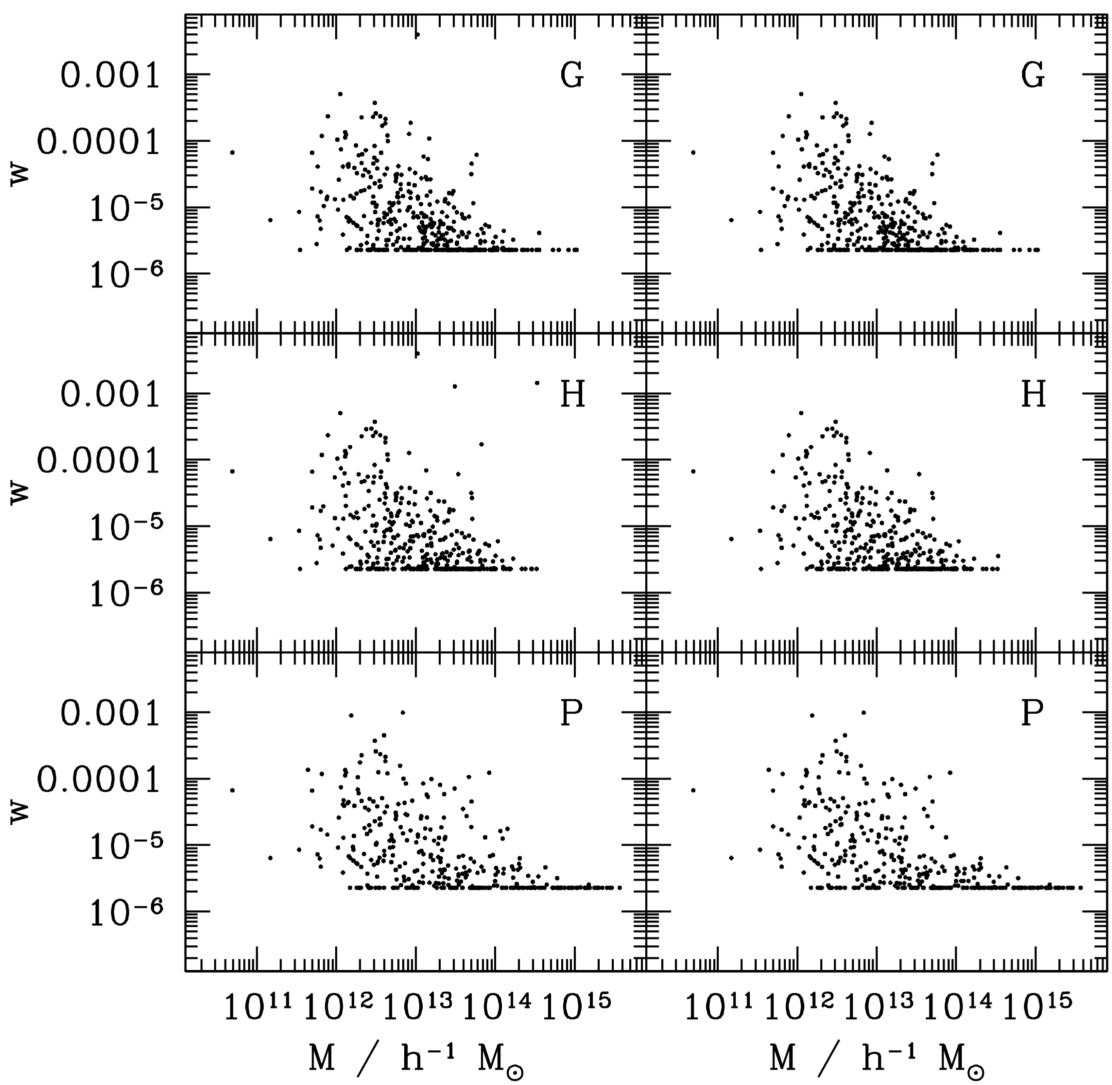

FIG. 1.—For the three catalogs, left panels show that groups generally lie in a well-defined region of the weight-mass plane. Right panels show the same, after recomputing the value of weights for a few groups that lie far from this region (see text).

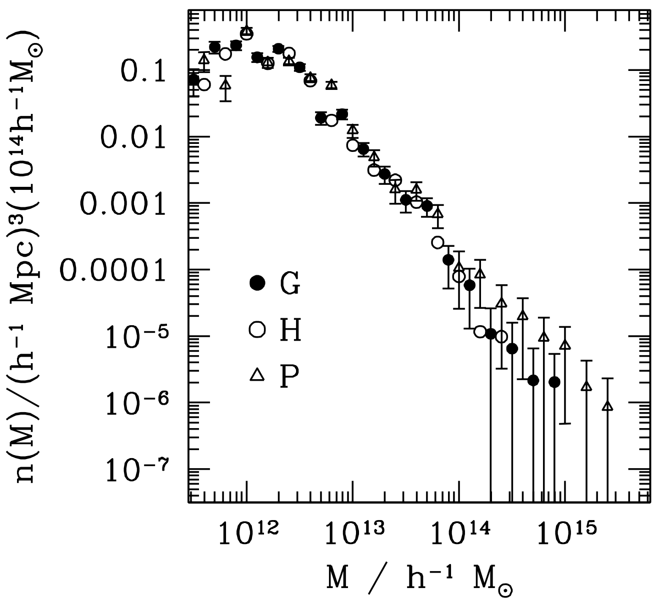

FIG. 2.—Comparison of mass functions as computed from the three catalogs. G, H, and P groups are denoted by filled circles, open circles, and open triangles, respectively. To avoid confusion, we give error bars (1 σ Poissonian uncertainties) only for G and P groups.

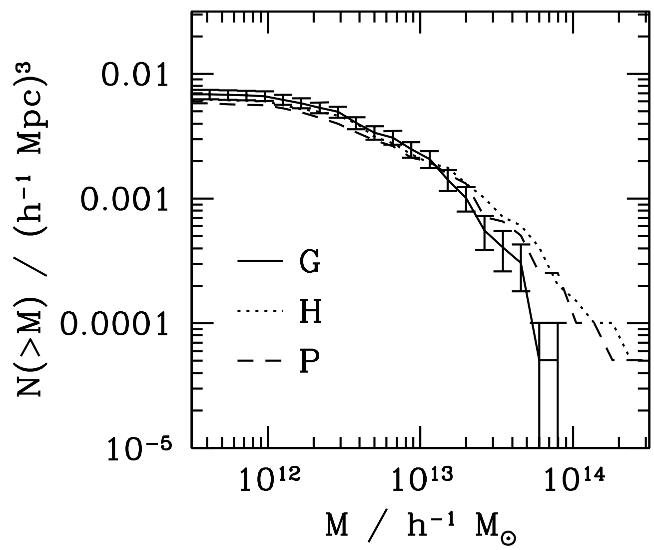

FIG. 3.—Cumulative mass function for the nearby groups of G, H, and P catalogs (with $cz \leq 2000$ km s^{-1}). Error bars represent 1 σ Poissonian uncertainties.

1.7×10^{-3} $(h^{-1}$ Mpc$)^{-3}$ for the G, H, and P catalogs, respectively.

5. ON THE STABILITY OF THE GROUP MASS FUNCTION

First we consider groups with $cz \leq 2000$ km s^{-1}. In particular, we have 136, 124, and 117 G, H, and P nearby groups, respectively, with Galactic latitude $|b| \geq 20°$. For each catalog, the observed group population in the nearby subsamples can be considered a good representation of the total population, because we do not see any significant trend between mass and distance. Therefore, the nearby groups can be considered a complete sample, except for the less massive ones, which could not be identified out to the distance limit of 20 h^{-1} Mpc, since their third-brightest galaxy is not bright enough. If we assume that the nearby groups form a complete sample, we can directly compute the MF for each of the three catalogs. There is no significant difference among the three mass distributions (according to the Kruskas-Wallis test; e.g., Ledermann 1982; cf. Fig. 3). Moreover, apart from the density of low-mass groups, $M \sim 10^{12}$ h^{-1} $M_{\odot}$, where the completeness of the nearby groups is questionable, there is a good agreement between the number densities estimated from the whole catalogs and those from the nearby ones (cf. Fig. 4). This result reassures us of the reliability of our weighting procedure (cf. § 4).

The physical reality of the detected groups is often discussed in the literature. In particular, the efficiency of the percolation algorithm has been repeatedly checked through cosmological N-body simulations (e.g., Nolthenius & White 1987; Moore et al. 1993; Nolthenius, Klypin, & Primack 1994, 1997; Frederic 1995a, 1995b; Diaferio et al. 1999) and geometrical Monte Carlo simulations (Ramella et al. 1997). These computations show 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 et al. 1995; Mahdavi et al. 1997). By following the results of Ramella et al. (1997; cf. also Diaferio et al. 1999), we reduce the weights of groups with $N_m = 3$ and $4 \leq N_m \leq 5$ members by 70% and 20%, respectively. Figure 5 shows the effect on the cumulative MF of P groups. The MF at large masses is quite stable; however, the number density at the completeness limit of 9×10^{12} h^{-1} $M_{\odot}$ could be overestimated only by a factor of $\lesssim 50\%$.

Galaxy density is known to show significant fluctuations around the mean density. Redshift surveys reveal voids of sizes up to 50 h^{-1} Mpc and large bidimensional sheets (e.g., de Lapparent, Geller, & Huchra 1986; Geller & Huchra et al. 1989; Vettolani et al. 1997). Indeed, there is also an indication of a local underdensity of the above size (e.g., Zucca et al. 1997; Marinoni et al. 1999). Since group catalogs are obtained from galaxy catalogs, one could suspect that the amplitude of the group MF we estimate in the local universe is far from being a fair value. In order to shed light on this point, we use the groups identified in the northern Center for Astrophysics redshift survey (CfA2N) by Ramella et al. (1997). The CfA2N covers a smaller solid angle (1.2 sr) than the survey analyzed by G93, but it is deeper ($cz \leq$ 12,000 km s^{-1}) and contains the Great Wall, a very overdense structure. From Ramella et al. (1997), we take group dynamical quantities, $M_{\rm vir}$ and $t_{\rm cr}$, and apply the same procedure outlined in §§ 3 and 4 for the evolutionary correction and for the computation of weights (we take the luminosity of the third-brightest galaxies from M. Ramella et al. 2000, in preparation). The resulting MF is shown in Figure 6. The number density of the CfA2N groups with $M > 9 \times 10^{12}$ h^{-1} $M_{\odot}$ lies within the range of values we found for the G93 catalogs. In conclusion, although the CfA2N groups come from a quite different volume, their MF is similar to the MF of the G93 groups. This result agrees with that of Ramella et al. (1999), who found that different group catalogs, which sample different volumes, give similar velocity-dispersion distributions.

In § 4, in order to take into account the 10% redshift incompleteness of the parent galaxy sample (Marinoni et al. 1999), we have applied a rough, very small upward correction by 10% to the group densities. A more refined correc-

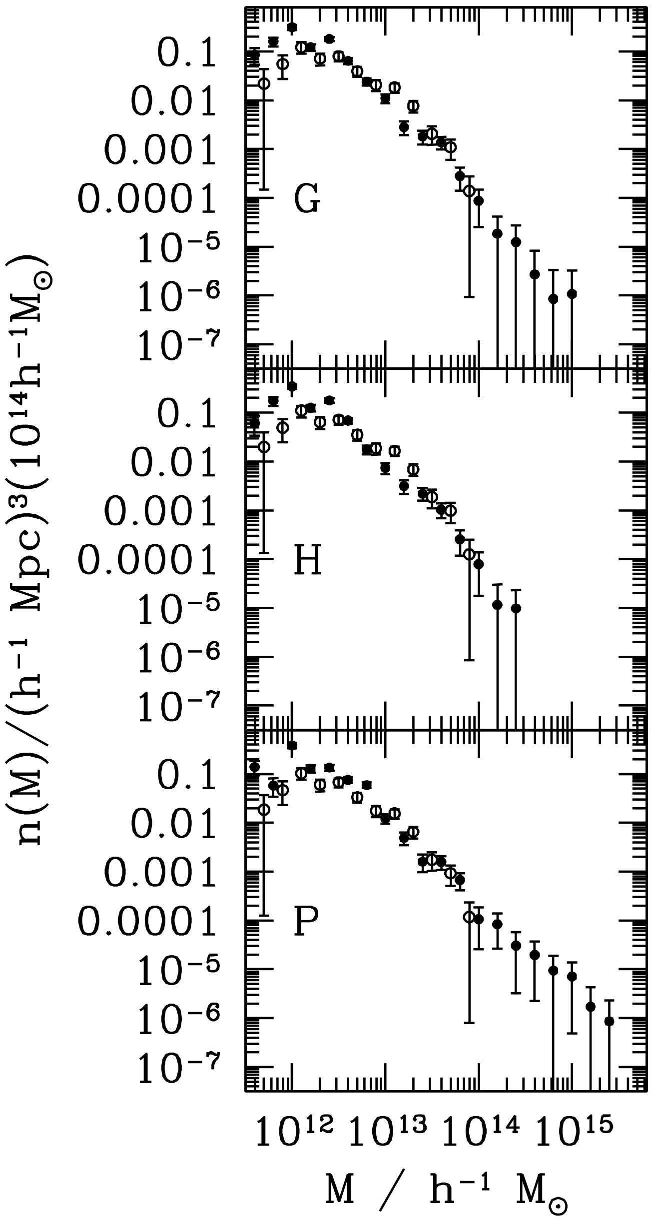

FIG. 4.—For the three catalogs, we compare mass functions as computed from all the groups (*filled circles*) and the nearby groups (*open circles*). Error bars represent 1 σ Poissonian uncertainties.

tion should take into account the number of members in each group. For instance, let us adopt the extreme view that the incompleteness of the parent galaxy sample does not affect the density of groups with more than three members, but affects only groups with three members. In the worst case, out of 100 groups (i.e., 300 galaxies, of which 30 are missed) one misses 30 groups. We recompute the MFs for the three catalogs allowing for this kind of incompleteness. The differences in densities for groups with $M > 9 \times 10^{12}$ are very negligible for G groups and at most amount to $\lesssim 10\%$, which is within the errors, for H and P groups.

6. GROUP VERSUS CLUSTER MASS FUNCTION

Contrary to the case of groups, recent determinations of the distribution of internal velocity dispersions for nearby rich clusters agree well within the errors (cf. Figs. 6 and 9 of Fadda et al. 1996). The cluster MF based on optical virial

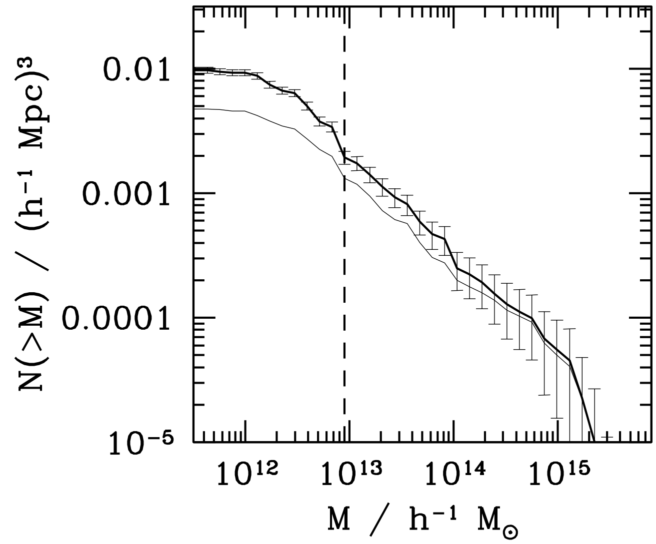

FIG. 5.—We show the effect of the presence of poor groups on the cumulative mass function of P groups. The thin line indicates the mass function obtained when the weight of poor groups is suitably reduced (see text). Error bars represent 1 σ Poissonian uncertainties. The mass completeness limit is indicated by the vertical dashed line ($M > 9 \times 10^{12}\ h^{-1}\ M_\odot$).

masses has recently been presented by G98. In particular, masses were computed within a radius enclosing the region in which clusters are virialized. The resulting MF is reliably estimated for masses larger than $4 \times 10^{14}\ h^{-1}\ M_\odot$ with ~ 50 nearby clusters available for this mass range.

We must take into account that the groups examined here extend outside their virialized regions for a meaningful comparison of group masses with cluster masses as well as with Press & Schechter (1974, hereafter PS) predictions, which hold for virialized objects (e.g., Eke, Cole, & Frenk 1996; Lacey & Cole 1996; Borgani et al. 1999).

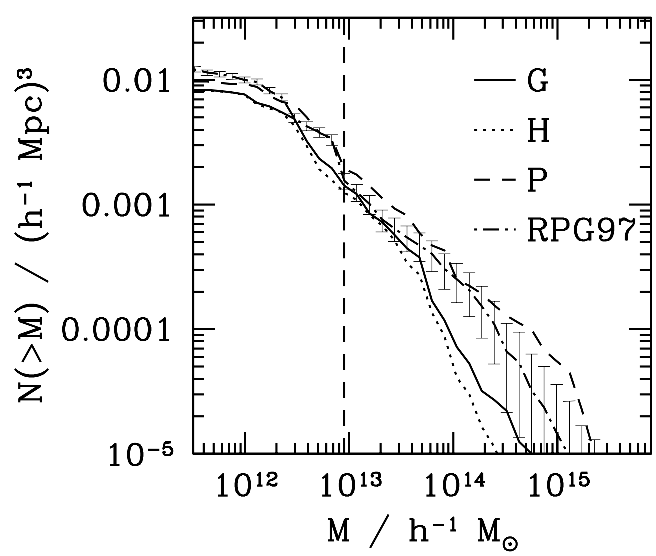

FIG. 6.—We compare the cumulative mass function of the CfA2N groups by Ramella et al. (1997; RPG97) with that of the G, H, and P groups. Error bars represent 1 σ Poissonian uncertainties. The mass completeness limit is indicated by the vertical dashed line ($M > 9 \times 10^{12}\ h^{-1}\ M_\odot$).

By using equation (3) of Ramella et al. (1997), we estimate that P groups have a limiting number density contrast of ~ 70, while for H groups, detected by imposing a luminosity density threshold (Gourgoulhon, Chamaraux, & Fouquè 1992; G93), we compute a luminosity density contrast of ~ 40. These calculations use the Schechter (1976) luminosity function with a slope of -1.1, a normalization factor of 0.014 h^3 Mpc^{-3}, and a characteristic magnitude of $M_{*B} = -20.0 - 5 \log h$, as well as the galaxy blue luminosity density, $\sim 4.5 \times 10^8$ $L_\odot$ h^3 Mpc^{-3}, as obtained by Marinoni et al. (1999) for the same parent galaxy sample. The estimated values of the density contrast should be considered as rough estimates, in view of the difficulties in obtaining group catalogs with a constant density contrast (e.g., Nolthenius & White 1987).

In order to compute the matter density contrast, $\delta\rho/\rho$, from the above galaxy density contrast, $(\delta\rho/\rho)_g$, one should know the biasing factor, $b = (\delta\rho/\rho)_g/(\delta\rho/\rho)$. Here we compute the value of bias as $b = 1/\sigma_8$, where σ_8, the rms mass density fluctuation in spheres of 8 h^{-1} Mpc radius, is estimated for different values of Ω_0 according to the G98 relation found by comparing PS predictions to the cluster MF (cf. their eq. [4]). Accordingly, we adopt $b = 1/0.60 \sim 1.7$ and $b = 1/1.23 \sim 0.8$ in the case of the $\Omega_0 = 1$ and $\Omega_0 = 0.2$ models, respectively.

The resulting $\delta\rho/\rho$ for P and H groups (41 and 24, respectively, for $\Omega_0 = 1$; 88 and 50 for $\Omega_0 = 0.2$) are much smaller than the values of ~ 180 and ~ 550 expected within the virialized region for $\Omega_0 = 1$ and 0.2, respectively (e.g., Eke et al. 1996).

After assuming that groups have a common radial profile (Fasano et al. 1993), we can roughly estimate the fraction of the mass contained in the virialized region. For each of the three catalogs, Figure 7 plots the cumulative distributions of the galaxy distances from the group (biweight) center, combining data of all the groups. To combine the galaxies of all groups, we divide each galaxy distance to the projected virial radius, R_{PV}, of its group. Moreover, in order to better show the behavior of galaxy density, we also normalize the distances to the value of $\langle R_{\max}/R_{\mathrm{PV}} \rangle$ for the catalog, where the maximum radius, $R_{\max}$, is the projected distance from the group center of the most distant galaxy, and we normalize the numbers of objects, N, to that contained within $\langle R_{\max}/R_{\mathrm{PV}} \rangle$.

From Figure 7, one can infer the fraction of the number of galaxies (i.e., the fraction of group mass if galaxies trace mass) contained within each radius (i.e., how density changes with radius). We are interested in determining the radius (and the corresponding galaxy number/group mass) for which one obtains a density enhancement that is large enough to reach the density contrast expected at virialization. In particular, in the case of $\Omega_0 = 1$, a reduction in radius of $\sim 50\%$ (i.e., in number/mass of $\sim 30\%$) is enough to reach the virialization density. In fact, from Figure 7 one infers that 70% of galaxies are contained within about half of the radius (0.545 for P groups; 0.49 for H groups). Therefore, considering only these central group regions, the density increase is $0.7/(0.545^3) \sim 4.3$ for P groups and $0.7/(0.49^3) \sim 5.9$ for H groups; in other words, the resulting density contrast in a $\Omega_0 = 1$ universe is $\sim 41 \times 4.3 \sim 180$ for P groups and $\sim 24 \times 5.9 \sim 140$ for G groups (these values are comparable to the virialization density contrast). In view of the inherent approximations, we simply adopt a reduction of group masses by 30% for all groups in each of the three catalogs. In the case of $\Omega_0 = 0.2$, similar arguments lead us to adopt a reduction in radius of $\sim 60\%$ (i.e., in number of $\sim 40\%$) to reach the virialization density.

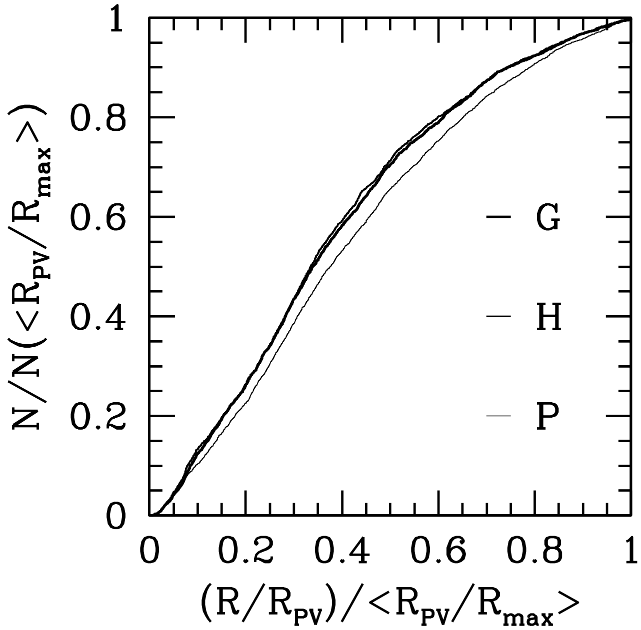

FIG. 7.—For each of the three catalogs, we give the cumulative distribution of the galaxy distances from group center. To combine the galaxies of all groups, we divide each galaxy distance to the projected virial radius, R_{PV}, of its group. We also normalize the distances to the value of $\langle R_{\max}/R_{\mathrm{PV}} \rangle$ for the catalog, and normalize the numbers of objects, N, to that contained within $\langle R_{\max}/R_{\mathrm{PV}} \rangle$. The distributions of G and H are nearly overlapping.

In the following comparison with clusters, we reduce group masses by 30% and 40% for the $\Omega_0 = 1$ and $\Omega_0 = 0.2$ cases, respectively. We remark that this kind of correction is taken to be equal for all groups, since we assume a common typical spatial distribution of member galaxies (Fasano et al. 1993) and do not consider each individual evolutionary state (note that the crossing time does not show any correlation with group mass; see the end of § 3).

Figure 8 shows the group and cluster MFs. The P group MF gives too high values at high masses compared to cluster results, while the G and H catalogs do not contain very massive groups. Therefore, the differences among group catalogs in describing the MF at high masses (see § 4) lead to strong uncertainties just where cluster data are available. However, for $M < 4 \times 10^{14}$ h^{-1} $M_\odot$, all three group MFs can be regarded as a smooth extrapolation of the cluster MF.

To provide a phenomenological fit to the data that takes into account the effect of mass uncertainties, we use the Schechter (1976) expression. A theoretical, PS approach is instead discussed at the end of this section.

Following a maximum-likelihood approach, we fit the Schechter expression for our MF on the whole mass range (groups with $9 \times 10^{12} < M < 4 \times 10^{14}$ h^{-1} $M_\odot$ and clusters with $M > 4 \times 10^{14}$ h^{-1} $M_\odot$):

$$n(M) = n_* \left(\frac{M}{M_*}\right)^{-\alpha} e^{-M/M_*} \,, \qquad (2)$$

where $n(M)$ is suitably convolved with the mass errors, ΔM. We compute uncertainties on group masses in the same way as in Girardi et al. (1998b): we propagate statistical errors in

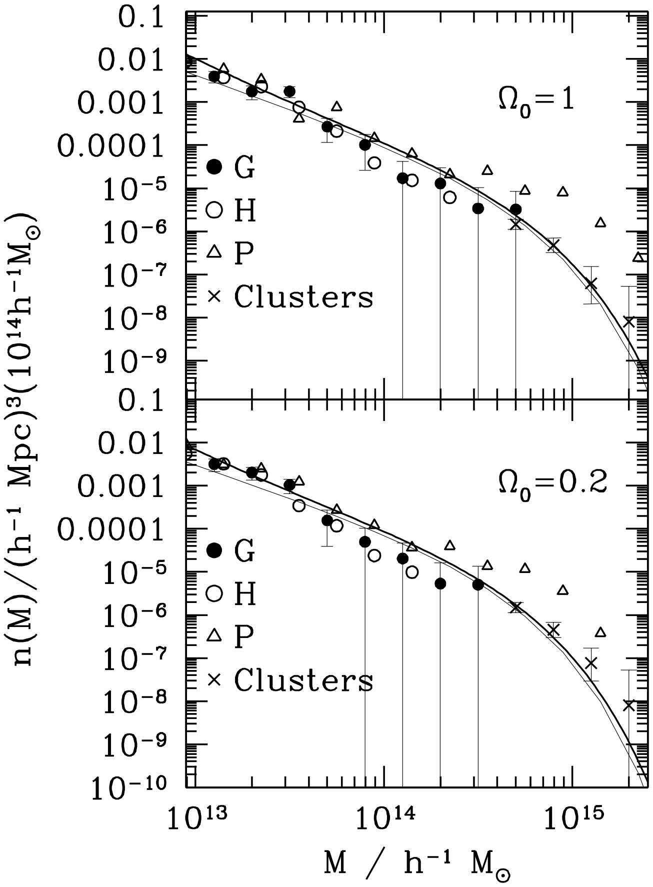

FIG. 8.—For the two reference cosmological models and for each of the three catalogs, we show group and mass functions, where masses are computed within the virialized region. Cluster data come from Girardi et al. (1998a). We show the fitted Schechter function and its convolution with errors (*thin and thick lines, respectively*) by combining data of G groups and clusters.

the estimate of the velocity dispersion, σ_v, and of the virial radius, $R_{\rm PV}$, for which errors are estimated via bootstrap and jackknife techniques, respectively. The resulting mass uncertainties range from $\sim$15% for clusters at $M \sim 2 \times 10^{15}\ h^{-1}\ M_\odot$ to $\sim$90% for groups at $M \sim 9 \times 10^{12}\ h^{-1}\ M_\odot$ [we fit $\log(\Delta M/M) = 4.548 - 0.355 \log M$], and we assume a lognormal error distribution. The effect of these uncertainties is negligible in the cluster mass range, but it becomes significant in the range of low-mass groups.

For instance, in the case of G groups ($\Omega_0 = 1$ model), the resulting fitted parameters are $n_* = (2.2 \pm 0.3) \times 10^{-5}\ (h^{-1}\ \mathrm{Mpc})^{-3}\ (10^{14}\ h^{-1}\ M_\odot)^{-1}$, $M_* = 3.1^{+1.8}_{-1.3} \times 10^{14}\ h^{-1}\ M_\odot$, and $\alpha = 1.55^{+0.14}_{-0.16}$. Table 2 gives the fit results for the three catalogs and for both cosmological models; column (3) gives the number of groups used in this analysis, and columns (4), (5), and (6) give the fitted n_*, M_*, and α parameters, respectively. The values of α vary in the range of 1.3–1.6, and the values of M_* vary in the range of 2.7–$3.9 \times 10^{14}\ h^{-1}\ M_\odot$.

The errors on the "shape" parameters α and M_* are directly given by the maximum-likelihood method (Avni 1976). We recover the error on the normalization n_* by considering the Poissonian error bars associated with the global number of objects considered (and assuming the best-fit parameters for the shape). These errors are the

TABLE 2

PARAMETERS OF THE MASS FUNCTION FIT

Catalog (1)	Model (2)	N (3)	n_* $[(h^{-1}\ \mathrm{Mpc})^{-3}$ $(10^{14}\ h^{-1}\ M_\odot)^{-1}]$ (4)	M_* $(10^{14}\ h^{-1}\ M_\odot)$ (5)	α (6)
G	$\Omega_0 = 1$	193	2.2×10^{-5}	3.1	1.55
H	$\Omega_0 = 1$	177	1.0×10^{-5}	3.9	1.64
P	$\Omega_0 = 1$	153	4.6×10^{-5}	3.1	1.42
G	$\Omega_0 = 0.2$	159	2.4×10^{-5}	2.7	1.49
H	$\Omega_0 = 0.2$	147	1.5×10^{-5}	3.1	1.55
G	$\Omega_0 = 0.2$	153	5.5×10^{-5}	3.0	1.31

formal ones and do not consider other additional effects. The effect of incompleteness (see the end of § 5) is very small, being smaller than Poissonian errors. The effect due to the presence of interlopers is evidenced by differences in results relative to different group-selection algorithms. In particular, for P groups, for which the presence of spurious groups is well studied in the literature, adopting the correction analyzed in § 5, we find values for the slope and characteristic mass ($\alpha = 1.5$ and $M_* = 3.3 \times 10^{14}\ h^{-1}\ M_\odot$ for the case $\Omega_0 = 1$, respectively) that are within the errors, but a n_* smaller by a factor of 50%, e.g., $n_* = 2.4 \times 10^{-5}\ (h^{-1}\ \mathrm{Mpc})^{-3}\ (10^{14}\ h^{-1}\ M_\odot)^{-1}$, as pointed out in § 5. However, this normalization is similar to that from the G catalog.

G98 applied the PS approach to constrain the cosmological parameters from the observational cluster mass function. The PS approach provides a fairly accurate analytical approximation to the number density of dark matter halos of a given mass. The halo mass that appears in the PS formula refers to the mass contained within the virialized region, i.e., the region with a present density contrast of $18\pi^2 = 178$ (for $\Omega_0 = 1$; see Eke et al. 1996 for values in different cosmologies). Moreover, the PS mass function has been compared with N-body simulations by several authors (e.g., Eke et al. 1996; Lacey & Cole 1993; Gross et al. 1998; Borgani et al. 1999; Governato et al. 1999) and has generally been shown to provide a rather accurate description of the abundance of virialized halos of cluster size.

It is worth verifying that the present group MF, in spite of all difficulties inherent in the analysis of groups (cf. § 7.1), is a good extension of the PS form fitted on clusters. We use the same PS approach used by G98 for describing the MF of galaxy clusters (cf. their eqs. [2] and [3] and details in § 3). In particular, G98 recovered the relation between σ_8 and Ω_0 (cf. their eq. 4 for $\Omega_\Lambda = 0$). Accordingly, we assume $\sigma_8 = 0.60$ and 1.23 for the $\Omega_0 = 1$ and $\Omega_0 = 0.2$ cosmological models, respectively, and we fix the shape parameter of the cold dark matter (CDM)–like power spectrum (e.g., Bardeen et al. 1986) to $\Gamma = 0.2$. Figure 9 shows a comparison between the predictions of PS and the observational mass functions. Observational data can be described by the PS models, except for the range of low-mass groups in the case of $\Omega_0 = 1$. Although it is well documented that the PS model that fits rich cluster data overpredicts the number density of low-mass halos compared to the simulations (e.g., Gross et al. 1998; Governato et al. 1999), the predicted difference is much smaller than the difference between our observational MF and the (convolved) PS. Unless the observed difference is due to some problems of data incompleteness in the low-mass range, the case for the open model seems to be preferable. We emphasize that the comparison

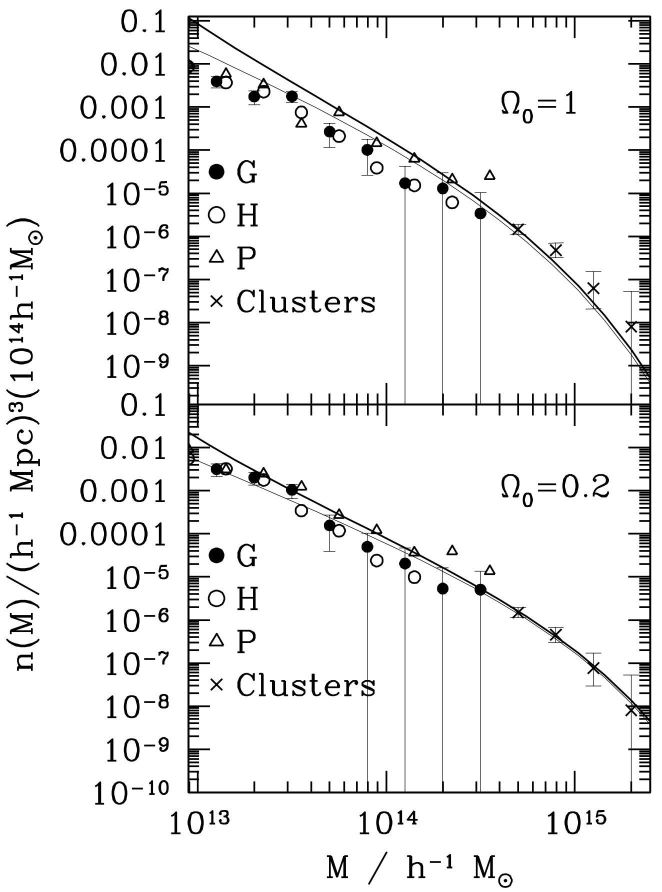

FIG. 9.—For the two reference cosmological models and for each of the three catalogs, we compare observational mass functions with Press-Schechter mass functions, with and without convolving with the uncertainties in the mass estimates (*thick and thin lines*, *respectively*). The plotted Press-Schechter mass functions are those found to well describe cluster data (Girardi et al. 1998a).

with PS predictions is not done here in order to determine the best-fitting cosmological model. Instead, it is aimed at verifying that our extension of the MF to group scales is reasonable.

7. DISCUSSION

7.1. *Group Mass Determination*

We find that G93 groups can be described as systems in a phase of collapse, in agreement with previous results from earlier group samples identified in redshift galaxy catalogs (e.g., Giuricin et al. 1988; P92; Mamon 1994; Diaferio et al. 1993). We find that the presumably virialized region in groups is only $\lesssim$ half the radius sampled by galaxy data.

In order to determine the dynamical status of groups and the corresponding mass correction, we use the method of Giuricin et al. (1988), which has been also applied by P92. This method is based on simple numerical simulations, in which groups are not framed within a cosmological environment and the galaxies are represented by mass points starting from a spherical distribution with zero velocity (Giuricin et al. 1984). The comparison with observations could be not straightforward, since the observed galaxies may be affected by several environmental effects, e.g., tidal stripping, dynamical friction, and merging events, which are not taken into account by these simple simulations. This is connected to the validity of the crucial hypothesis "mass distribution follows galaxy distribution," which is also needed for the standard virial mass estimate (see, e.g., Merritt 1987, 1988 for clusters) and is used by us in considering group masses contained within virialized regions (thus, our method of determining the dynamical status is fully consistent with the mass estimate itself).

Several *N*-body simulations of hierarchical clustering have been performed in order to study galaxy systems in realistic situations. However, until recently, the poor resolution of halos within dense environments has led to soft, diffuse halos that are rapidly dissolved by tidal forces (the so-called overmerging problem; White et al. 1987). This makes it difficult to compare simulations with observed group galaxies that are identified with halos. Recent simulations show that environmental effects can be important and affect the structure of individual galaxies (e.g., Moore et al. 1996; Tormen, Diaferio, & Syer 1998; Colpi, Mayer, & Governato 1999). As for the global distribution of galaxies within clusters, Ghigna et al. (1998, 2000) performed very high resolution simulations of clusters in which the overmerging seems to be globally unimportant (the same seems to hold for small systems; see Moore et al. 1999). Ghigna et al. found that the velocity dispersions of the halos agree with that of the dark matter particles. As for spatial biasing, they found that at an early epoch of cluster formation, halos and dark matter have number density profiles of similar shape, while at the final time halos are antibiased. In any case, since up to now these results concern virialized systems, studies of larger, unvirialized regions should be awaited before reaching definitive conclusions for just-forming groups.

From the observational point of view, the luminosity segregation of galaxies in clusters, attributed to dynamical friction and merging, was found to concern only the brightest or very bright galaxies (Biviano et al. 1992; Stein et al. 1997). The overall global properties of clusters do not appear to depend on galaxy luminosities; in addition, for groups, virial masses are largely insensitive to luminosity-weighting procedures (Giuricin et al. 1982; P92).

On the other hand, there is evidence that different galaxy populations (e.g., early- and late-type galaxies, blue and red galaxies, emission-line or non–emission-line galaxies, hereafter ELGs and NELGs) show different spatial and velocity distributions (Biviano et al. 1997; Carlberg et al. 1996, 1997b; den Hartog & Katgert 1996; Adami, Biviano, & Mazure 1998; Dressler et al. 1999; Girardi et al. 1996, 1998b; Mohr et al. 1996; Stein 1997; Koranyi & Geller 2000). As shown by the analyses of velocity-dispersion profiles and spatial distributions, the galaxy component whose behavior most differs from the norm is very late-type galaxies or, alternatively, ELGs, ELGs often being very late types and vice-versa (Biviano et al. 1997; Adami et al. 1998). Biviano et al. (1997) suggested that the dynamical state of the ELGs reflects the phase of galaxy infall rather than the virialized condition in the relaxed cluster core (see also Mahdavi et al. 1999). On the other hand, Carlberg et al. (1997a) suggested that, although differing in their distributions, both blue and red galaxies are in dynamical equilibrium with clusters; see also Mazure et al. (2000), who explain ELG dynamics by resorting to more radial orbits with respect to NELGs.

As for global properties, as estimated within large samples using ENACS (ESO Nearby Abell Clusters Survey) data, Biviano et al. (1997) found that the velocity dispersion and virial masses based on ELGs are, on average, 20% and 50%, respectively, larger than those based on NELGs. However, due to the small fraction of ELGs ($\sim$10% of cluster members), the presence of ELGs does not strongly affect the estimate of velocity dispersion and mass of clusters. As for groups, we consider the 20 well-sampled groups analyzed by Mahdavi et al. (1999). They detected no velocity dispersion segregation between ELGs and NELGs, together with a (not significant) decrease of masses by 20%, if ELGs are excluded from the sample. Therefore, even if global dynamical properties based on ELGs and NELGs can be significantly different, we expect that the possible presence of ELGs in the groups we analyze hardly affects our mass estimates significantly, on average.

Finally, we note that the dynamical status of the groups analyzed, as well as the small number of galaxy members, prevents us from applying refined analyses (used for clusters and well-sampled groups), e.g., the determination of velocity anisotropies from velocity dispersion profiles and the Jeans equation. In fact, since the Jeans equation rigorously holds only in regions in dynamical equilibrium, this analysis was generally applied to galaxy clusters (e.g., Carlberg et al. 1996, 1997b; Girardi et al. 1998b). This kind of analysis was also applied out to external regions of galaxy groups as a successful approximation (Mahdavi et al. 1999), but in any case it requires a large number of data. In this case, Mahdavi et al. combined data of a well-behaved subset of groups as selected by an analysis of the velocity-dispersion profiles of individual groups. In this sense, the approach we use should be viewed as an alternative method for deriving masses in the case in which available data do not allow sophisticated analyses.

7.2. *Comparison with Previous MF*

At present, P92 is the only study of the mass distribution function of loose groups. P92 determined the group mass function by analyzing nearby groups ($cz \leq 2000$ km s^{-1}) of two catalogs based on the percolation method (38 groups by Geller & Huchra 1983 and 21 by Maia, da Costa, & Latham 1989) and one catalog based on the hierarchical method (107 groups by Tully 1987). The three catalogs have parent galaxy samples that differ considerably in both selection criteria and the sky region covered.

P92 noted significant differences between the group MFs resulting from the three catalogs of groups and claimed that these differences were not due to the inhomogeneity of the catalogs, but rather to the choice of the group-selection algorithm, the percolation methods giving larger masses than the hierarchical one.

Here we consider the three group catalogs of G93, each having about 450–500 groups with $cz \leq 5500$ km s^{-1}. For the determination of the MF, we retain only groups having $|b| \geq 20°$, in order to avoid regions of high Galactic extinction. The homogeneity of the three catalogs, which come from the same parent galaxy sample, allows us to cast light on the compatibility of different selection algorithms. If we take only the nearby groups ($cz \leq 2000$ km s^{-1}, i.e., 117, 124, and 136 groups) for a better comparison with P92, we find no difference in MF among the three catalogs. This probably occurs because G93 chose the free parameters of the selection algorithms so as to obtain similar catalogs of groups.

However, if we consider the whole catalogs (for which statistics are better, particularly at high masses) we find that percolation and hierarchical algorithms give very different MFs, the former providing larger masses. A similar difference is also reported by P92, and it is proved here to be clearly due to differences in the algorithms. Indeed, it has been suggested that the drawback of percolation methods is the inclusion in the catalogs of possible nonphysical systems, such as a long galaxy filament aligned close to the line of sight, which 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., Gourgoulhon et al. 1992).

The difference among the three MFs is particularly relevant in the high-mass range and leads to a flatter MF in the case of P groups. This effect is not seen in the analysis of P92, since they have no groups with $M > 4 \times 10^{14}\, h^{-1}\, M_\odot$ and less than 10 groups for $M > 10^{14}\, h^{-1}\, M_\odot$.

As for the completeness, an inspection of the three differential MFs indicates that our samples are complete for $M > 9 \times 10^{12}\, h^{-1}\, M_\odot$. Similarly, P92 assumed that the selection functions of both algorithms are efficient for $M \gtrsim 1.1 \times 10^{13}\, h^{-1}\, M_\odot$.

As for the theoretical comparisons, P92 fitted their data to Press-Schechter predictions by assuming a unique power law for the fluctuation power spectrum. However, since P92 did not give the amplitude of the fitted MF, a quantitative comparison with our results is not straightforward. We only note here that their MF power-law slope lies in the range $1.5 \lesssim \alpha \lesssim 1.7$, thus being consistent with our result from the Schechter-like fit, $1.3 \lesssim \alpha \lesssim 1.6$. As for the value of M_*, P92 determined it with quite large uncertainties, due to the small number of high-mass systems in their sample.

8. SUMMARY AND CONCLUSIONS

We analyze the three catalogs of nearby loose groups by Garcia (1993). This author identified groups in a magnitude-limited redshift galaxy catalog, which covers about $\sim\frac{2}{3}$ of the sky within $cz = 5500$ km s^{-1}, by using two methods, a percolation method and a hierarchical method. She tuned the free parameters of the group-selection algorithms in order to obtain two similar catalogs of groups and proposed a third catalog of groups defined as a combination of the two. Each catalog contains $\sim$450–500 groups.

In agreement with previous works on earlier catalogs, we find that these groups can be described as collapsing systems. Their typical sampled size is considerably larger than their expected virialized region. For all groups, we compute the virial mass and correct this mass by taking into account the young dynamical status of these groups. We estimate corrected group masses, M, for two reference cosmological models, a flat one with $\Omega_0 = 1$ for the matter density parameter and an open one with $\Omega_0 = 0.2$. For each of the three catalogs we calculate the group mass function, MF.

Our main results are the following:

1. The number density of groups is not very sensitive to the choice of the group-identification algorithm. In fact, we find that the density of groups with $M > 9 \times 10^{12}\, h^{-1}\, M_\odot$, which is the adopted limit of sample completeness, ranges in the interval 1.3–1.9 $\times\, 10^{-3} (h^{-1}$ Mpc$)^{-3}$ for $\Omega_0 = 1$ and it is about a factor of 15% lower for $\Omega_0 = 0.2$.

2. As for the MF shape, the percolation catalog gives a flatter MF than other catalogs. The difference decreases if

we do not consider the most massive groups, for which reliable results come from galaxy cluster analysis.

3. After obtaining the masses contained within the central, presumably virialized, group region by adopting a reduction in mass of $\sim 30\%$–40%, we do a comparison with results from the virial analysis of nearby rich galaxy clusters (Girardi et al. 1998a). All three group MFs can be regarded as a smooth extrapolation of the cluster MF at $M < 4 \times 10^{14}\ h^{-1}\ M_{\odot}$, which is the completeness limit of the cluster sample. Following a maximum-likelihood approach and taking into account mass uncertainties, we fit the Schechter expression for our MF on the whole mass range (groups with $9 \times 10^{12} < M < 4 \times 10^{14}\ h^{-1}\ M_{\odot}$ and clusters with $M > 4 \times 10^{14}\ h^{-1}\ M_{\odot}$), and we obtain a slope of ~ -1.5 and a characteristic mass of $\sim 3 \times 10^{14}\ h^{-1}\ M_{\odot}$.

Our result strengthens the growing evidence in favor of the continuity of clustering properties from poor groups to very rich clusters (e.g., Ramella et al. 1989; Burns et al. 1996; Mulchaey & Zabludoff 1998; Ramella et al. 1999; Girardi et al. 2000).

Our resulting mass function of galaxy systems, which extends over 2 orders of magnitude, seems to be reasonably described by Press-Schechter predictions of models that at larger masses describe the rich cluster mass function (in particular in the case of the open model).

The analysis of wide forthcoming group catalogs, e.g., the Updated Zwicky Catalog (UZC) groups by A. Pisani et al. (in preparation) and the Nearby Optical Galaxies (NOG) groups by Giuricin et al. (2000), as well as extensive spectroscopy observations of individual groups (e.g., Zabludoff & Mulchaey 1998; Mahdavi et al. 1999), will be of great aid in improving the determination of the group MF, in particular at the low-mass range, which is affected by larger uncertainties.

Furthermore, future studies of N-body cosmological simulations for different cosmological scenarios will improve our understanding of nonvirialization effects on the estimate of group masses (e.g., Diaferio et al. 1999).

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