DISCOVERY OF EXTREME EXAMPLES OF SUPERCLUSTERING IN AQUARIUS

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ABSTRACT

The results of spectroscopic observations of 46 $R \geq 1$ clusters of galaxies from the Abell and Abell, Corwin, & Olowin (hereafter ACO) catalogs are presented. The observations were conducted at the ESO 3.6 m telescope with the Meudon-ESO Fibre Optics Spectrograph (MEFOS) multiple-fiber spectrograph. Thirty-nine of the clusters lie in a $10^\circ \times 45^\circ$ strip of sky that contains two supercluster candidates (in Aquarius and Eridanus). These candidates were identified by a percolation analysis of the Abell and ACO catalogs, using estimated redshifts for clusters that had not yet been measured. With our measurements and redshifts from the literature, the target strip is now 85% complete in redshift measurements for $R \geq 1$ ACO clusters with $m_{10} \leq 18.3$. Seven other clusters were observed in a supercluster candidate in the Grus-Indus region. Seven hundred thirty-seven galaxy redshifts were obtained in these 46 cluster fields. We find that one of the supercluster candidates is a collection of 14 $R \geq 1$ ACO/Abell clusters with a spatial number density that is 20 times the average spatial density for rich ACO clusters. This overdensity has a maximum extent of $\sim 110 h^{-1}$ Mpc, making it the longest supercluster composed only of $R \geq 1$ clusters to be identified to date. This filament of clusters runs within $6^\circ$ of the line of sight in the Aquarius region, and, on its high-$z$ end, four $R = 0$ ACO clusters (three of which are $R = 1$ in the Abell catalog) appear to bridge gaps to other clusters, extending the structure to $\sim 150 h^{-1}$ Mpc. Our analysis also reveals that another supercluster, consisting of eight rich clusters with an extent of $\sim 75 h^{-1}$ Mpc, runs roughly perpendicular to Aquarius near its low-redshift end. Both of these superclusters are remarkably filamentary. Fitting ellipsoids to all $N \geq 5$ clumps of clusters (at $b = 25 h^{-1}$ Mpc) in the measured-$z$ Abell/ACO $R \geq 1$ clusters sample, we found two other superclusters with axis ratios $\geq 3$ (long-to-midlength axis). The frequency of such filaments ($\sim 20\%$) was nearly identical with that found among “superclusters” in Monte Carlo simulations of random and random-clumped cluster samples, however, so the Abell/ACO clusters have no particular tendency toward filamentation. The Aquarius and Aquarius-Cetus superclusters, in this one region of the sky, have axis ratios of 4.3 and 3.0, respectively. The Aquarius filament also contains a “Knot” of six $R \geq 1$ clusters at $z \sim 0.11$, with five of the clusters close enough together to represent an apparent overdensity of 150 $h$.$\bar{\Omega}$. Three of these clusters have a spatial number density at $z \sim 0.11$ and another of these clusters at $z \sim 0.01$, with five of the clusters close enough together to represent an apparent overdensity of 150 $h$.$\bar{\Omega}$. There are three other $R \geq 1$ cluster density enhancements similar to this knot at lower redshifts: Corona Borealis, the Shapley concentration, and another grouping of seven clusters in Microscopium. All four of these dense superclusters appear near the point of breaking away from the Hubble flow, and some may now be in collapse, but there is little indication of any being virialized. With four such objects, studies of them as a class may now lead to much greater insight into large-scale processes.

Subject headings: galaxies: clusters: general — galaxies: distances and redshifts

1. INTRODUCTION

In the last two decades, several important discoveries of large-scale structure have been made through magnitude-limited redshift surveys of individual galaxies. The first was the Coma/A1367 supercluster and void combination (Gregory & Thompson 1978; Tifft & Gregory 1988), which turned out to be part of the Great Wall and “bubble” structures of the de Lapparent, Geller, & Huchra (1988, 1991) CfA redshift survey “slices.” Later came Perseus-Pisces (Gregory, Thompson, & Tifft 1981), the Hercules supercluster (Tarenghi et al. 1979; Chincarini, Rood, Thompson 1981; Gregory & Thompson 1984), the Local Supercluster (Yahil, Sandage, & Tammann 1980; Tully 1982; and the early CfA survey work of Huchra et al. 1983), and the Hydra-Centaurus supercluster (Chincarini & Rood 1979), most recently thoroughly mapped along with the slightly more distant region of the Great Attractor by Dressler (1988, 1991). All of these efforts to map using magnitude-limited surveys of individual galaxies (and a few other, not-complete samplings of some apparent supercluster regions) have identified structures of order 30–100 $h^{-1}$ Mpc or more, but they are limited to volumes only about 100 $h^{-1}$ Mpc deep. The Sloan Digital Sky Survey and the Two-Degree Field Survey (2dF) being undertaken in Australia will, with a few years work, provide redshifts for the $\sim 10^7$ galaxies needed to map scales of a few hundred megaparsecs with such tracers. To study such scales now, one needs to sample more sparsely, perhaps by using pencil-

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beam surveys to probe deeply with individual galaxies (see, e.g., Postman, Huchra, Geller 1986b; Kirshner et al. 1987; Broadhurst et al. 1990; Small et al. 1998) or by randomly sampling galaxies in strips across larger areas of the sky as in the Las Campanas survey (Shectman et al. 1996).

Rich galaxy clusters are potentially excellent tracers of mass on the larger scales. With average spatial separations of $\sim 50 \ h^{-1} \ Mpc$, they are efficient for mapping scales approaching those measured by the COBE satellite. Recent analyses of clusters from the Abell (1958) and Abell, Corwin, & Olows (1989, hereafter ACO) catalogs reveal evidence of three-dimensional superclustering on scales of $50-100 \ h^{-1} \ Mpc$ (see, e.g., Miller et al. 1999b; Batuski & Burns 1985b; Batuski et al. 1991; Postman, Geller & Huchra 1986a; Postman, Huchra, & Geller 1992; Bahcall & Soniera 1983; Tully 1987; Tully et al. 1992). We also note that rich (Abell/ACO) clusters are primary constituents of all the superclusters mentioned in the preceding paragraph.

However, less than one-third of the Abell/ACO clusters have measured redshifts (and most of these have only one or two galaxies measured [Struble & Rood 1991b; Postman et al. 1992]), although recent multifiber spectrographic cluster surveys such as Katgert et al. 1996 and Slinglend et al. 1998 have started to improve this situation. This leads to large uncertainties in the cluster redshift because of the possibility of measuring a foreground or background galaxy not associated with the given cluster (such projection effects being important in about 14% of Abell cluster fields with only a single previously published redshift measurement, according to Miller et al. 1999b), or the possibility of measuring an "outlier" in a cluster's velocity distribution, which can introduce an error of 500 km s$^{-1}$ or more about 36% of the time (Miller et al. 1999b). The projection problem is especially dangerous for part of the region targeted for this redshift survey, because of the very high surface number density of rich clusters. Our effort here has been an attempt to minimize these projection effects by collecting 20 or more redshifts per cluster field and then to use the resulting high-confidence redshift data to investigate superclusters of Abell/ACO clusters.

We have used the Meudon-ESO Fibre Optic Spectrograph (MEFOS; see Felenbok et al. 1997 for a description) on the 3.6 m telescope at ESO to observe clusters in a strip of sky that includes two particularly interesting supercluster candidates (SCCs), one in Aquarius and one in Eridanus, to determine the significance of the apparent superclustering. Another nearby (Grus-Indus) supercluster candidate was also observed. Our sample was limited to ACO richness class $\geq 1$ clusters, with one or zero measured redshifts in the literature, at high Galactic latitude (|$b| > 30^\circ$).

Our first run of this program took place in 1994 August, and the second was in 1995 September. Two clusters were also observed in 1995 May. We observed 39 clusters in the Aquarius-Eridanus strip (targeting to get 20 or more redshifts per cluster field) and seven clusters in the Grus-Indus SCC. We have, to this point, completed 85% of the redshift survey of the strip to $m_{10} \leq 18.3$ (estimated $z < 0.16$). We had 47 target clusters in the strip to this magnitude limit, seven of which had redshifts in the literature, and we obtained redshifts of 33 more. Seven remain with unmeasured redshifts, including three that we observed but for which we got insufficient data for a cluster velocity determination. A preliminary report on this survey was given in Slinglend et al. (1995), and the final results are presented here.

Section 2 defines the sample of clusters observed in our primary target strip, and § 3 summarizes the procedures for conducting the observations and reducing the data. The cluster redshift results are presented in § 4 for both the Aquarius-Eridanus strip and Grus-Indus, along with a discussion of our analyses of the Aquarius superclusters. Section 5 contains our conclusions.

### 2. CLUSTER SAMPLE IN THE AQUARIUS-ERIDANUS STRIP

Our entire sample is made up of $R \geq 1$ ACO clusters within a $10^\circ \times 45^\circ$ strip of sky in the southern hemisphere (see Fig. 1). Each point in Figure 1 represents an $R \geq 1$ cluster with $m_{10} \leq 18.3$. We used the ACO richness classification for consistency throughout the strip, and we note that clusters on the northern end of the strip (north of $\delta = -27^\circ$) were also in the original Abell (1958) catalog, classified in richness with a variable background subtraction in the member galaxy count, rather than the global background subtraction of ACO. The ACO $m_{10}$ magnitude estimations were also used throughout our study.

This particular strip was chosen so as to include two apparent overdensities in the spatial distribution of rich clusters. These overdensities (SCCs) were identified using a percolation algorithm based upon the redshifts from the literature or redshifts estimated from the magnitude of the tenth brightest cluster member, using the $m_{10}+2$ relation of ACO. Distances were calculated using (Sandage 1975)

$$D = \frac{cz}{H_0} \left(1 + z/2\right)$$

for a Friedmann universe with $q_0 = 0$. The percolation parameter used to identify these apparent superclusters was $30 \ h^{-1} \ Mpc$, which corresponds to a spatial cluster density of about 5 times the average ACO cluster spatial number density of $8 \times 10^{-6} \ h^3 \ Mpc^{-3}$ (Miller et al. 1999b). Since most of the clusters had only estimated redshifts, these two

![Fig. 1.—Gnomonic projection plot of the $R \geq 1$ ACO clusters with $m_{10} \leq 18.3$ in the general region of the sky of the strip (box) containing the two supercluster candidates targeted for the observations. North of $\delta = -17^\circ$ in this plot, the clusters are $R \geq 1$ Abell (1958) clusters and are limited to $z \leq 0.15$ (measured or estimated), approximately the estimated redshift of an $m_{10} \leq 18.3$ ACO cluster.](image)
tentative supercluster identifications were considered simply as promising targets in the selection of the strip for observing. The clusters in this strip are at high Galactic latitude ($b \sim -50^\circ$ to $-70^\circ$), so that obscuration is not a concern.

There has been some discussion in the literature concerning the adequacy of the Abell and ACO catalogs of clusters for tracing large-scale structure. Sutherland (1988), Olivier et al. (1990), and Sutherland & Efstathiou (1991) suggest the impact of redshift-angular separation anisotropies due to projection effects in the visually selected Abell catalog is severe. Struble & Rood (1991a) show that such effects are small ($\sim 3\%$) among the 1682 clusters in the “statistical sample” subset of Abell's catalog. Also, Postman et al. (1992) give a strong argument that the spurious structure due to projection effects is insignificant in the sample of 351 Abell clusters with measured redshift that they present. On the other hand, Efstathiou et al. (1992) find significant indications of artificial anisotropies in the Postman et al. sample and show that the clusters selected from the APM automatic plate measurement (APM) system at Cambridge University galaxy catalog have no such anisotropies. Bahcall & West (1992) counter with another analysis, comparing Abell cluster results directly to the APM work, which indicated little effect from projection for the Abell clusters. Recently, Miller et al. (1999b) also use newly expanded samples of Abell and ACO $R \geq 1$ clusters with measured redshifts to show that anisotropies in the catalogs are on the same order as in the APM catalogs and not significant for purposes of large-scale studies. The new sample of Miller et al. consists of a large number (289) of $R \geq 1$ Abell/ACO clusters, 96% complete to $m_B = 16.8$. This sample is comprised of 198 northern Abell clusters (188 of which have more than one measured redshift, with most of these redshifts from the MX Northern Abell Cluster Survey of Slinglend et al. 1998) and 105 southern ACO clusters (most of the redshifts from the ESO Nearby Abell Cluster Survey of Katgert et al. 1996).

During our first observing run (1994 August at ESO), we concentrated on the more dense of the two supercluster candidates. The Aquarius candidate is well outlined by a $10^\circ$ box on the sky centered on $\alpha = 23h3, \delta = -22^\circ$ (upper left of the $10^\circ \times 45^\circ$ strip shown in Fig. 1). We first worked to complete observations of the previously unmeasured clusters in this smaller region, and during the second run (1995 September), we covered the larger strip down to our magnitude limit of $m_{10} \leq 18.3$.

3. Observations and Data Reduction

The observations took place over nine nights in 1994 August, 1995 May, and 1995 September. The observations were under conditions of good to adequate seeing ($0.5'-2.0'$) and transparency. The instrument used was the Meudon-ESO Fibre Optic Spectrograph (MEFOS) mounted on the ESO 3.6 m telescope. The grating-CCD combination used resulted in a dispersion of 170 $\AA$ mm$^{-1}$ and a resolution of about 11 $\AA$. The wavelength range was chosen to be 3800–6150 $\AA$.

We collected approximately 15–20 redshift-quality spectra within a given cluster field per hour. Comparison frames of helium and neon were taken before each exposure for wavelength calibration. “Fiber flats” (continuum spectra) were also taken for use in determining the location of the spectra on the CCD images.

3.1. Data Reduction

The data was reduced in the IRAF$^2$ environment, utilizing standard IRAF routines as well as modified routines designed for Steward Observatory’s MX Spectrometer. The MX-specific routines were written by J. Hill, B. Oegerle, D. Batuski, and K. Slinglend. The two-dimensional CCD images were bias subtracted, and the individual spectra were extracted after being located on corresponding fiber flat (quartz lamp) exposures. A dispersion solution from each object’s comparison (helium-neon) frame provided the spectra wavelength calibrations. A sky subtraction was performed after averaging all the sky spectra from a given exposure and normalizing by the strength of the [O I] 5577 $\AA$ night-sky line.

A problem has been reported (Felenbok et al. 1997) with some of the MEFOS fibers having persistent offsets after wavelength calibration, resulting in shifts of $\sim 0.5$ $\AA$ in the measured wavelength of the 5577 $\AA$ night-sky line. We examined our data for this problem and found that seven of our object fibers did indeed have such large offsets. Therefore, the wavelength solutions for galaxies observed with those fibers were each shifted by the negative of the average offset that we measured for the fiber in question.

3.2. Cross-Correlation

We used the IRAF task FXCOR to perform our cross-correlations. Each spectrum was first cross-correlated against template spectra of eight stars with high-precision published velocities (Maurice et al. 1984). Each of these template stars was observed with MEFOS, in single-fiber mode. The star spectra were cross-correlated against each other, and the resultant velocities were compared with published values. Adjustments to our calculated velocities were then made to better match the published values. These corrections were on the order of 10–15 km s$^{-1}$ and were made to reduce errors in the star template velocities due to night-to-night instrument variations.

For an alternate determination of each galaxy’s velocity, a bootstrap technique was used. That is, the galaxy spectra were also cross-correlated against 20 low-redshift galaxy templates also observed on MEFOS (chosen for their high signal-to-noise ratio). The velocities of these galaxy templates had been previously determined through cross-correlation with the eight star templates mentioned above. In cases of high-redshift object spectra ($z > 0.1$), the galaxy templates often provided a much more reliable velocity determination because of the greater number of comparable lines between the spectrum of the object and that of the template.

Each cross-correlation returned a heliocentric velocity and a cross-correlation strength (the Tonry & Davis 1979 $R$ value). For a particular target object, the set of calculated velocities (20 when the galaxy templates were used, or eight when the star templates were used) was then weighted by $(R + 1)^2$ and averaged. Velocity errors were estimated using the $\sigma_v = Q/(R + 1)$ method of Hill & Oegerle (1993) and Pinkney et al. (1993). $Q_{\text{MEFOS}}$ was determined from a selection of 22 galaxies that were each observed with MEFOS on two different occasions. The variations in these velocities

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$^2$ IRAF is distributed by the National Optical Astronomy Observatories, which is operated by the Association of Universities for Research in Astronomy, Inc. (AURA), under cooperative agreement with the National Science Foundation.
were directly calculated, resulting in an average value of $Q_{\text{MEFOS}} = 260 \text{ km s}^{-1}$. Each of the measured velocities was then assigned an error of $\sigma_v = 260/(R + 1)$, where $R$ is now an average value (over the successful cross-correlations with the eight star templates or the 20 galaxy templates). To avoid unreasonably small errors for galaxies with $R$-values greater than 13, we established a minimum error of 20 km s$^{-1}$. This lower limit allows for wavelength calibration and other errors in our system, and the magnitude of the minimum error was estimated from the scatter in measurements of the 5577 Å night-sky line, mentioned in § 3.1 above.

The results from the star template and galaxy template cross-correlations for each object were then compared. Cases that did not meet our minimum requirements ($R > 2.5$, median absolute deviation [MAD] of the velocities found for a galaxy less than 250 km s$^{-1}$, and a minimum of more than one-half of the templates cross-correlating successfully with the spectrum of the target) were discarded. For cases in which a reliable redshift was determined from both the star template and the galaxy template cross-correlations, a comparison was made between the two sets of correlations, considering $R$, MAD, and the number of matched templates to determine which ($R + 1$)-weighted velocity was more reliable. In most cases the velocity from the star template cross-correlation matched the velocity of the galaxy template’s cross-correlation to within $1 \sigma_v$. In the rare instances in which these two determinations did not agree, a visual inspection of the galaxy spectrum was used to determine which, if either, of the ($R + 1$)-weighted velocities was correct. All of the spectra for the galaxies listed were examined visually to ensure that the velocities obtained were not occasionally the results of fluke occurrences in the data.

3.3. Emission-Line Redshifts

All of our sky-subtracted galaxy spectra were examined for emission lines. If any reasonably likely candidate lines were found in a spectrum, the redshift of the galaxy was calculated using the RVSAO.EMSAO package provided by the Smithsonian Astrophysical Observatory Telescope Data Center as an add-on to IRAF. If a galaxy had two or more apparent emission lines, all the good (not distorted by cosmic-ray strikes, too-low signal-to-noise ratio, etc.) lines were used in EMSAO for the calculation. If only one emission line was found, and an absorption-line velocity had been obtained that was in rough agreement with the emission-line velocity, the single line velocity was accepted. A single emission-line velocity was also considered acceptable even when the absorption-line velocity for a galaxy was not deemed good enough for publication, if there were absorption features in good agreement with the location of the emission line.

The EMSAO task calculates a mean velocity by weighting the velocities returned by each emission-line fit where

$$W_i = \frac{1}{dvel_i^2} \sum_{j} \frac{1}{dvel_j^2},$$

where $dvel_i$ is the error in the fit of the emission line with an RMS dispersion of 0.05 Å. EMSAO returns similarly weighted errors. In addition to the line-fit errors, we have found a 16 km s$^{-1}$ root mean square variation when comparing the 5577 Å lines locations (see § 3.1). Total errors in the emission-line velocities were calculated by the root sum square of the error in the line fit and this inherent scatter (in the night-sky line wavelengths) due to the instrument. For the few galaxies where only $\mathrm{O\ II}$ $\lambda$3727 was detected, a third systematic error was added because of the lower accuracy of the wavelength calibration toward the blue end of the spectra. This additional error was determined to be 22 km s$^{-1}$ by comparing the velocity determination using only the $\mathrm{O\ II}$ $\lambda$3727 Å line with the velocity using multiple lines. We used 18 galaxies with multiple emission lines that included $\mathrm{O\ II}$ $\lambda$3727 for the calculation of this third error.

4. RESULTS

The recession velocities of all the galaxies observed in this program are presented in Tables 1, 2, and 3. Table 1 lists the results for galaxies in the MEFOS fields of clusters in the 10° square region of sky centered on $\alpha = 23^h 3^m, \delta = -22^\circ$, the heart of the Aquarius supercluster candidate. Table 2 gives the galaxy data for the clusters in the remainder of the target strip shown in Figure 1. Table 3 presents the results for another supercluster candidate (Grus-Indus) that we had the opportunity to observe. Columns (2) and (3) in each of these tables are the right ascension and declination coordinates (J2000) of the galaxies observed. Column (4) contains the ($R + 1$)-weighted heliocentric velocities, and column (5) of each table lists the estimated errors ($\sigma_v$). The last column has an object number entered if

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### TABLE 1

| Cluster (1) | $\alpha$ (J2000) (2) | $\delta$ (J2000) (3) | Velocity (km s$^{-1}$) (4) | Error (km s$^{-1}$) (5) | Emission Reference (6) |
|------------|---------------------|---------------------|--------------------------|----------------------|----------------------|
| 2523........ | 23 03 04.08 ........ | -16 50 06.4 ........ | 9138 ........ | 89 ........ | ........ |
| .............. | 23 03 16.24 ........ | -17 14 36.0 ........ | 37928 ........ | 75 ........ | ........ |
| .............. | 23 03 35.41 ........ | -17 04 20.8 ........ | 37026 ........ | 73 ........ | ........ |
| .............. | 23 03 37.31 ........ | -17 08 49.2 ........ | 38898 ........ | 96 ........ | ........ |
| .............. | 23 04 52.07 ........ | -17 16 25.4 ........ | 22188 ........ | 73 ........ | ........ |
| .............. | 23 04 28.21 ........ | -17 16 14.4 ........ | 38213 ........ | 52 ........ | ........ |

Notes: Table 1 appears in its entirety in the electronic edition of the Astrophysical Journal. Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
the subject galaxy has an emission-line velocity (for cross-reference to Table 4). Velocities and errors given in Tables 1, 2, and 3 were calculated from the absorption lines in the spectra, unless there is an entry in the last column (“Emission Reference”) that ends with the letter “e.” In those cases, the emission-line velocity is listed. Entries that end with the letter “a” in the last column indicate that an emission-line velocity was determined (and is listed in Table 4), but the absorption-line velocity is listed in Tables 1, 2, or 3 and was used in our subsequent study of structure in the region.

Table 4 lists the emission-line velocities for all our target galaxies that had acceptable emission lines. The first column indicates the Abell/ACO cluster, while the second column lists the reference number from column (6) in Tables 5A, 5B, 5C, and 5D. The third and fourth columns list the emission-line velocities and estimated errors. The fifth column indicates which lines were detected in the spectrum. Lines within parentheses were seen but not used in the velocity determination.

We obtained 737 redshifts in 46 cluster fields in our program. Thirty-nine of those cluster fields were in our 10° × 45° strip. Nineteen additional R ≥ 1 clusters in the strip had previously been observed, including three by Batuski et al. (1995) and eight with a single redshift per cluster by Ciardullo, Ford, & Harms (1985). The velocities of these clusters are presented in Tables 5A, 5B, 5C, and 5D. Tables 5A, 5C, and 5D list the Abell/ACO cluster number in column (1). The mean and standard deviation are calculated, any galaxies that do not fall within 3σ of the mean velocity are excluded from cluster membership for the next iteration of the classical statistics calculation. In some cases, there are simply too few galaxy velocities in the cluster to do a statistical analysis. When N = 3 (and in one case, A3205, in which cluster membership appeared very likely, N = 2), estimators were calculated using the ROSTAT statistical analysis package developed by Beers, Flynn, & Gebhardt (1990). All velocities reported have been corrected for heliocentric motion. The final column indicates the number of galaxy redshifts that went into the velocity determinations. Table 5B lists 14 clusters that are in the 10° square containing the Aquarius supercluster but observed by other researchers.

Insufficient data were collected on clusters A2641, A3842, and A3861 to make velocity determinations. Clusters A3725 and A3944 were determined not to be clusters at all, but simply many galaxies strung out along the line of sight. These two clusters have been dropped from our sample, although, since A3725 has m10 = 18.5, it did not affect our level of completion within the strip.

Mean cluster velocities for the observed Abell clusters in this program have been determined with a procedure that has grown from a compilation of ideas of previous investigators (e.g., Batuski & Burns 1985a; Postman et al. 1992; Singlend 1996). The data for each cluster field are examined for a grouping of galaxy velocities with no gaps greater than 900 km s⁻¹. These velocities are then used to calculate the classical mean and standard deviation, as well as a biweight location and scale of the cluster. These locations and scales are determined using the ROSTAT package (Beers et al. 1990). After the mean and standard deviation are calculated, any galaxies that do not fall within 3σ of the mean velocity are excluded from cluster membership for the next iteration of the classical statistics calculation. In some cases, there are simply too few galaxy velocities in the cluster to do a statistical analysis. When N = 3 (and in one case, A3205, in which cluster membership appeared very likely, N = 2),

### Table 2

| Cluster | α (J2000) | δ (J2000) | Velocity (km s⁻¹) | Error (km s⁻¹) | Emission Reference |
|---------|-----------|-----------|------------------|---------------|--------------------|
| 2500     | 22 51 34.26 | −25 38 08.3 | 21425            | 38            |                    |
|         | 22 51 51.02 | −25 33 30.9 | 8476             | 92            |                    |
|         | 22 52 20.87 | −25 15 05.6 | 22603            | 38            |                    |
|         | 22 52 46.54 | −25 41 12.6 | 23074            | 52            |                    |
|         | 22 53 01.68 | −25 32 33.1 | 15373            | 52            |                    |
|         | 22 53 31.30 | −25 33 20.7 | 23320            | 42            |                    |

Notes.—Table 2 appears in its entirety in the electronic edition of the Astrophysical Journal. Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

### Table 3

| Cluster | α (J2000) | δ (J2000) | Velocity (km s⁻¹) | Error (km s⁻¹) | Emission Reference |
|---------|-----------|-----------|------------------|---------------|--------------------|
| 3148    | 3 36 44.20 | −32 53 35.0 | 19811            | 67            |                    |
|         | 3 37 12.80 | −32 28 35.2 | 31423            | 24            |                    |
|         | 3 37 17.17 | −32 51 41.6 | 35416            | 43            |                    |
|         | 3 37 32.06 | −32 26 01.6 | 31753            | 25            |                    |
|         | 3 37 33.33 | −32 21 15.6 | 11799            | 55            |                    |
|         | 3 38 05.93 | −32 25 33.3 | 35503            | 23            |                    |

Notes.—Table 3 appears in its entirety in the electronic edition of the Astrophysical Journal. Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.
| Cluster  | Galaxy Reference | Velocity (km s\(^{-1}\)) | Error (km s\(^{-1}\)) | Lines Found |
|---------|-----------------|---------------------------|------------------------|-------------|
| A2557   | 1a 28074        | 45                        | O II*                  |
| 2a      | 19648           | 30                        | O II, H\(\beta\)      |
| A2585   | 3a 26793        | 20                        | O II, (H\(\beta\), O III) |
| 4a      | 13613           | 30                        | O II                  |
| 5a      | 8386            | 30                        | O II                  |
| 6a      | 21308           | 20                        | O II, (H\(\beta\))    |
| 7e      | 56905           | 20                        | O II, H\(\beta\), O III \(\lambda 5007\), (O III \(\lambda 4958\)) |
| A2599   | 8a 26839        | 44                        | O II                  |
| 9a      | 26651           | 20                        | O II, \(\lambda 4958\), (H\(\beta\)), (O III \(\lambda 5007\)) |
| 10a     | 1709            | 20                        | H\(\beta\), O III, (H\(\gamma\)) |
| 11e     | 33158           | 20                        | O II, H\(\beta\), O III \(\lambda 4958\), (O III \(\lambda 5007\)) |
| 12a     | 25938           | 20                        | O II, (H\(\beta\))    |
| 13a     | 27213           | 41                        | O II*                 |
| 14a     | 34098           | 20                        | O II, H\(\beta\), O III |
| A2600   | 15a 18649       | 33                        | O II*                 |
| 16a     | 26094           | 37                        | O II                  |
| 17a     | 18118           | 20                        | O II, H\(\beta\), O III |
| 18a     | 18127           | 20                        | O II, H\(\beta\)      |
| 19a     | 18075           | 40                        | O II                  |
| 20a     | 18644           | 30                        | O II                  |
| 21a     | 16389           | 26                        | O II, O III           |
| 22a     | 35558           | 30                        | O II                  |
| 23a     | 35575           | 30                        | O II                  |
| 24a     | 34289           | 37                        | O II*                 |
| 25a     | 34522           | 20                        | O II, O III \(\lambda 4958\), (O III \(\lambda 5007\)) |
| 26a     | 36890           | 30                        | O II, (H\(\beta\))    |
| 27a     | 36717           | 31                        | O II                  |
| A2601   | 28e 37842       | 20                        | O II, H\(\beta\), O III |
| 29e     | 2765            | 20                        | H\(\beta\), O III \((\text{Ne III}, \text{He I}, \text{He II}, \text{He I}, \text{He II})\) |
| 30a     | 20201           | 34                        | O II, H\(\beta\)      |
| A2608   | 31a 35472       | 37                        | O II                  |
| 32a     | 19579           | 20                        | O II, H\(\beta\)      |
| 33a     | 14110           | 20                        | O II, H\(\beta\)      |
| A2609   | 34a 16504       | 20                        | O II, O III, (H\(\beta\)) |
| 35a     | 27208           | 52                        | O II                  |
| 36e     | 65277           | 20                        | O II, H\(\beta\), O III \(\lambda 5007\), (O III \(\lambda 4958\)) |
| 37a     | 32976           | 20                        | O II, H\(\beta\)      |
| 38a     | 25548           | 30                        | O II, H\(\beta\), O III |
| A2641   | 39a 9788        | 20                        | O II, H\(\beta\), O III \(\lambda 4958\), (O III \(\lambda 5007\)) |
| 40e     | 22378           | 20                        | O II, O III \(\lambda 5007\), (O III \(\lambda 4958\)) |
| 41e     | 31204           | 20                        | O II, H\(\beta\), O III |
| 42a     | 8414            | 20                        | H\(\beta\), O III \(\lambda 5007\), (O II, O III \(\lambda 4958\)) |
| 43a     | 31675           | 37                        | O II                  |
| 44a     | 9896            | 20                        | O II, O III \(\lambda 5007\), (O III \(\lambda 4959\)) |
| A3148   | 45a 13318       | 23                        | H\(\beta\), O III     |
| 46a     | 13393           | 36                        | H\(\beta\), O III     |
| A3169   | 47a 22438       | 34                        | O II, H\(\beta\)      |
| 48e     | 16624           | 30                        | O II, H\(\beta\), O III |
| A3171   | 49e 7041        | 35                        | H\(\beta\), O III     |
| A3197   | 50a 30391       | 26                        | O II, O III           |
| 51a     | 28106           | 24                        | O II, H\(\beta\), O III |
| A3200   | 52a 21276       | 23                        | O II, H\(\beta\), O III |
| A3725   | 53a 29832       | 30                        | O II, (H\(\beta\))    |
| 54a     | 12960           | 20                        | O II, H\(\beta\), O III |
| 55a     | 12978           | 20                        | O II, H\(\beta\), O III |
| 56a     | 16897           | 37                        | O II                  |
| 57a     | 24764           | 30                        | O II                  |
| 58a     | 24914           | 20                        | O II, H\(\beta\), O III, (H\(\gamma\)) |
| 59a     | 20621           | 31                        | O II                  |
| 60e     | 32270           | 20                        | O II, O III           |
| A3750   | 61e 49131       | 36                        | O II                  |
| 62a     | 18288           | 20                        | O II, H\(\beta\), O III |
| 63a     | 49610           | 37                        | O II                  |
| 64e     | 54349           | 44                        | O II                  |
only a simple mean is calculated from galaxies that fall within a \pm 3000 \text{ km s}^{-1} \text{ grouping. In these cases, the calculated mean should be interpreted with caution.}

In general this program did not observe Abell clusters for which redshifts had been previously measured. However, most of the previously measured clusters within the Aquarius region have only a single measured redshift, and four of these were observed in our program for comparison, as well as confirmation of the redshifts. A2547, A2548, A2555, and A2556 were studied by Ciardullo et al. (1985) at Cerro Tololo Inter-American Observatory and observed again for this paper. These four were chosen because they constitute

\begin{table}[h]
\centering
\begin{tabular}{|c|c|c|c|c|}
\hline
Cluster Reference & Galaxy Reference & Velocity & Error & Lines Found \\
\hline
A3757 & 65a & 2766 & 20 & H\beta, O \text{ iii}, (H\gamma, H\delta) \\
A3757 & 66a & 23532 & 22 & O \text{ ii}, H\beta, O \text{ iii ??} \\
A3775 & 70a & 31429 & 20 & O \text{ ii}, H\beta, O \text{ iii} \\
A3775 & 74a & 31944 & 44 & O \text{ ii} \\
A3834 & 81a & 10281 & 26 & H\beta, O \text{ iii} \\
A3834 & 82a & 8645 & 33 & O \text{ iii} \\
A3839 & 83e & 17105 & 27 & O \text{ ii}, H\beta, O \text{ iii} \\
A3841 & 85e & 17170 & 38 & O \text{ ii}, O \text{ iii} \\
A3844 & 87a & 17530 & 30 & O \text{ iii} \\
A3844 & 88a & 43925 & 34 & O \text{ iii} \\
A3844 & 89a & 21965 & 30 & O \text{ iii} \\
A3844 & 90a & 26690 & 34 & O \text{ iii} \\
A3858 & 91a & 36303 & 50 & O \text{ iii} \\
A3861 & 92e & 49640 & 31 & O \text{ ii}, H\beta, O \text{ iii} \\
A3861 & 93e & 20708 & 32 & O \text{ ii}, H\beta, O \text{ iii} \\
A3892 & 95a & 8437 & 24 & H\beta, O \text{ iii} \\
A3896 & 96e & 16749 & 38 & O \text{ ii}, H\beta, O \text{ iii} \\
A3928 & 98a & 8204 & 23 & H\beta, O \text{ iii} \\
A3944 & 99a & 10169 & 33 & H\beta, O \text{ iii} \\
A3951 & 100a & 9468 & 22 & H\beta, O \text{ iii} \\
A3951 & 101a & 30786 & 23 & O \text{ ii}, O \text{ iii} \\
A3959 & 102a & 25295 & 20 & O \text{ ii}, O \text{ iii} \\
A3959 & 103a & 9233 & 29 & O \text{ ii}, H\beta, O \text{ iii} \\
A3959 & 104a & 21524 & 20 & O \text{ ii}, H\beta, O \text{ iii} \\
A3959 & 105a & 54535 & 20 & O \text{ ii}, H\beta, O \text{ iii} \\
A3959 & 106a & 32990 & 26 & O \text{ ii}, H\beta \\
A3959 & 107e & 16419 & 21 & O \text{ ii}, O \text{ iii} \lambda 5007, (H\beta, O \text{ iii} \lambda 4958) \\
A3959 & 108a & 16480 & 20 & O \text{ ii}, H\beta, O \text{ iii} \lambda 5007, (O \text{ iii} \lambda 4958) \\
A3959 & 109e & 26152 & 26 & O \text{ ii}, H\beta, O \text{ iii} \\
A3959 & 110a & 53016 & 38 & O \text{ ii}, (H\beta) \\
A3959 & 111a & 17735 & 20 & O \text{ ii}, H\beta, O \text{ iii} \\
A3959 & 112e & 25177 & 65 & O \text{ ii} \\
A3978 & 113a & 14864 & 20 & O \text{ ii}, H\beta, O \text{ iii} \\
A3978 & 114a & 9738 & 20 & O \text{ ii}, H\beta, O \text{ iii} \lambda 5007, (O \text{ iii} \lambda 4958) \\
A3996 & 119a & 7127 & 26 & H\beta \\
A3996 & 120e & 32787 & 39 & O \text{ ii}, O \text{ iii} \lambda 4958, (H\beta, O \text{ iii} \lambda 5007) \\
A3996 & 121a & 17632 & 21 & O \text{ iii}, O \text{ iii}*, (H\beta)^a \\
A3996 & 122a & 7743 & 20 & O \text{ iii}, (O \text{ ii}) \\
\hline
\multicolumn{5}{l}{Notes.—Galaxy references with an “a” or an “e” indicate which velocity, absorption or emission, respectively, is published in Table 1. Emission lines within parentheses indicate that the line was detected but not included in the velocity determination.}
\multicolumn{5}{l}{^a Low signal-to-noise ratio.}
\end{tabular}
\end{table}
two pairs with small angular separations and each pair could be observed during a single exposure. Note that different galaxies were measured for this program than the ones measured by Ciardullo et al. The velocities for A2547, A2556 and A2557 were each well within the typical dispersion of Abell A2548, and A2556 that were determined by Ciardullo et al. The velocities for A2547, A2556 and A2557 were each well within the typical dispersion of Abell A2548, and A2556 that were determined by Ciardullo et al. The velocities for A2547, A2556 and A2557 were each well within the typical dispersion of Abell A2548, and A2556 that were determined by Ciardullo et al.

### Table 5A

| Cluster | \(\mu\) (km s\(^{-1}\)) | \(C_{\text{HI}}\) (km s\(^{-1}\)) | \(\sigma\) (km s\(^{-1}\)) | \(S_{\text{HI}}\) (km s\(^{-1}\)) | \(N\) |
|---------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----|
| A2523... | 38016                      | 38037                      | 776                         | 818                         | 4   |
| A2547... | 44672                      | 360                         | 3                           | 3                           |    |
| A2548a... | 32771                      | 33168                      | 799                         | 81                           | 4   |
| A2553... | 34279                      | 34272                      | 763                         | 189                         | 7   |
| A2555... | 33114                      | 322                         | 3                           | 3                           |    |
| A2556... | 26257                      | 26247                      | 154                         | 164                         | 4   |
| A2557... | 51653                      | 51631                      | 1327                        | 1397                        | 6   |
| A2579... | 33660                      | 33363                      | 882                         | 735                         | 6   |
| A2585... | 56624                      | 57113                      | 1314                        | 981                         | 5   |
| A2599... | 26634                      | 26666                      | 399                         | 407                         | 8   |
| A2600... | 36049                      | 36110                      | 1452                        | 1520                        | 12  |
| A2600b... | 18283                      | 18286                      | 395                         | 403                         | 7   |
| A2601... | 33357                      | 33624                      | 819                         | 587                         | 7   |
| A2608... | 14927                      | 14907                      | 742                         | 805                         | 5   |
| A2609... | 40449                      | 41148                      | 1763                        | 2049                        | 6   |
| A2609b... | 32944                      | 32932                      | 124                         | 134                         | 4   |
| A2609c... | 34619                      | 34423                      | 1606                        | 1743                        | 8   |

* \(R = 0\) cluster, according to ACO criteria.
* Possible foreground/background contamination.
* Insufficient data.

### Table 5B

| Cluster | \(\mu\) (km s\(^{-1}\)) | \(N\) | Reference |
|---------|-----------------------------|-----|-----------|
| A2509... | 69180                      | 1   | 1         |
| A2521... | 40200                      | 2   | 2         |
| A2528... | 28650                      | 1   | 1         |
| A2531... | 52230                      | 1   | 1         |
| A2534... | 92980                      | 3   | 2         |
| A2536... | 59130                      | 1   | 1         |
| A2538... | 40350                      | 1   | 1         |
| A2539... | 52050                      | 1   | 1         |
| A2541... | 30540                      | 1   | 1         |
| A2546... | 33570                      | 1   | 1         |
| A2550... | 46290                      | 1   | 1         |
| A2554... | 33240                      | 28  | 3         |
| A2565... | 38130                      | 1   | 1         |
| A2566... | 24630                      | 1   | 1         |

### References
1. Ciardullo et al. 1985; 2. Struble & Rood 1991b; 3. Zabludoff et al. 1993.

### Table 5C

| Cluster | \(\mu\) (km s\(^{-1}\)) | \(C_{\text{HI}}\) (km s\(^{-1}\)) | \(\sigma\) (km s\(^{-1}\)) | \(S_{\text{HI}}\) (km s\(^{-1}\)) | \(N\) |
|---------|-----------------------------|-----------------------------|-----------------------------|-----------------------------|-----|
| A2500... | 23009                      | 23132                      | 909                         | 915                         | 6   |
| A3725... | 49483                      | 49442                      | 449                         | 425                         | 6   |
| A3757... | 28807                      | 29447                      | 1002                        | 993                         | 6   |
| A3775... | 31867                      | 31868                      | 435                         | 447                         | 9   |
| A3817... | 36620                      | 36461                      | 557                         | 520                         | 5   |
| A3818... | 18647                      | 18524                      | 358                         | 397                         | 5   |
| A3821... | 42328                      | 41864                      | 2089                        | 41                          | 5   |
| A3834... | 45555                      | 45636                      | 283                         | 299                         | 5   |
| A3839... | 17461                      | 17184                      | 571                         | 431                         | 4   |
| A3841... | 17281                      | 17284                      | 153                         | 160                         | 5   |
| A3842... | 17624                      | 17633                      | 203                         | 211                         | 5   |
| A3844... | 22385                      | 21972                      | 836                         | 203                         | 4   |
| A3844b... | 43804                      | 43810                      | 326                         | 349                         | 4   |
| A3861... | 46929                      | 46281                      | 1659                        | 1347                        | 10  |
| A3892... | 34647                      | 1458                        | 3                           | 3                           |    |
| A3896... | 46108                      | 46144                      | 723                         | 560                         | 7   |
| A3896b... | 21939                      | 22036                      | 1119                        | 491                         | 10  |
| A3920... | 38917                      | 38875                      | 1397                        | 1477                        | 9   |
| A3928... | 33595                      | 35172                      | 2603                        | 1780                        | 7   |
| A3944... | 21446                      | 21728                      | 822                         | 298                         | 7   |
| A3995... | 26056                      | 26165                      | 413                         | 300                         | 7   |
| A3995b... | 16885                      | 16365                      | 826                         | 152                         | 6   |
| A3978... | 26181                      | 26124                      | 171                         | 99                          | 7   |

* Not a cluster.
* Insufficient data.
* Possible foreground/background contamination.

### 4.1. The Aquarius Superclusters

One of the particular supercluster candidates (located in Aquarius) we investigated in the 1994 August and 1995 September ESO runs is one that was originally identified by Ciardullo et al. (1985). Ciardullo et al. identified the supercluster candidate via a "friends of friends" percolation scheme very similar to the one discussed in § 2. They then measured single redshifts for 20 R \(\geq 0\) Abell clusters in this region of sky and, from their results, concluded that there was no supercluster, only a chance projection of clusters along the line of sight out to \(z \leq 0.2\). However, as pointed out earlier, measuring only a single redshift is dangerous, particularly in a region of such high surface density. We similarly (via percolation, see § 2) identified a more extended version of the same supercluster candidate. Our identifica-
tion included 39 clusters, 20 of which were originally identified by Ciardullo et al. (1985). The additional clusters from our analysis were, in projection, apparently farther outside the densest clump of clusters in Figure 1 than the targets of Ciardullo et al. (1985).

The major finding to emerge in our analysis of this data is the confirmation of the presence of two extremely large and dense superclusters in Aquarius. Figure 2 is the conﬁrmation of the presence of two extremely large and dense superclusters in Aquarius. Figure 2 consists of eight clusters in a 75 h^{-1} Mpc filament. We note also that the Perseus-Pegasus supercluster filament (Batuski & Burns 1985b) and several other previously identified superclusters did not show up in this analysis since they are composed of a substantial number of R = 0 clusters.

The value of n = \frac{8}{\pi} is essentially the minimum value within the supercluster, since it corresponds to the value of the percolation length that connects the structure through its sparsest regions. The average density of this supercluster can be estimated by calculating the volume in a near-rectilinear box that encloses all the 14 clusters within their extremes of x, y, and z. Such a box has a density that is a factor of 20 times the average R \geq 1 ACO cluster spatial number density.

Of the 14 clusters in the filament, four (listed in Table 5B) still have only single measured redshifts, and, as we mentioned in §1, this increases the risk of problems due to projection effects. However, with only four clusters in this condition and with about 14% of Abell clusters with single reported redshifts turning out to have substantially revised redshifts after multiple measurements (see §1), it is unlikely that additional observations will have large negative impact on the structure we report here. On the other hand, there

![Figure 2](image-url)

**Fig. 2.** *Left panel:* Abell/ACO R \geq 1 cluster positions. The plot is 45° along our observed slice of sky by 10° in width (out of the page). Triangles in this figure represent R \geq 1 clusters that now have at least one measured redshift within our 10° \times 45° strip of the sky. The triangles in this figure represent the clusters with m_{10} \leq 18.3 (on the ACO scale, which, largely because of the different media used, differs from the Abell 1958 magnitude scale), which are 85% complete, with 40 of 47 clusters measured. The crosses are a few fainter clusters that had redshifts in the literature or that we observed because more time was available each night for the ends of the strip. Asterisks represent the few R = 0 ACO clusters with measured redshifts. As mentioned below, several of these R = 0 clusters were classified as R \geq 1 in Abell (1958). Figure 3 is the same as Figure 2, except that R = 0 clusters are not plotted and Abell/ACO catalog numbers have been added.

The region from cz = 24,000 to cz = 36,000 km s^{-1} (an extent of \sim 110 h^{-1} Mpc) around \theta = 10° in Figure 3 contains 14 Abell/ACO clusters that percolate into a single structure with a percolation parameter of length b = 25 h^{-1} Mpc, which corresponds to a spatial number density of clusters, n, that is 8 times the average spatial number density of ACO clusters, \bar{n} (see §2). In a percolation analysis at this density threshold of all the Abell/ACO R \geq 1 clusters with measured redshift (similar to that of Bachall & Soniera 1984 and Batuski & Burns 1985a), but including redshifts from Slinglend et al. 1998, Katgert et al. 1996, and other sources in the literature), this was the structure of greatest extent that appeared. It was also one of the two structures with the largest number of member clusters. The Shapley concentration percolates at this density to also include 14 R \geq 1 clusters with an extent of only 56 h^{-1} Mpc, while Corona Borealis becomes a complex of 10 clusters with a 60 h^{-1} Mpc extent. Two other supercluster complexes, each with six member clusters, have longest dimensions of 60 h^{-1} Mpc in this analysis, and one structure (discussed below) consists of eight clusters in a 75 h^{-1} Mpc filament.

The major finding to emerge in our analysis of this data is the confirmation of the presence of two extremely large and dense superclusters in Aquarius. Figure 2 is the conﬁrmation of the presence of two extremely large and dense superclusters in Aquarius. Figure 2 consists of eight clusters in a 75 h^{-1} Mpc filament. We note also that the Perseus-Pegasus supercluster filament (Batuski & Burns 1985b) and several other previously identified superclusters did not show up in this analysis since they are composed of a substantial number of R = 0 clusters.

The value of n = \frac{8}{\pi} is essentially the minimum value within the supercluster, since it corresponds to the value of the percolation length that connects the structure through its sparsest regions. The average density of this supercluster can be estimated by calculating the volume in a near-rectilinear box that encloses all the 14 clusters within their extremes of x, y, and z. Such a box has a density that is a factor of 20 times the average R \geq 1 ACO cluster spatial number density.

Of the 14 clusters in the filament, four (listed in Table 5B) still have only single measured redshifts, and, as we mentioned in §1, this increases the risk of problems due to projection effects. However, with only four clusters in this condition and with about 14% of Abell clusters with single reported redshifts turning out to have substantially revised redshifts after multiple measurements (see §1), it is unlikely that additional observations will have large negative impact on the structure we report here. On the other hand, there
are six additional single-measurement clusters in Table 5B that do not currently appear to be part of Aquarius, and about 20 fainter clusters with no measurements that could be found to occupy or extend this filament upon further observation.

There is an especially tight knot of six clusters in the region near \( cz = 33,000 \, \text{km s}^{-1} \) and \( \theta = 10^\circ \) in Figures 2a and 3 (clusters A2546, A2553, A2554, A2555, A2579, and A3996). These clusters percolate with \( b = 15.7 \, h^{-1} \, \text{Mpc} \) \((n = 32\bar{n})\), and, without A2553, the remaining five hold together at \( b = 12.5 \, h^{-1} \, \text{Mpc} \) \((n = 64\bar{n})\). If their redshifts are directly translated into distance according to equation (1), this group of five occupies a sphere with radius \( 10 \, h^{-1} \, \text{Mpc} \) (allowing sufficient room for the clusters to "fit" by adding \( 2 \, h^{-1} \, \text{Mpc} \) to the minimum radius that would barely contain the apparent cluster center positions). The sphere would then have a spatial number density about 150 times the average for \( R \geq 1 \) ACO clusters, an amazing result, comparable to the five-cluster, densest portion of Corona Borealis supercluster (Postman et al. 1986b), which is about \( 100\bar{n} \), and the nine \( R \geq 1 \) clusters of the Shapley concentration (Scaramella et al. 1989) that percolate at \( b = 10 \, h^{-1} \, \text{Mpc} \) to have \( \sim 110\bar{n} \) for a similar spherical volume.

Only one of the clusters in the Aquarius knot, A2546, is limited to a single measured galaxy redshift, so high confidence can be placed on the reality of this extreme density peak (as is also the case for the three other peaks discussed above). Note also that A2548, an \( R = 0 \) cluster that was included on our list of targets because it could be observed in the large MEFOS field at the same time we were observing A2547, also happens to have a redshift that places it in the knot, contributing further to the density of the region. A2548 had been classified \( R = 1 \) by Abell (1958).

On the high-redshift end of the Aquarius filament, four \( R = 0 \) (by ACO criteria) clusters are in positions that bridge gaps at \( b = 30 \, h^{-1} \, \text{Mpc} \) (see the asterisk symbols in Fig. 2a), further extending the structure to a total length of 150 \( h^{-1} \, \text{Mpc} \), by connecting in the \( R \geq 1 \) clusters A2521, A2547, A2550, and A2565. Three of these clusters, A2518, A2540, and A2542, had been classed as \( R = 0 \) in Abell's catalog and were reclassified as \( R = 0 \) in ACO. The other cluster, A2568, is classified \( R = 0 \) in both catalogs. Redshifts for all four of these clusters were measured by Ciardullo et al.
al. However, since the $R = 0$ cluster redshifts are very incomplete in this region (for instance, only five of 16 measured in the $10^\circ \times 10^\circ$ square of sky around the projected Aquarius filament), no analysis of the significance of their contribution to the structure in the region is appropriate at this time.

There is another collection of eight ACO/Abell $R \geq 1$ clusters that percolates at $b = 25\, h^{-1}$ Mpc ($n \sim 8\sigma$) across the foreground in the region of the Aquarius supercluster. The member clusters are A2456, A2480, A2559, A2569, A2638, A2670, A3897 (also listed as A2462 in Abell 1958), and A3951. Since A2670 is near the Aquarius-Cetus boundary, we will hereafter identify this supercluster as Aquarius-Cetus, to distinguish it from the Aquarius supercluster discussed above. The wedge plot in Figure 4 is centered on the dashed line in Figure 1, and, with its $12^\circ$ width, it covers both of the superclusters in this region. The 14 clusters of the Aquarius supercluster are identified with filled circles, while Aquarius-Cetus clusters are shown with filled triangles. The Aquarius-Cetus complex spans an overall distance of $75\, h^{-1}$ Mpc, and it also has an especially high-density group of four clusters (A2456, A2480, A3897, and A3951), with an average density (box-average method above) of $90\sigma$. Three of these clusters have only a single measured redshift, however, so more redshift observations are necessary for high confidence in the reality of this grouping.

At the relatively low density threshold of $n \sim 4\sigma$, the Aquarius and Aquarius-Cetus superclusters percolate together, through the crossing of the gap between A2538 and A3951.

Another approach to analyzing our redshift data for the Aquarius region is to consider our observations as $1^\circ$ wide pencil-beams sampling this small region of the sky in several spots (especially since one is compelled, with the large field and the mechanical arms of MEFOS, to choose several target galaxies per field that are well away from the apparent cluster center). We can then view the aggregate velocity distribution of the galaxies observed in this region with histograms (Figs. 5 and 6). As one might expect from the above discussion of the knot of six clusters, these plots show a large peak at $\sim 33,000\, \text{km s}^{-1}$. However, when the velocities associated with the clusters in each of our fields are subtracted, we have the result in Figure 6, which shows that a sizable (about 20 galaxies) peak in the velocity distribution remains at $\sim 33,000\, \text{km s}^{-1}$. This suggests that several of the fields targeted toward other clusters might be sampling a more extended “background” population around the six-cluster knot. The 2dF survey of this region should confirm whether or not such extended structure exists around the knot of clusters.

We also point out that the percolation analysis of $R \geq 1$ Abell/ACO clusters with measured redshifts adds a seventh cluster (A3677) to another high-density (percolating at $b \sim 12.5\, h^{-1}$ Mpc) supercluster in Microscopium identified by Zucca et al. (1993) as consisting of six measured-redshift $R \geq 1$ clusters (A3682, A3691, A3693, A3695, A3696, A3705). Each of these seven clusters has many measured redshifts from Katgert et al. (1996). Fitting of a sphere around the five of these clusters that percolate at $b = 10\, h^{-1}$ Mpc results in $n = 130\sigma$. Of course, the densities calculated by this sphere-fitting algorithm may differ considerably from the actual spatial densities of the clumps considered, if there is much of a peculiar velocity/dynamical component to the redshifts of the clusters (see § 4.3 below), but treating these apparent peaks in the same way allows for a rough estimation of their comparative densities. Thus, including Shapley and CrB, we have four very high-density peaks, each involving at least five rich clusters, within $z \leq 0.11$.

4.2. Significance of the Superclustering in Aquarius

We took two approaches to evaluating the statistical significance of the Aquarius supercluster filament. Both of
these involved analysis of simulated “universes” of point locations in space corresponding to the centers of pseudo-clusters of galaxies with two-point spatial correlation functions very similar to that of the $R \geq 1$ Abell clusters. Following the procedure of Batuski & Burns (1985b), which was based on the hierarchical nested-pairs technique of Soneira & Peebles (1978), 100 catalogs of pseudoclusters were created by placing pairs of pairs within a spherical volume in such a manner that $\xi(r)$ closely matched that of the recently enlarged sample of Abell clusters with redshifts analyzed in Miller et al. (1999b), as shown in Figure 7. This procedure can be visualized as placing a “long rod” at a random point in space with a random orientation, then at each end of the rod placing a short rod, again with random orientation, and finally placing a cluster at each end of each short rod, dropping any clusters that were outside the radius of the spherical volume of the simulation. The lengths of the rods were governed by

$$\Lambda = A(1 - Bx^a),$$

where $A = 22$ h$^{-1}$ Mpc and $B = 0.5$ for the long rods, $A = 11$ h$^{-1}$ Mpc and $B = 0.96$ for the short rods, $a = 1.5$

for both cases, and $x$ is a uniformly distributed random number between 0 and 1. Finally, 25% of the points generated with this algorithm were randomly selected for deletion from the models so that $\xi(r)$ on small scales ($5-10$ h$^{-1}$ Mpc) closely follows the Abell/ACO case and so that the ratio of triple-cluster clumpings to double-cluster clumpings (about 7:1) could begin to approach that observed in the Abell/ACO catalogs (about 3:1) at $b = 25$ h$^{-1}$ Mpc. These simulations thus have large-scale clumping very similar to that of the Abell/ACO clusters but no particular tendency to form filamentary structures, since the spatial orientations of all the pairs were determined randomly (uniform in $\phi$ in the $x$-$y$ plane and uniform in cos $\theta$ for the angle with the $z$-axis).

4.2.1. Two-dimensional Density Peaks

We first examined each of the 100 pseudocluster catalogs from the central position within its spherical volume of space to find peaks in the projected two-dimensional number density of clusters on the “sky” of an imagined observer at the center of such a universe. In the $10^5 \times 10^5$ square of sky centered on the densest part of the Aquarius supercluster ($\alpha = 23^h 3^m, \delta = -22^\circ$), there are 23 $R \geq 1$ Abell/ACO clusters to a depth of 400 h$^{-1}$ Mpc, only one of which has an unmeasured redshift (estimating the redshift from the ACO $m_{10} - z$ relation, the 400 h$^{-1}$ Mpc limit corresponds to an ACO magnitude limit of $m_{10} < 18.3$ and an Abell magnitude limit of $m_{10} < 17.6$). This is the most pro-
nounced peak surface density of measured and unmeasured \( R \geq 1 \) clusters to this depth on our sky. (One might think that part of this effect is the result of this region being so complete in redshifts, but even counting more deeply, using 500 Mpc or 600 Mpc as the cutoff, beyond which distances there are few clusters with measured \( z \) so that effectively there is only a uniform magnitude limit, this peak remains the highest in our sky by at least 15%.)

In the 100 pseudocluster simulations, surface density peaks of similar amplitude (22–25 clusters in a \( 10^3 \) square) were identified on the sky of our central observer, and then the clusters within that square were checked to see how often they would percolate, with \( b = 25 \) \( h^{-1} \) Mpc, into a structure of length \( 100 \) \( h^{-1} \) Mpc or greater. This happened in about 1% of the peak surface-density cases, so having such a long structure roughly along the line of sight is a 2 \( \sigma \) event in a population of pseudoclusters that are clumped in a scheme that closely approximates the two-point correlation function of rich Abell clusters but avoids the introduction of more than chance filamentation. This result suggests that finding such a structure as the Aquarius filament through the observational approach that we used is very unlikely unless rich clusters in the real universe are more commonly members of filamentary supercluster structures in comparison to the pseudoclusters in the simulations.

4.2.2. Ellipsoid Fitting

In the second analysis of the significance of the Aquarius supercluster, we first fit a triaxial ellipsoid through the 14 member cluster positions, using the technique of Jaaniste et al. (1998). The resulting ellipsoid had axes ratios of 4.3:1.0:0.70, with the long axis tilted at 69:9 from the line of sight. For examining filamentation in the Abell/ACO catalogs and the 100 pseudocluster catalogs, we chose to classify as filaments supercluster ellipsoids with a long axis at least 3 times the length of the longer of the other two axes (axis ratio of \( R_x \geq 3.0 \)), so that such identified filaments could have some substantial curvature as well as one axis that was clearly much longer than the others.

The Abell/ACO sample that we examined for filamentation includes all \( R \geq 1 \) clusters with Galactic latitude at least 30° from the galactic plane, measured redshifts, and distances less than 300 \( h^{-1} \) Mpc, using equation (1). The sample includes 50 new cluster redshifts soon to be published in Miller et al. (1999a). The distance cutoff was chosen because Miller et al. (1999b) show that the \( R \geq 1 \) Abell clusters north of \( \delta = -17° \) and the \( R \geq 1 \) ACO clusters south of that declination each have a relatively flat spatial number density distribution out to \( z = 0.10 \) before it drops off steeply, indicating that redshift coverage is quite complete within \( D \sim 300 \) \( h^{-1} \) Mpc. In this sample of 370 clusters, using a percolation length of \( b = 25 \) \( h^{-1} \) Mpc, as we used above for defining the Aquarius and Aquarius-Cetus superclusters, there are 64 superclusters (with two or more member clusters), 14 of which having five or more members. One of these superclusters consists of six of the clusters found to be members of the Aquarius supercluster (the other eight Aquarius member clusters are more distant than 300 \( h^{-1} \) Mpc and were thus excluded from the sample), and another is Aquarius-Cetus.

When we fit ellipsoids to the superclusters with five or more members (\( N_c \geq 5 \) at \( b = 25 \) \( h^{-1} \) Mpc), only three among these 14 superclusters satisfied our definition of a filament: Ursa Major (with \( N_c = 5 \) had \( R_A = 4.7 \), Virgo-Coma (\( N_c = 6 \), none of which is the Coma Cluster) had \( R_A = 3.2 \), and Aquarius-Cetus (\( N_c = 8 \) had \( R_A = 3.0 \). Ursa Major runs closest to the line of sight, with a tilt of only 14°, while Virgo-Coma and Aquarius-Cetus are tilted 68° and 73°, respectively. The ellipsoid fit to the fragment of the Aquarius supercluster that lies within \( D = 300 \) \( h^{-1} \) Mpc had \( R_A = 2.5 \), so it did not qualify as a filament.

We then searched for filaments in 50 catalogs of pseudoclusters with \( \xi(r) \) constrained to approximate that of Abell/ACO clusters. Limiting these catalogs to the same distance and Galactic latitude ranges as the Abell/ACO case above, there were an average of 440 pseudoclusters per sample. This number is somewhat greater than the 370 Abell/ACO clusters in our sample, primarily because we chose to use the average space number density of ACO clusters (~8 \( \times 10^{-6} \) \( h^3 \) Mpc\(^{-3} \)) throughout these pseudocluster catalogs rather than the density of Abell clusters (~6 \( \times 10^{-6} \) \( h^3 \) Mpc\(^{-3} \); Miller et al. 1999b) or an average of the two densities. We chose the ACO density because we have been using ACO criteria throughout the characterization of the Aquarius supercluster. We also point out that the parameter of interest here is the fraction of \( N_c \geq 5 \) superclusters that have \( R_A \geq 3.0 \), which is not affected by a small change in density.

With \( b = 25 \) \( h^{-1} \) Mpc, each of the pseudocluster catalogs percolated an average of 7.7 superclusters with five or more members, and 20% of these superclusters satisfied the \( R_A \geq 3 \) definition of a filament. (For reference, the same analysis of 100 catalogs of entirely random cluster positions yielded 0.64 \( N_c \geq 5 \) superclusters per catalog, 19% of which were filamentary, indicating that our pseudocluster creation algorithm did indeed not introduce extraneous filamentarity.)

The surprising conclusion to this analysis is that even though filamentary arrangements of galaxies and clusters of galaxies (generally including \( R = 0 \) clusters) have commonly been reported in observational studies of large-scale structure (e.g., Batuski & Burns 1985b; de Lapparent et al. 1988, 1991; Giovanelli & Haynes 1993; da Costa et al. 1994) and even though this one region of the sky in Aquarius contains two pronounced filaments of rich clusters, the large and nearly complete sample of \( R \geq 1 \) Abell/ACO clusters actually shows no more filamentation than what could be expected by chance alignments in a clumpy universe. While the Abell/ACO sample contains a much higher number of large (\( N_c \geq 5 \) superclusters than the average pseudocluster catalog (14 vs. 7.7), essentially the same fraction of such superclusters in either case (21% for Abell/ACO and 20% for pseudoclusters) satisfy \( R_A \geq 3 \).

4.3. Dynamics of the Aquarius Knot

Knowledge of the masses and dynamical states of the superclusters discussed in this paper are significant to the study of the mass distribution on large scales in general. The entire Aquarius and Aquarius-Cetus filaments each have spatial extents that imply crossing times that are a few times the Hubble time (assuming peculiar velocities of ~1000 km s\(^{-1}\)—see discussion below), so these structures can not have broken away from the Hubble flow and may well not be gravitationally bound overall. Until they have been studied in far more detail, little can be said about dynamics within such extended structures. However, the knot within the Aquarius filament is dense enough and has sufficient red-
shift information available to warrant a closer look now. The same is true of the newly identified Microscopium supercluster, which we will also examine in this section.

The knot within the Aquarius supercluster is comparable in density enhancement to the Shapley concentration and the Corona Borealis (CrB) superclusters (see § 4.1). However, Tables 5A and 5B show how sparsely the region has been sampled thus far. While most of the clusters observed for this program have enough galaxy redshifts for reliable cluster velocity determinations, none have enough for accurate velocity dispersions, which are needed for reasonable cluster mass determinations.

Recent work by Small et al. (1998) has shown that both the virial mass estimator and the projected mass estimator (Bahcall & Tremaine 1981) give reasonable mass estimates for clusters with ~30 or more galaxy observations. Small et al. (1998) determined a mass for CrB of at least $3 	imes 10^{16} h^{-1} M_\odot$ and a mass-to-light ratio of $726 h (M/L)_\odot$. The small number of galaxies measured for our initial observations prohibits a similar determination of mass for the Aquarius superclusters. At best, a simple sum of the “typical” masses of Abell clusters would give a lower limit to the total mass. Since both filaments discovered contain some clusters with single measured redshifts, only the knot within Aquarius has enough clusters with velocity dispersions (although rather uncertain) for estimates of individual cluster masses. Thus, assuming A2546 and A2555 to be typical Abell/ACO R $\geq 1$ clusters with $z_\odot \sim 800$ km s$^{-1}$ (as we found for A2553 and A2579 and as Zabludoff, Geller, & Huchra 1990 found for A2554), we estimate each to have a cluster mass $\sim 7 \times 10^{15} h^{-1} M_\odot$ and find a total lower limit mass for the knot $\sim 6 \times 10^{15} h^{-1} M_\odot$ (about one-half of the mass coming from the large dispersion of A3996). Similar calculations using the velocity dispersions reported by Katgert et al. (1996) for clusters of the Microscopium supercluster result in a lower limit mass of $\sim 4 \times 10^{15} h^{-1} M_\odot$. We note that the sum of the masses of the clusters in CrB as determined by Small et al. (1998) in the same manner is $5.3 \times 10^{15} h^{-1} M_\odot$, which is a factor of 6–8 smaller than their mass determinations by the virial mass estimator or the projected mass estimator.

Eventually, it should become feasible to conduct a study of the dynamics among these clusters to further constrain the mass of the system. The 2dF redshift survey of this region, already underway, should provide a large number of redshifts for galaxies within and between clusters in the knot (as well as for the rest of the supercluster). Currently, however, there is no secondary distance indicator that can provide distances of sufficient accuracy. The clusters in the knot have a radial distance range of about 13 $h^{-1}$ Mpc (using their redshifts directly), at an average distance of about 325 $h^{-1}$ Mpc, so one would need accuracies of only a few percent from the secondary indicator. Some standard candle–type analyses that might apply at such distances, such as brightest (or third or tenth brightest) cluster galaxies, or even entire cluster luminosity function analyses as attempted by Small et al. on Corona Borealis, are sufficiently coarse that they are unlikely ever to provide the accuracy needed for a study of dynamics within the knot. Other methods, such as approaches using relations like Tully-Fisher or those employing Type I supernovae, hold the promise of achieving the necessary accuracy when vast amounts of observational data become available for their application.

We can at the present time get a rough conception of the dynamics of the Aquarius knot and Microscopium by looking at typical supercluster crossing times and virialization timescales and by applying a technique Sargent & Turner (1977) developed to measure the slowing of the Hubble flow for systems for which only redshift information is known. One can calculate the angle between the separation vector and the plane of the sky at the midpoint between clusters using

$$\alpha = \arctan \left( \frac{1}{2} (z_1/z_2 - 1) \cot \left( \frac{1}{2} \Delta_{12} \right) \right) , \quad 0 \leq \alpha \leq \pi/2 ,$$

where $z_1 \geq z_2$ and $\Delta_{12}$ is the separation between clusters 1 and 2 on the sky in radians. If $\bar{\alpha} < 32.7^\circ$, the region is expected to have a slowed Hubble flow. If violent relaxation has not yet occurred, such a system should appear flattened in the redshift direction. If $\bar{\alpha} > 32.7^\circ$, the region may have reached virial equilibrium and the system would appear elongated along the line of sight. If $\bar{\alpha} \sim 32.7^\circ$, its isotropic value, we expect an unperturbed Hubble flow or a system in the midst of relaxation.

Postman, Geller, & Huchra (1988) calculated $\bar{\alpha} = 56.5^\circ \pm 12.7^\circ$ for CrB (with A2124 excluded from the analysis because of its apparently greater separation from the rest of the supercluster), a significant indication of virialization, although they noted that true spatial elongation rather than dynamical redshift-space elongation could easily be the major factor in the case of this one well-studied supercluster. The value of $\bar{\alpha}$ for the six-cluster knot within the Aquarius supercluster is $\bar{\alpha} = 28.8^\circ \pm 18.5^\circ$. Since this result is well within the errors (determined as in Wagner & Perrenod 1981) of the isotropic result, the knot is clearly not significantly elongated or flattened along the line of sight. This suggests either that the supercluster has not yet significantly broken away from the Hubble expansion or that it has begun violent relaxation but is not yet virialized.

From the extent of the system on the sky, we expect the supercluster crossing time of a typical cluster with $v_{pec} \sim 800$ km s$^{-1}$ (typical of many recent findings; see, e.g., Bahcall, Gramman, & Cen 1994; Croft & Efstathiou 1994; but a bit high compared to $v_{pec} \sim 500$ km s$^{-1}$ from Bahcall & Oh 1996) to be $T_c \sim 5 \times 10^9$ yr; thus, the Aquarius knot could be gravitationally bound. The virialization timescale for a spherically symmetric collapsing mass is (Gunn & Gott 1972)

$$T_v = \frac{2.14}{\sqrt{G \rho}} ,$$

where $\rho$ is the current-epoch mass density. Postman et al. (1988) determined $T_v$ for CrB to be $\sim 2 \times 10^{10}$ yr, so they concluded that it was unlikely that the supercluster was virialized, although they found that the mass of CrB was sufficient to bind the supercluster (as did Small et al. 1998). We would expect $T_v$ to be about the same for the Aquarius knot, which has roughly the same rich-cluster spatial density as CrB. These values of $\bar{\alpha}$, $T_v$, and $T_c$ for the knot do not allow for discrimination between the two cases of continued expansion with the Hubble flow and violent relaxation.

We also note that $\bar{\alpha}$, $T_v$, and $T_c$ are very similar to the values for the Aquarius knot for the seven clusters of Microscopium ($\bar{\alpha} = 31.7^\circ \pm 17.2^\circ$) and for the nine clusters of
Shapley ($\bar{z} = 34:3 \pm 16:2$). Thus, of the four rich-cluster density peaks, none show noticeable flattening in the redshift direction, indicative of slowing expansion. CrB has a $z$ value suggesting virialization (although this seems unlikely from other measures), while Aquarius, Microscopium, and Shapley have isotropic appearances but could possibly be in the process of relaxation, given the timescales involved. These results highlight the importance of further study of all four of these complexes of clusters. Much work has already been done on Shapley and CrB, but the Aquarius and Microscopium peaks could provide new insight into large-scale dynamics in the universe.

4.4. The Other Targeted SCCs

The Eridanus SCC was also included in our target strip on the sky (Fig. 1). The clusters identified in the friends-of-friends analysis as likely members (A3802, A3817, A3818, A3820, A3834, A3841, and A3845) lie roughly along $\theta = 40^\circ$ in Figure 2. However, the clusters near that line that we measured (A3820 and A3845) were not observed because they are slightly fainter than our magnitude limit of $m_{150} = 18.3$ in the strip) have widely differing redshifts (see Table 5C), and there is no indication of superclustering in that region. A3817 was observed previously (Batuski et al. 1995), and we have included those redshifts in Table 2.

The redshift distribution that we found for the Grus-Indus SCC (seven clusters near $z = 4^\circ$, also listed in Table 5D) is a bit more interesting, with three clusters, A3148, A3166, and A3171, within the range $32,800 \leq cz \leq 37,200$ km s$^{-1}$. These clusters have spatial separations of 19 and $28 h^{-1}$ Mpc, suggesting superclustering, but with so few clusters involved there is no great statistical significance to their proximity. In 100 catalogs of pseudoclusters distributed randomly in space to a distance of $400 h^{-1}$ Mpc (about 1060 pseudoclusters per catalog, with exclusion of a region bounded by a latitude limit of $\pm 30^\circ$ to simulate Galactic obscuration), we found an average of 35 “superclusters” per catalog consisting of three pseudoclusters that would percolate at $b = 30 h^{-1}$ Mpc. Only five superclusters of six or more points were found per catalog, and a supercluster of 10 or more was found in only one of five catalogs. Thus, with $\sim 10\%$ of clusters in three-dimensional groupings of three clusters, an observing program targeting apparent two-dimensional clumpings on the sky would have considerable likelihood of finding some superclusters of three clusters even if the spatial distribution of the clusters were entirely random. On the other hand, finding several more populous superclusters, as researchers have done, obviously requires a spatial distribution something akin to that represented by the two-point spatial correlation functions of Figure 7.

5. CONCLUSION

The Aquarius supercluster is a highly significant single structure of $14 R \geq 1$ ACO clusters that percolates at $b = 25 h^{-1}$ Mpc ($n = 8\bar{n}$) and extends in a filamentary fashion at least $110 h^{-1}$ Mpc. This is the largest structure involving such rich clusters at such a density contrast that has been identified to date. With the inclusion of four $R = 0$ ACO clusters that were classed as $R = 1$ by Abell, the apparent filament can be traced to an extent of $150 h^{-1}$ Mpc, with 22 member clusters, at $b = 30 h^{-1}$ Mpc. Aquarius is also the second most filamentary of the superclusters that percolate among the measured-$z$, rich Abell/ACO clusters at $b = 25 h^{-1}$ Mpc, having $R_A = 4.3$ for its ellipsoidal fit.

The scale of this structure is similar to that seen in the Great Wall of galaxies (de Lapparent et al. 1988, 1991) and in the Perseus-Pisces-Pegasus supercluster (see, e.g., Gregory et al. 1981; Haynes et al. 1988; and extended with primarily $R = 0$ clusters by Batuski & Burns 1985a). The lengths of all these structures are approaching $5\%$–$10\%$ of the horizon length of the universe, the scale of many of the features observed by COBE in the cosmic microwave background (Smoot et al. 1992).

Besides the extent and shape of Aquarius, the high-density peak that it contains is also of great interest. Our analysis of available redshift data for the clusters in this peak and the estimated timescales involved leaves open the possibility that the grouping may have broken away from the Hubble expansion to be currently in collapse toward an eventual virialized state. Including the seven-cluster supercluster in Microscopium, four such large cluster overdensities are now known to exist within $z \leq 0.11$. These observations constrain the theoretical models for the formation of such structure, since simulations based on such models will need to generate similar numbers of high-density peaks in the cluster distribution, with their sizeable impacts on statistics of large-scale structure like the two-point spatial correlation function, as illustrated by Postman et al. (1992) and Miller et al. (1999b). Postman et al. found that Corona Borealis accounted for $20\%$ of the power in $\xi(r)$ for their $156 R \geq 1$ Abell cluster sample, while Miller et al. found that CrB and Microscopium contributed $\sim 20\%$ to $\xi(r)$ in their sample of $289 R \geq 1$ Abell/ACO clusters. These knots of clusters will no doubt also eventually help in the determination of $\Omega_0$, once we have secondary distance indicators of sufficient accuracy.

The filamentary structure of the Aquarius supercluster may have even greater extent than what is reported here. As can be seen in Figure 3, A2547 and A2550 lie just beyond the high-$z$ end of the filament, in position to extend the structure to a length greater than $200 h^{-1}$ Mpc if other clusters (or galaxy bridges) are found to fill in the gaps upon future observation. There are another dozen clusters nearby on the sky (mostly fainter than the limit that was set) that percolate at and its own apparent knot of four clusters percolating at $n = 8\bar{n}$ and its own apparent knot of four clusters. One-half of the cluster redshifts for this structure are based on single-galaxy measurements, however, so this supercluster identification is somewhat more uncertain than Aquarius. The filamentary shapes of both the Aquarius and Aquarius-Cetus superclusters turn out to be unusual in the spatial distribution of $R \geq 1$ Abell/ACO clusters. Our analysis in § 4.2 revealed that, while the Aquarius region contains two clearly filamentary structures among such rich clusters, the Abell/ACO samples do not appear to have appreciably more filamentation than could be expected by chance within a population of objects with similar two-point correlation function. While poorer clusters and individual galaxies have been seen to follow filamentary...
patterns in many observational programs, the $R \geq 1$ clusters do not appear to participate in such patterns, at least for aggregates of five or more rich clusters.

The superclusters in this extremely interesting region should be observed in a very thorough redshift survey of thousands of individual galaxies in the immediate vicinity. (Such a survey is now being conducted as part of the 2dF program; Jones, Bland-Hawthorn, & Kaiser 1994). This is desirable in order to get more velocities of cluster members in those cases where only one galaxy has been measured and also to look for bridging structure among the clusters, such as that found in Chincarini et al. (1981), de Lapparent et al. (1988, 1991), Gregory & Thompson (1984), Gregory et al. (1981), Tarenghi et al. (1979), Postman et al. (1988), Small et al. (1998), and other papers on previously identified superclusters. The proximity and filamentary arrangements of so many clusters makes the Aquarius supercluster and Aquarius-Cetus remarkable occurrences, but the details of structure connecting the clusters will also be important in determining their true significance for the purpose of modeling and understanding large-scale structure in the universe.

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