THE HYDRA–CENTAURUS REGION AND THE NEARBY UNIVERSE[1]

C. N. A. WILLMER

Departamento de Astronomia, CNPq/Observatório Nacional, Rua General José Cristino 77, Rio de Janeiro, RJ 20921-030, Brazil and UCO/Lick Observatory, University of California, Santa Cruz, California 95064

L. N. DA COSTA[2]

Departamento de Astronomia, CNPq/Observatório Nacional, Rua General José Cristino 77, Rio de Janeiro, RJ 20921-030, Brazil and Institut d'Astrophysique, 98 bis Boulevard Arago, Paris, F75116, France

P. S. PELLEGRINI

Departamento de Astronomia, CNPq/Observatório Nacional, Rua General José Cristino 77, Rio de Janeiro, RJ 20921-030, Brazil

A. P. FAIRALL

Department of Astronomy, University of Cape Town, Rondebosch 7700, South Africa

DAVID W. LATHAM

Harvard–Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, Massachusetts 02138

WOLFRAM FREUDLING

Space Telescope–European Coordinating Facility, Karl Schwarzschild Strasse 2, D84748, Garching, Germany and European Southern Observatory, Karl Schwarzschild Strasse 2, D84748, Garching, Germany

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ABSTRACT

In this paper we present maps of the spatial distribution of galaxies in the general direction of the Hydra–Centaurus complex and discuss how that distribution relates to other structures located in the volume within 6000 km s^{-1} of the Local Group, using a sample of over 5700 galaxies brighter than $m_{B(0)}=14.5$ with essentially complete redshift information. Our sample covers about 50% of the sky and allows us to follow structures over large extensions. From the inspection of these maps we find that the galaxies are distributed in a pattern of interconnected structures, many of them with a rather regular wall-like appearance.

1. INTRODUCTION

The past decade has seen an enormous growth in the number of galaxies with measured redshifts [see Giovanelli & Haynes (1991) for a review], much effort being placed in mapping the distribution of galaxies in the nearby Universe, particularly at relatively high Galactic latitude in order to minimize the effects of absorption. The two most important wide-angle complete surveys of the Galactic caps were the CfA1 (Davis *et al.* 1982; Huchra *et al.* 1983) in the northern celestial hemisphere ($b\geqslant 40°$) and the SSRS (da Costa *et al.* 1988, 1991) in the south ($b\leqslant -30°$). However, in spite of the large angular coverage of those surveys, a full understanding of the galaxy distribution in the nearby Universe was still not possible. The main reasons for this were the lack of contiguity between the CfA1 and SSRS, there being a relatively large unsurveyed area in the equatorial region ($-17.5°\leqslant\delta\leqslant -2.5°$); the different selection criteria adopted by the CfA1 (magnitude limited) and SSRS (diameter limited); and finally, the paucity of data at low Galactic latitudes.

The first two of these shortcomings were addressed by Pellegrini *et al.* (1990) who constructed a homogeneous magnitude-limited catalogue by merging the Zwicky *et al.* (1962–1968), ESO/Uppsala (Lauberts 1982), and Morphological Catalogue of Galaxies (Vorontsov-Velyaminov *et al.* 1962–1968, hereafter referred to as MCG). This involved estimating magnitudes for ESO/Uppsala galaxies from measured diameters, and converting MCG magnitudes into the same system as used in the Zwicky *et al.* catalogue. Thus, it became possible to define an observational sample with a magnitude limit equal to the CfA1 (i.e., $m_{B(0)}=14.5$) which contained primarily galaxies in the equatorial region ($|b|\geqslant 30°$ and $0°\geqslant\delta\geqslant -17.5°$). This sample also contained a few ESO/Uppsala galaxies in the Southern Galactic Cap with diameters smaller than the SSRS limit, but whose estimated magnitudes where brighter than $m_{B(0)}=14.5$. The description of the observed galaxy distribution in the Galactic cap with $b\leqslant -30°$ has been presented by Pellegrini *et al.* (1990), while galaxy redshifts in the region have been reported by da Costa *et al.* (1991) and Huchra *et al.* (1993).

In this paper we use redshift data from the recently completed MCG equatorial sample in the Northern Galactic Cap (Fairall *et al.* 1992) combined with previous surveys carried

[1]Partly based on observations made at the Complejo Astronomico El Leoncito, San Juan, Argentina; the European Southern Observatory, La Silla, Chile; Laboratório Nacional de Astrofísica, Brasópolis, Brazil; and the South African Astronomical Observatory, Sutherland, South Africa.
[2]John Simon Guggenheim Fellow.

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out in the general direction of the Hydra–Centaurus supercluster (e.g., Hopp & Materne 1985; da Costa *et al.* 1986; da Costa *et al.* 1987; Fairall *et al.* 1989; Dressler 1988, 1991; Willmer *et al.* 1991) to examine the distribution of galaxies in the Northern Galactic Cap south of $\delta \leqslant 0°$. By combining these data with the CfA1 (Huchra *et al.* 1983) and the sample of Pellegrini *et al.* (1990) we then have an essentially complete catalogue of galaxies brighter than 14.5 with redshifts in both Galactic caps covering the regions where absorption is negligible.

Although the combined optical sample allows us to examine the distribution of galaxies over large portions of the sky, it does not provide much information on the distribution of galaxies in the zone of avoidance. This difficulty can be overcome combining the optical data with the complete flux-limited survey of *IRAS* galaxies (Strauss *et al.* 1992b), which is not much affected by Galactic obscuration for $|b| \geqslant 5°$. Therefore, in this paper we will attempt to consolidate the somewhat fragmentary picture of our local neighborhood utilizing optical samples in both Galactic caps that are on a consistent magnitude system, in conjunction with the *IRAS* sample to follow structures through the zone of avoidance. This combined optical-*IRAS* sample allows us to investigate the local cosmography for galaxies out to about 6000 km s^{-1} from the Local Group. A similar effort, using a sample limited in diameters has been carried out by Hudson (1993) while previous works to describe the galaxy distribution in a volume centered on the Galaxy include Tully & Fisher (1987, hereafter TF87) for $v \leqslant 3000$ km s^{-1}, and Saunders *et al.* (1991) on larger scales using a deep ($\approx$15 000 km s^{-1}) but sparse sample survey of *IRAS* galaxies. A complementary effort, that of identifying underdense regions, has been done by Kauffman & Fairall (1991, hereafter referred to as KF).

Our main goal in this paper is to identify the most prominent structures in the nearby Universe in order to help the identification of likely gravitational sources which may be responsible for the measured peculiar motions of galaxies in our vicinity. This identification is carried out primarily in a qualitative way but is confirmed *a posteriori* by the derivation of the density field of galaxies.

This paper is organized as follows: a brief description of the data is given in Sec. 2, while the Hydra–Centaurus region is described in Sec. 3. Section 4 presents a detailed description of the structures within 6000 km s^{-1} of the Local Group, followed by a summary in Sec. 5.

2. THE DATA

For the study of the galaxy distribution in the Northern Galactic Cap south of $\delta=0°$, described in Sec. 3, we have constructed a magnitude-limited sample using the two available optical catalogues covering this region, namely the MCG for galaxies with $-17.5° \leqslant \delta \leqslant 0°$, while south of $\delta = -17.5°$ objects were taken from the original diameter-limited ESO/Uppsala Catalogue (Lauberts 1982). The magnitudes for objects in the latter were taken either from the subsequent Lauberts & Valentijn (1989, hereafter referred to as ESO-LV) catalogue, or, for fields where photographic photometry was not available, we have used magnitudes estimated from diameters, as described by Pellegrini *et al.* (1990). In order to have a catalogue of galaxies in a magnitude system consistent with that used by the CfA1 survey, all magnitudes were transformed into $B(0)$. This transformation consisted of adding 0.5 mag to galaxies listed in the MCG (Pellegrini *et al.* 1990), while the ESO-LV B_T magnitudes were converted through $m_{B(0)} = B_T + 0.26$ (Felten 1985).

Two points should be kept in mind concerning the sample for $\delta \leqslant -17.5°$: first, galaxies were originally drawn from a diameter-limited catalogue which only marginally reaches $m_{B(0)} = 14.5$, particularly for early type galaxies (Pellegrini *et al.* 1990; ESO-LV), though other morphological types are reasonably complete down to about $m_{B(0)} = 14.8$ (e.g., ESO-LV); second, below $|b| = 30°$ we expect the samples to be incomplete due to Galactic absorption. Redshifts were obtained from our own observations (da Costa *et al.* 1986, 1987; Fairall *et al.* 1989, 1992; Willmer *et al.* 1991), supplemented by measurements in Dressler (1991) and the compilations of Fairall & Jones (1991), ZCAT (Huchra 1989), and ESO-LV, all of which provide the original references.

In the study of the Nearby Universe (Sec. 4) we have combined the various wide angle optical surveys in both Galactic caps (Huchra *et al.* 1983; Pellegrini *et al.* 1990; da Costa *et al.* 1991) with the surveys carried out in the equatorial regions (Huchra *et al.* 1993; Fairall *et al.* 1992). Thus, one can define a homogeneous optically selected catalogue of galaxies brighter than $m_{B(0)} = 14.5$, for $|b| \geqslant 30°$, that has high redshift completeness (over 90%) and which covers about 50% of the sky. In the description of structures in Sec. 4, we have also considered galaxies from the apparent diameter-limited catalogue of Dressler (1991) for the region between $-30° \leqslant b \leqslant +15°$ for $\delta \leqslant -17.5°$. For the zone of avoidance galaxies were taken from the Strauss *et al.* (1992b) survey of *IRAS* galaxies. The final merged catalogue is used to describe the distribution of galaxies in a volume of about 6000 km s^{-1} centered on the Local Group, which probes deeper than TF87, more densely than Strauss *et al.* (1992a), and with a higher completeness than Hudson (1993). In the following descriptions, all radial velocities were corrected for a Galactic rotation of 300 km s^{-1} following de Vaucouleurs *et al.* (1976).

3. THE HYDRA–CENTAURUS REGION

To illustrate the nature of the galaxy distribution in the Hydra–Centaurus region of the sky we will first consider a sample containing all MCG and ESO/Uppsala galaxies brighter than $m_{B(0)} = 14.5$. However, because this supercluster is at low Galactic latitude, and many of its most important concentrations are below $b = 30°$, a more detailed map of galaxies in this region requires that a compromise between angular coverage and catalogue completeness be reached. For this reason in the region covered by the ESO/Uppsala and ESO-LV catalogues ($\delta \leqslant -17.5°$), we have included galaxies down to $b = 15°$ in our description, particularly as the redshift completeness for these galaxies is fairly high, on the order of 90%. On the other hand, because of the low redshift completeness in the region covered by the MCG catalogue ($\delta > -17.5°$) in the range $15° \leqslant b \leqslant 30°$ the latter has not been considered in this description. The sample used in this section contains 1173 galaxies and redshifts have been measured for about 93% of the galaxies.

In Fig. 1 we present the distribution of galaxies on the sky in different radial velocity ranges. We also show in each plot as dashed lines the limits in Galactic latitude for the region we have considered, i.e., $b=30°$ for $-17.5°\leqslant\delta\leqslant 0°$ and $b=15°$ for $\delta\leqslant -17.5°$.

The first panel, Fig. 1(a), contains galaxies with $v\leqslant 1500$ km s^{-1}. Galaxies belonging to the Local Supercluster Southern Extension (TF87) can be seen at around 13^{h} between $-20°\leqslant\delta\leqslant 0°$. The center of the nearby Centaurus group, identified by de Vaucouleurs (1975) is at about ($13^{\mathrm{h}}\ 30^{\mathrm{m}}$, $\delta=-35°$), though it is not a very prominent system. The absence of galaxies in the eastern portion of this panel is real particularly in the northern part of Fig. 1(a), and is due to the Local Void (e.g., TF87).

The next slab, Fig. 1(b), shows galaxies between $1501\leqslant v\leqslant 3000$ km s^{-1}. Various concentrations of galaxies are visible in Fig. 1(b) the most prominent being that at ($13^{\mathrm{h}}20^{\mathrm{m}}$, $-30°$), which contains a few groups of galaxies such as that associated to NGC 5044 (Sandage 1975) at ($13^{\mathrm{h}}\ 10^{\mathrm{m}}$, $-16°$) and HG 31 (Huchra & Geller 1982) at ($13^{\mathrm{h}}\ 15^{\mathrm{m}}$, $-27°$). At about ($10^{\mathrm{h}}\ 00^{\mathrm{m}}$, $-35°$), galaxies of the Antlia cluster (Hopp & Materne 1985) can be seen. This cluster is associated with the Hydra Complex, which also contains the Hydra cluster, as well as a few other smaller groups (Hopp & Materne 1985). At ($12^{\mathrm{h}}\ 45^{\mathrm{m}}$, $-42°$) are lower redshift galaxies belonging to the Centaurus cluster. Galaxies that trace a link between Centaurus and the Hydra Complex (Fairall *et al.* 1989) are seen along the line between ($10^{\mathrm{h}}\ 30^{\mathrm{m}}$, $\delta=-37°$) and ($12^{\mathrm{h}}\ 30^{\mathrm{m}}$, $-40°$). At about 12^{h} are some groups of galaxies which are suggestive of making up a linear structure. HG 33 at ($12^{\mathrm{h}}\ 00^{\mathrm{m}}$, $-20°$); de Vaucouleurs No. 44 at ($12^{\mathrm{h}}\ 00^{\mathrm{m}}$, $-30°$). This structure delineates one side of an underdense region ($\approx$2000 km s^{-1} across) centered at ($12^{\mathrm{h}}\ 30^{\mathrm{m}}$, $-20°$). Another underdensity can be seen centered at (14^{h}, $-20°$), which extends radially to at least 6000 km s^{-1}, as can be seen in the subsequent panels.

The distribution of galaxies in Fig. 1(c) ($3001\leqslant v\leqslant 4500$ km s^{-1}) presents three very prominent concentrations. These are the main body of the Centaurus cluster at ($12^{\mathrm{h}}\ 45^{\mathrm{m}}$, $-42°$); the Hydra cluster ($10^{\mathrm{h}}\ 30^{\mathrm{m}}$, $-29°$); and various groups belonging to the Centaurus Concentration. The latter contains rich clusters listed in the Abell *et al.* (1989, hereafter referred to as the ACO) catalogue such as those associated to the galaxies IC 4296 (ACO 3565, $13^{\mathrm{h}}\ 30^{\mathrm{m}}$; $-33°$); NGC 5419 (S753, $14^{\mathrm{h}}\ 00^{\mathrm{m}}$, $-33°$), as well as smaller systems such as NGC 4936 group ($13^{\mathrm{h}}\ 00^{\mathrm{m}}$, $-30°$), originally identified by Sandage (1975). The Centaurus Concentration (following the nomenclature of Lynden-Bell *et al.* 1989) forms together with the groups of galaxies in the vicinity of the Hydra cluster and the Centaurus cluster the main portions of what is known as the Hydra–Centaurus supercluster (e.g., da Costa *et al.* 1986, 1987). As can be seen, the Centaurus Concentration is a distinct, though looser concentration of objects, at roughly the same redshift as the Centaurus cluster. A somewhat diffuse link between both structures is suggested by galaxies at ($13^{\mathrm{h}}\ 15^{\mathrm{m}}$, $-35°$). For a more detailed discussion on the nomenclature of features in this region, we refer the reader to Lynden-Bell *et al.* (1989).

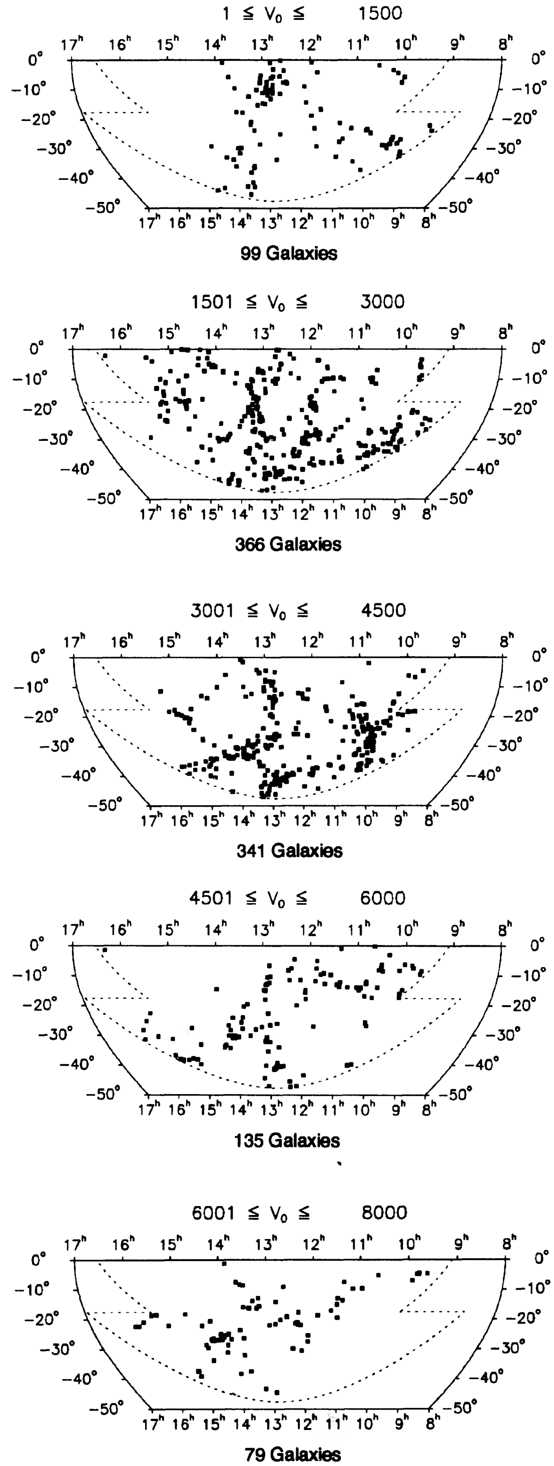

FIG. 1. Distribution of galaxies in the Hydra–Centaurus supercluster in five different radial velocity intervals, noted on the top of each panel. The dashed line delineates the region for which systematic redshift surveys of optically selected galaxies have been carried out, and corresponds to $b\geqslant 30°$ for $\delta > -17.5°$ and $b\geqslant 15°$ for $\delta < -17.5°$.

The following panel, Fig. 1(d) ($4501\leqslant v\leqslant 6000$ km s^{-1})

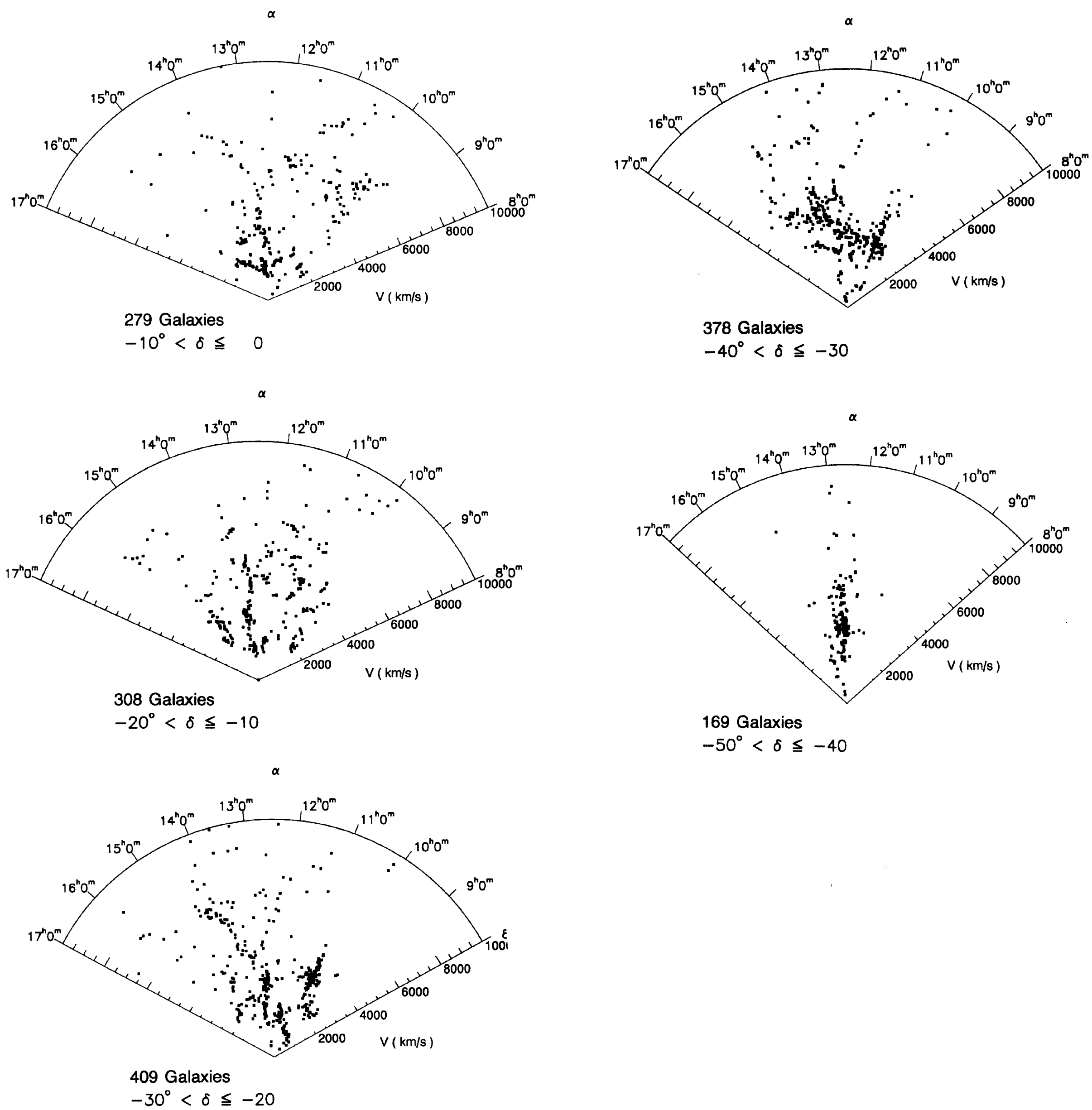

FIG. 2. Redshift by Right Ascension wedge diagrams in 10° intervals from $\delta=0°$ to $\delta=-50°$, for the same sample as in Fig. 1.

still shows galaxies belonging to the Centaurus Concentration, mainly higher redshift components of clusters. One can also see the most distant group of the Centaurus concentration, Klemola 27 (ACO 3574, $13^h\ 45^m$, $-30°$), showing that this structure extends along the radial direction to about 6000 km s^{-1}. The underdense region at (11^h, $-30°$) is the Hydra void(e.g., KF).

The last panel, Fig. 1(e) ($6001 \leq v \leq 8000$ km s^{-1}) shows galaxies in the background of the Hydra–Centaurus supercluster; the structures are less sharp here, mainly because of the loss of lower luminosity objects due to the magnitude limit. The prominent cluster at ($14^h\ 00^m$, $-26°$) is ACO 3581, at a mean radial velocity of about 6500 km s^{-1}.

Complementing the information offered by the sky plots, in Fig. 2 we present, for the same sample as Fig. 1, a sequence of maps of right ascension versus radial velocity, in declination slices of 10°. We should note that the lack of objects at the edges is due to the adopted galactic latitude cut, which varies with declination (see Fig. 1). One should also be aware that absorption may affect the slices south of $\delta \approx -20°$.

The first slice, Fig. 2(a), contains galaxies in the declination range $-10° \leq \delta \leq 0°$. The dense feature at about $12^h\ 50^m$, 1500 km s^{-1} contains galaxies which are part of the Virgo Southern Extension ($v \leq 2500$ km s^{-1}). Another prominent feature runs from about (13^h, 1000 km s^{-1}) to about ($15^h\ 15^m$, 2000 km s^{-1}), somewhat suggestive of a wall-like nature, given that it is not parallel to the line of sight. This feature can be seen as a rather loose distribution of points in Fig. 1(b), at about (14^h, $-5°$). A few underdense regions can be identified in this panel. The most well defined is KF 24 at roughly ($13^h\,30^m$, 2000 km s^{-1}). Other not so clearly defined underdensities are the Leo Void at ($11^h\,30^m$, 4000 km s^{-1}), which can be followed north into the slice $0° \leq \delta \leq 10°$ of the CfA1 survey (Davis *et al.* 1982); KF 10 at ($10^h\,15^m$, 8000 km s^{-1}) and KF 81 at ($14^h\,30^m$, 6000 km s^{-1}). The latter two are rather uncertain however, given that their centers are already where there might be a significant loss of objects because of the adopted magnitude limit.

Panel 2(b), for galaxies in the range $-20° \leq \delta \leq -10°$ presents a prominent and rather linear structure, which is parallel to the line of sight at about 13^h out to about 6000 km s^{-1}. This reflects the virial distortions of a few groups along the line of sight. However, the following panel [2(c)] still presents a feature occupying the same range in right ascension and radial velocity. The same can be seen, though less prominently, in panels 2(a) and 2(d). The coherence over such a large declination range is suggestive that it could be a wall of galaxies. This feature could be what has been described previously as constituting the link between the Virgo and Hydra–Centaurus superclusters (e.g., Hopp & Materne 1985; Richter 1987; TF87; Fairall *et al.* 1989; Saunders *et al.* 1991; Strauss *et al.* 1992a; and Hudson 1993). Some of the underdense regions present in Fig. 2(a) are still seen in Fig. 2(b), though in general smaller. The galaxies at about (15^h, 3000 km s^{-1}), suggest the presence of a poor cluster, probably S 773 (ACO).

In panel 2(c) the Hydra–Centaurus supercluster becomes prominent at ($10^h\,40^m$, 4000 km s^{-1}), and the distortion due to virial motions is apparent. The other major feature in this panel is the Hydra Void in the background of the Hydra cluster. Other smaller groups are also visible, both in the Centaurus Concentration and in the complex of galaxies associated with the Hydra and Antlia clusters.

Figure 2(d) is completely dominated by the main structures of the Hydra–Centaurus complex including the Hydra cluster ($10^h\,30^m$, 3500 km s^{-1}); a small portion of the Centaurus cluster ($12^h\,45^m$, 3000 km s^{-1}); the bridge between these two clusters, and finally the Centaurus Concentration located at (13^h–14^h, 4500 km s^{-1}). The Hydra Void is still present in panel 2(d) and is the large empty region behind the Hydra–Centaurus complex.

Finally, Figure 2(e) contains mainly galaxies of the Centaurus cluster, very prominent because of the distortion caused by virial motions, although the distribution of galaxies in this cluster is suggestive of multiple concentrations. The complexity of the Centaurus cluster has been discussed by Lucey *et al.* (1986, 1989) and a clearer dynamical picture is further complicated by the proximity of the Great Attractor (GA). The nominal center of the GA is also contained in this panel, at approximately ($13^h\,20^m$, 4200 km s^{-1}), but no obvious "finger of god" can be seen that could be associated to a centrally condensed GA. The low redshift galaxies in this plot belong to the de Vaucouleurs (1975) Centaurus group.

Because of the large induced peculiar velocities of galaxies in this region, we also investigated the galaxy distribution after applying velocity corrections based on the Faber & Burstein (1988) model. Although the relative positions of galaxies changed, the overall picture was still very similar to that presented above, and thus the basic interpretation of the distribution of galaxies was relatively unaffected.

4. THE NEARBY UNIVERSE

4.1 Three-Dimensional Maps

In this section, our emphasis will be in the identification of structures beyond the volume studied by TF87 while trying to relate these new features with those of TF87 to give a unified description of our local neighborhood. For this, we will use the sample of galaxies described in Sec. 2. In order to minimize the predominance of the foreground structures relative to those at larger distances, we have made a cut in absolute magnitude, such that only galaxies that would be included in the catalogue, if placed at a distance of 4000 km s^{-1} or further, will be considered in the sample.

In Fig. 3 we present the galaxy distribution of the combined optical samples. Here we have adopted Cartesian supergalactic coordinates, with projections identical to those used by Bertschinger *et al.* (1990) and Freudling *et al.* (1994), so that our plots can be easily compared to their results of the density field. In this representation the SGX-axis points to SGL$=0°$ and the SGY-axis points nearly in the direction of the north Galactic pole (de Vaucouleurs *et al.* 1976). Each row contains three parallel and nonoverlapping slabs 3000 km s^{-1} thick, with the middle slab centered on the Galaxy. We should remind the reader that some projections are affected by Galactic obscuration while the decrease of objects at larger distances is present in all panels. In Fig. 3 the SG$Y=0$ plane [panel (b)] is almost coincident with the Galactic plane while panels (a) and (c) contain galaxies situated in the Southern and Northern Galactic Hemispheres, respectively. The supergalactic plane is coincident with panel (e) of Fig. 3. As mentioned in Sec. 2, for the region between $-30° \leq b \leq +15°$ we have included galaxies observed by Dressler (1988, 1991). This allows us to probe the distribution of optical galaxies in the general direction of the GA, not covered by the magnitude-limited surveys. These galaxies are represented as crosses in Fig. 3 to remind the reader of the limited sky coverage and the different selection criterion (diameter limited) of this sample. Despite potential problems due to absorption, limited coverage in galactic longitude, and different selection criteria, this combined optical sample is useful to investigate the relation of the GA region to the other structures in the nearby universe.

To further help the description of the three-dimensional distribution of galaxies in the nearby Universe, we plot in Fig. 4 galaxies of the *IRAS* 1.9 Jy sample (Strauss *et al.* 1992b). By comparing Figs. 3 and 4 we benefit from the denser sampling of the optical catalogues coupled to the larger sky coverage of the *IRAS* sample. The former provides the necessary density of points to allow the identification of structures while the latter allows us to follow these structures through the Galactic plane. We note that no attempt to correct for peculiar motions has been made, nor do we make any correction for the loss of objects with distance for galaxies beyond 4000 km s^{-1}.

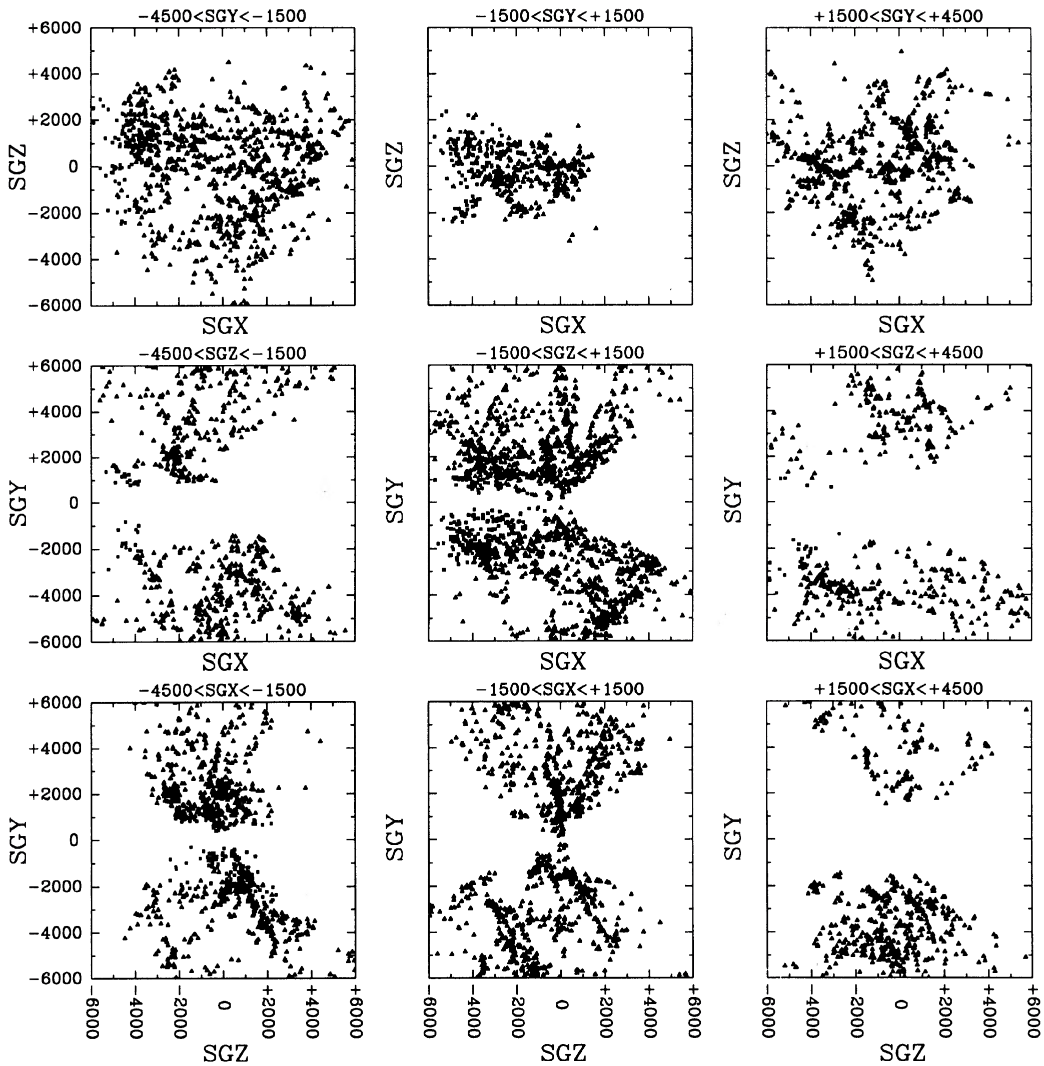

FIG. 3. Distribution of optically selected galaxies within 6000 km s^{-1} of the Local Group, semivolume limited to 4000 km s^{-1}. The projection is in cartesian Supergalactic Coordinates and each row represents a 3000 km s^{-1} slab along the SG*Y*[panels (a), (b), and (c)], SG*Z* [(d), (e), (f)] and SG*X* [(g), (h), (i)] axes. Triangles represents galaxies from magnitude-limited surveys and crosses galaxies from the diameter-limited Supergalactic Plane Survey of Dressler (1991).

Some prominent groups and clusters in this volume are labeled in Fig. 5. These groups and clusters, most of which contain at least 10 members with redshifts, were compiled from the literature (e.g., TF87; Huchra & Geller 1982; Geller & Huchra 1983; Haynes & Giovanelli 1988; Maia *et al.* 1989; Tully *et al.* 1992). We should note that these groups do not represent a proper uniform statistical sample selected at the same density contrast (e.g., Huchra & Geller 1982), although most resulted from identifications made with objective group-finding algorithms.

Here we have attempted to identify and describe only the major structures in the surveyed volume. This identification was carried out in the following way: we first inspected Figs. 3 and 4 and selected linear features in each of the panels. We then selected galaxies in a region around it, choosing the width from the original panel and the depth by looking at the adjacent panels along the same direction. Next its projection in the orthogonal directions was examined in order to determine its three-dimensional characteristics (wall-like, filament). After some experimentation we generated a sequence of figures where we isolated each individual structure, using for these plots both the optical and *IRAS* samples. These may be obtained from the authors upon request.

We should note that the definition of walls or sheets (typically two-dimensional structures) and filaments (mainly one-dimensional structures) is somewhat arbitrary as we do not use any objective algorithm to determine its coherence. The ease of detecting a structure also depends on its orientation relative to the adopted coordinate system. Most wall-like structures are not perfect planes nor do they have the galaxies uniformly distributed. When other projections are inspected, many of these structures may appear clumpy and irregular. However, since our primary goal is to label structures to ease the description of possible gravitational sources,

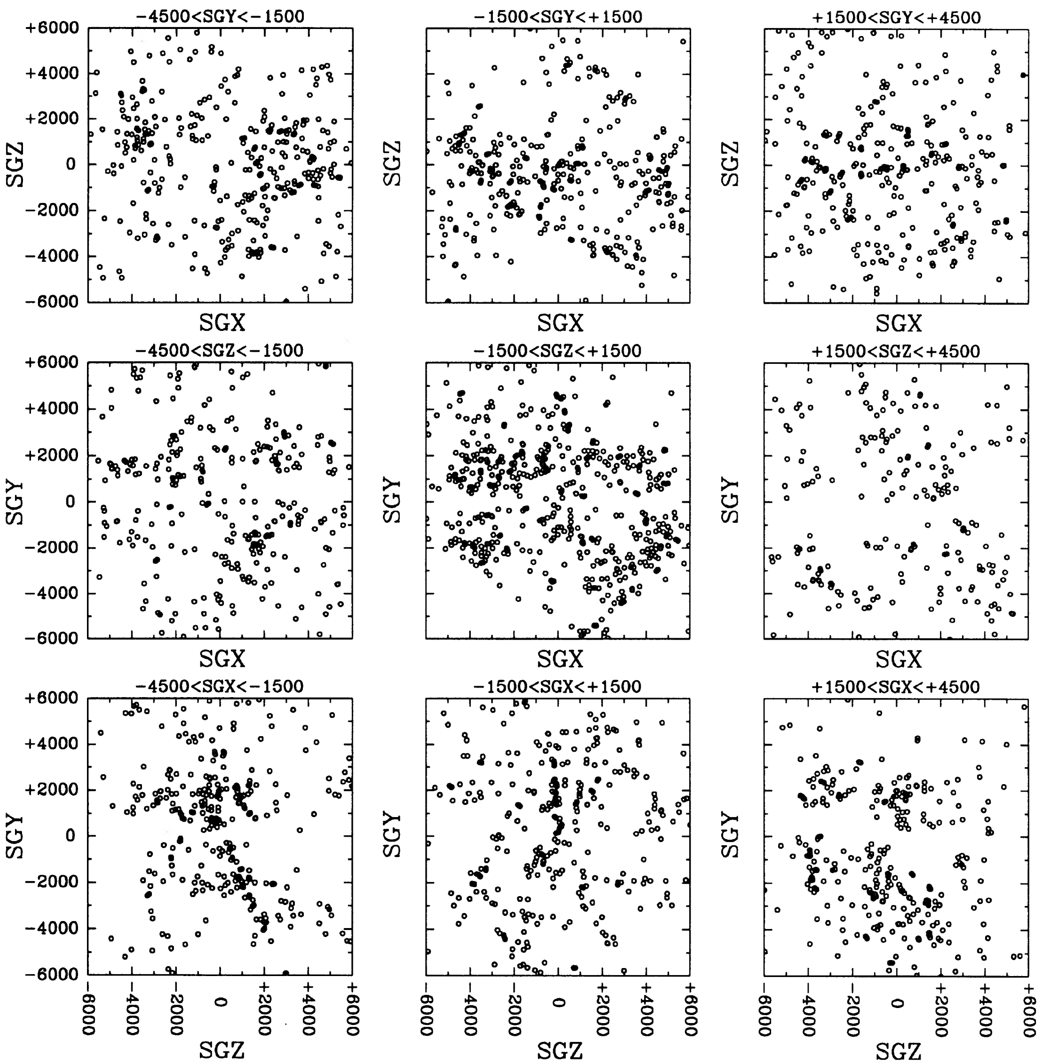

FIG. 4. Distribution of *IRAS* galaxies from the 1.9 Jy survey of Strauss *et al.* (1992b), semivolume limited to 4000 km s^{-1}. The overall impression is that both samples trace the same structures and that most of the features that populate the Galactic plane (SGY≈0 km s^{-1}) are extensions of structures that had already been detected by optical samples.

that may account for the observed or reconstructed peculiar velocity field, we have not employed any quantitative measure of the coherence and density contrast in the definition of each individual structure (but see below).

Other problems may affect our interpretation: the slabs shown are relatively thick and may lead, in some cases, to the superposition of different structures; virial motions in clusters and groups can also produce misleading elongations which may sometimes be confused with filmanetary structures; differences in the sampling rate of the optical and *IRAS* catalogues; and finally Galactic absorption, which affects data at low Galactic latitudes. Moreover, features that appear striking in a given panel may not be as easily identified in other projections, because in general these structures, if wall like, are not parallel to the slabs and, as mentioned above, are not uniformly populated.

Taking into consideration the above caveats, a total of 14 structures were identified, seven in each galactic cap. The figures showing the identified structures in isolation can be obtained from the authors upon request. In naming the structures we have tried to follow the existing nomenclature (e.g., TF87, KF, Saunders *et al.* 1991) whenever possible. In Fig. 6 we show a schematic representation of the main structures we identify in this section. For a better understanding Fig. 6 should be used together with Figs. 3 and 4. The units throughout this section are km s^{-1}.

4.2 Southern Galactic Hemisphere

The most outstanding wall-like structures in the volume we are considering are the closest part of the Southern or Sculptor Wall (SW), first identified by da Costa *et al.* (1988) and the Telescopium–Pavo–Indus wall (TPI). These are prominent in panels (g) and (h) of Fig. 3 and somewhat less

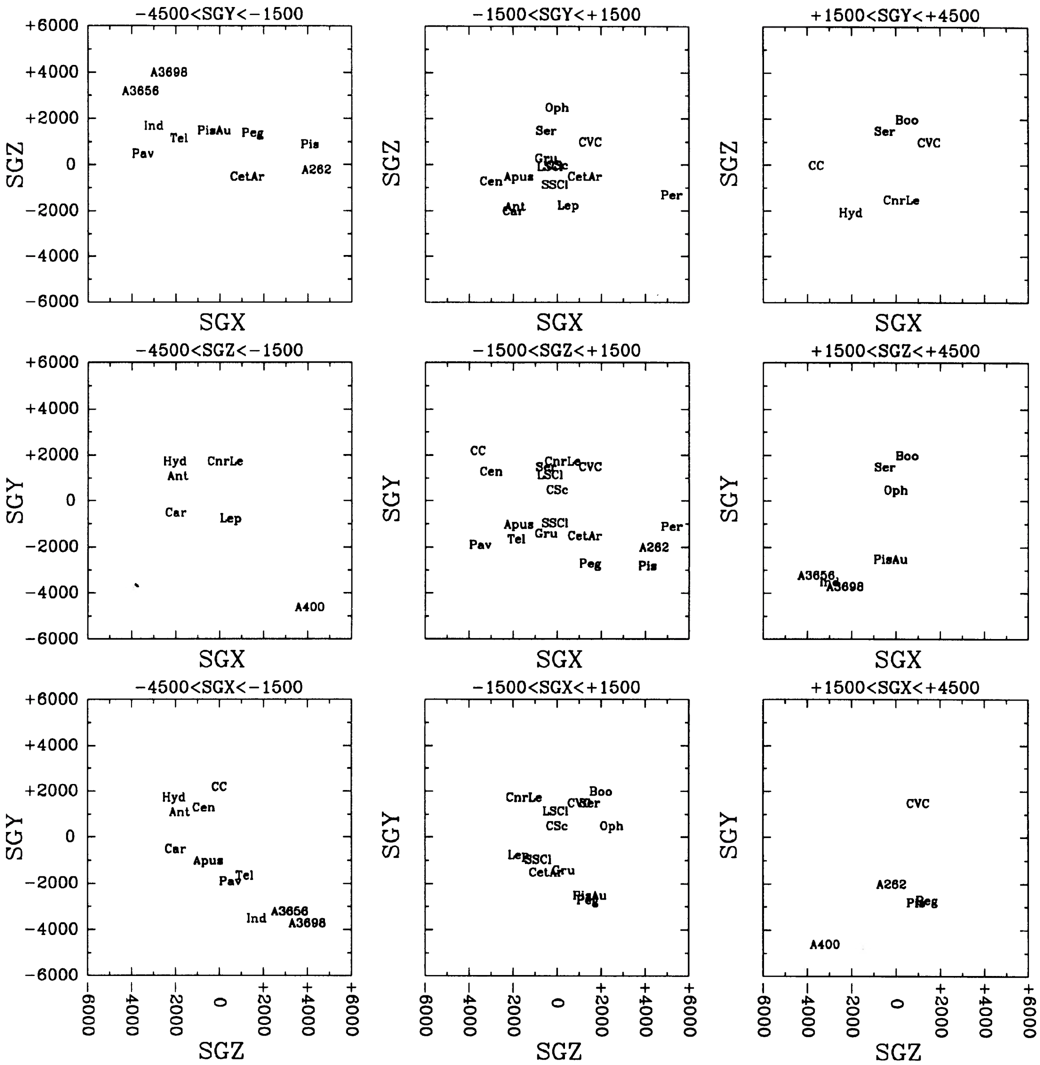

FIG. 5. Diagram showing the positions of some of the richer groups, clusters, and clouds of galaxies contained in the volume considered in this work. These were compiled from various catalogues of groups, and do not represent a homogeneous sample.

in Fig. 4. As can be seen in Figs. 3 and 4, these features extend for about 6000 km s^{-1}, and when seen face on present a clumpy distribution, alternating concentrations with small gaps. Inspecting Fig. 5 we see that the part of the Southern Wall within the volume surveyed contains no rich groups with bright galaxies, while TPI has various groups (e.g., Maia *et al.* 1989; Huchra & Geller 1982; de Vaucouleurs 1975; Sandage 1975) and clouds of galaxies (TF87).

These two walls seem to be connected by two smaller structures, the more distant Cetus sheet (CS in Fig. 6), originally described by Maurellis *et al.* (1990) and the Mensa–Octans sheet (MOS in Fig. 6), noted previously by Kraan-Korteweg (1992). These are most prominent in panels (g) and (h) of Fig. 3, respectively. Another prominent wall-like structure is the Aquarius wall (AqW) also identified by Hudson (1993) and best seen in panel (e) of Fig. 3. The Aquarius wall extends from the constellation of Pegasus towards the zone of avoidance and seems to contain the clusters associated with the Perseus–Pisces supercluster (e.g., Fig. 5).

The five structures above (SW, TPI, Aquarius, Cetus, and Mensa–Octans) also define two underdense regions which had been discovered by Winkler (1983), the Eridanus ($SGX=-1000$, $SGY=-3000$, $SGZ=-1000$) and Sculptor voids ($SGX=-1500$, $SGY=-4500$, $SGZ=-1000$), which correspond to voids 2 and 3 of da Costa *et al.* (1988). The outer edge of the Sculptor void is outside our volume but recent work (da Costa *et al.* 1989; Tully *et al.* 1992; Rhee & Katgert 1992; da Costa *et al.* 1994) has shown that this boundary is defined by the Cetus wall (Tully *et al.* 1992).

Two additional structures can be identified in the southern Galactic hemisphere. The Cetus–Aries cloud (TF87; CetAr in Fig. 6) which is prominent in panel (e) of Fig. 3 and that appears to intersect the Aquarius wall close to the position of the Perseus–Pisces supercluster. We should note that the latter is only partially contained in these maps due to the radial velocity cut. A sparser structure is the Lepus cloud (Lep),

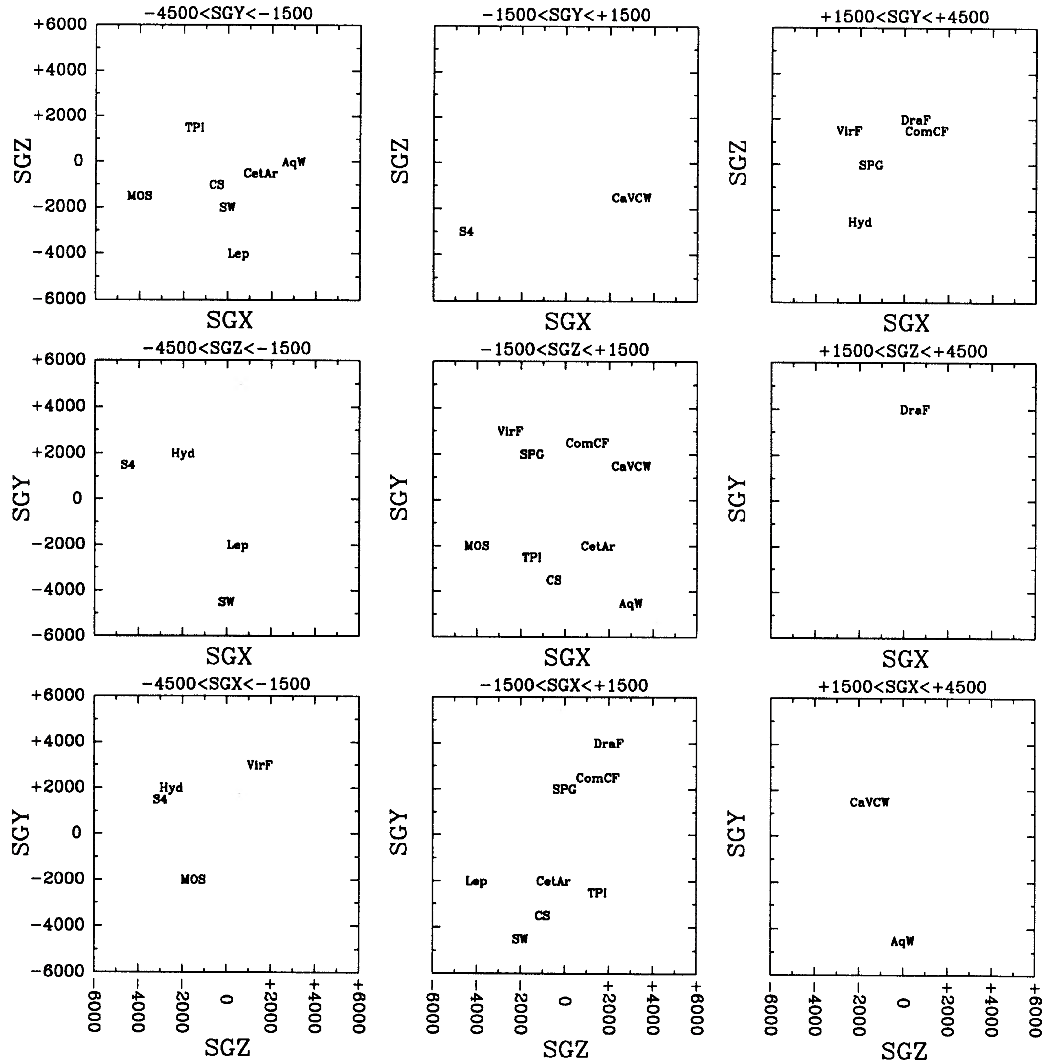

FIG. 6. Schematic diagram showing the rough positions of some of the main structures identified in the text.

also identified by TF87, barely visible in panel (h) of Figs. 3 and 4. Inspection of the latter suggests that it might extend into the zone of avoidance.

4.3 Northern Galactic Hemisphere

The most prominent structure in the northern Galactic hemisphere can be seen in Fig. 3(c) where it has a linear appearance at $SGZ \approx 0$ and is seen face-on in panel 3(e). This is the northern Galactic cap portion of the Supergalaxy (SPG), a name given by Lynden-Bell *et al.* (1988) to a large coherent structure that contains galaxies in both galactic hemispheres, which crosses the zone of avoidance (see Fig. 8 in their paper). The Supergalaxy contains the Local Supercluster and portions of the Hydra–Centaurus supercluster (particularly the Centaurus cluster). When seen in isolation, the Supergalaxy presents itself clumpier than any of the structures described above, being made up of several smaller concentrations. The nominal center of the GA is also contained in this structure at approximately ($SGX = -4000$, $SGY = 1400$, $SGZ = -400$).

Other structures can be identified in this Galactic hemisphere, though not as prominent. Most were identified in panel (c) of Fig. 3 and their locations are indicated in Fig. 6. The Hydra Complex has a wall-like appearance and it is formed by galaxies associated to the Hydra and Antlia clusters and the Centaurus Concentration. The Hydra Complex eventually intersects the Supergalaxy near the nominal position of the GA. The nearer edge of the Hydra Void (KF), centered at ($SGX = -4500$, $SGY = 3000$, $SGZ - 2000$), is defined by the Hydra Complex, the Supergalaxy, and S4 supercluster of Saunders *et al.* (1991).

Three additional filamentary structures seem to intersect the Supergalaxy, located in the constellations of Virgo (VirF), Draco (DraF), and Coma–Canes Venatici (ComCF). The filament in Virgo defines one of the boundaries of the Coma

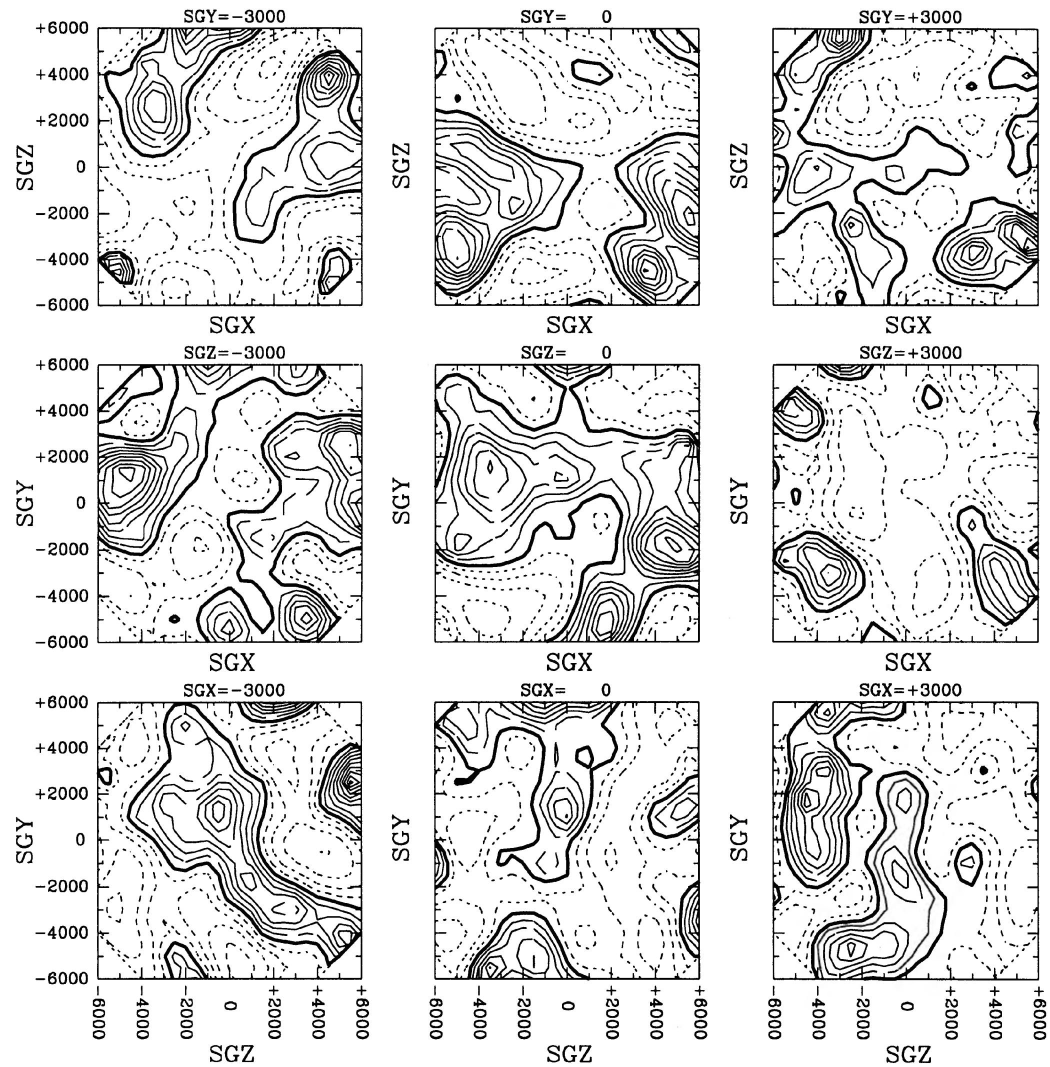

FIG. 7. Contours of the density field spaced by δ=0.2. Solid lines correspond to positive density fluctuations while dashed lines correspond to negative fluctuations. The thick solid line marks the δ=0 contour.

void, which is also delineated by the Supergalaxy and, outside the volume considered in this work, the Great Wall. This void is centered at about (SGX=$-$3000, SGY=3000, SGZ =2500). The structure in Draco, also of a filamentary nature, runs parallel to that in Virgo, and contains several small concentrations, among which is Serpens and Boötes (TF87). The filaments in Virgo and Draco are apparently connected by ComCF a somewhat tenuous sheetlike structure which extends in the direction of the zone of avoidance and possibly also intersects the Supergalaxy. Finally, two structures can only be defined using the *IRAS* sample, because of their low Galactic latitude, but which are fairly prominent. The first is the Canes Venatici–Camelopardalis (CavCW) wall, identified in panel (e) of Fig. 4, which might extend towards the Aquarius wall. The other structure corresponds to the S4 supercluster of Saunders *et al.* (1991) visible in panel (d) of Fig. 4.

4.4 Smoothed Density Field

Until now we have discussed the cosmography of our local vicinity based on a qualitative inspection of the point distribution. This was done for the sole purpose of helping to isolate what appear to be individual structures in the galaxy distribution and to show that wall-like structures are a common feature. In order to have a more quantitative picture of the relative prominence of the identified structures we show in Fig. 7 the smoothed density field computed from the combined optical-*IRAS* sample. Here we follow the procedure discussed in detail by Freudling *et al.* (1994). The density field is the result of a self-consistent reconstruction of the density and peculiar velocity field for the case of no relative bias between the optical and *IRAS* galaxies and taking into account the different selection functions of the optical and *IRAS* samples. The smoothed density field was computed in cells 500 km s^{-1} to the side and Gaussian smoothed with a scale of 500 km s^{-1}. We note that in contrast to previous figures we show the contours of the density contrast along the indicated planes rather than slabs 3000 km s^{-1} thick. Therefore is not surprising that there is not a one-to-one correspondence between the structures seen in Figs. 3 and 4 and those in Fig. 7.

As can be seen most of the features identified above seem to form coherent structures with an overdensity $\delta > 0.2$ with much high density contrast structures embedded within them. In the southern galactic cap, structures like TPI, AqW. CetAr, and SW seem to be unquestionably real, forming large coherent structures. Others like MOS, CS, and Lep are not seen but it is important to recall that we only show a plane rather than a slab. In the northern galactic cap structures like SPG, Hyd, S4, and CaVCW are all clearly visible. Even less outstanding structures like ComCF can be seen to form lower contrast features with $\delta \approx 0.1$, while DraF and VirF are not seen.

The inclusion of fainter galaxies coupled to the correction by the selection function makes more distant structures rather more prominent in Fig. 7 than in the previous figures. This effect is particularly striking in the upper-left-hand corner of panel (a) in Fig. 7, where we see a projection of TPI which seems to include the clusters A3656/A3698; in the upper left-hand corner and lower right-hand corner of panel (c) in Fig. 7, both delineated by *IRAS* galaxies; in panel (h) of Fig. 7 where one sees the connection between the SPG and the nearside of the Great Wall. Panel (c) also illustrates remarkably well the fact that the region of the GA is an intersection of several structures which include Hyd, SPG, S4, and the one described above. Besides confirming our description based on the point distribution these contour maps lend further support to the claim that the galaxy distribution consists of extended, coherent wall-like structures.

5. SUMMARY

In this paper we have examined the galaxy distribution in the general direction of the Hydra–Centaurus supercluster, and subsequently how this complex relates to other structures in the nearby Universe, in order to understand the overall nature of the three-dimensional distribution of galaxies. This was done using a wide-angle, magnitude-limited sample, covering $\approx 50\%$ of the sky and the 1.9 Jy survey of Strauss *et al.* (1992b), to probe low Galactic latitude regions. However, we should point out that our conclusions are only partially dependent on the *IRAS* data, since most of the major structures extend out of the zone of avoidance. As shown in Sec. *4.4* they are also not sensitive to peculiar motions.

The description of the galaxy distribution in our vicinity is meant to underscore the following points.

(1) The distribution of galaxies in the nearby Universe appears to consist of a complex cellular network, qualitatively similar to that inferred from ongoing deeper surveys (Geller & Huchra 1989; Shectman *et al.* 1992; da Costa *et al.* 1994). The nearby Universe appears to be void filled, with galaxies tending to lie on primarily wall-like structures between interconnecting voids. The characteristic size of voids ranges from about 2000 to 5000 km s^{-1}. Some examples of large voids are the Sculptor, Hydra, and Coma voids.

(2) Although *IRAS* galaxies are of great importance in understanding the distribution in the zone of avoidance, the 1.9 Jy survey is very sparse, undersampling important structures even within 6000 km s^{-1}.

(3) The GA region appears to be located near the intersection of several structures perhaps including the Supergalaxy, Telescopium–Pavo–Indus, Lepus, Hydra, and the S4 superclusters. The location of the GA near the intersection of several structures may explain why this region is overdense, thus playing an important role in the local velocity flows. This may explain the amorphous nature of the distribution of galaxies in the direction of the GA noted by Dressler (1991). An understanding of the observed geometry of the galaxy distribution in the GA direction may help the interpretation of the measured peculiar velocities of galaxies and may help settle the controversy concerning the existence of a backside infall (Dressler & Faber 1990, Mathewson *et al.* 1992).

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REFERENCES

Abell, G. O., Corwin, H. G., & Olowin, R. P. 1989, ApJS, 70, 1 (ACO)

Bertschinger, E., Dekel, A., Faber, S. M., Dressler, A., & Burstein, D. 1990, ApJ, 364, 370

da Costa, L. N., *et al.* 1994, ApJ, 424, L1

da Costa, L. N., Nunes, M. A. Pellegrini, P. S., Willmer, C., Chincarini, G., & Cowan, J. J. 1986, AJ, 91, 6

da Costa, L. N., Pellegrini, P. S., Davis, M., Meiksin, A., Sargent, W. L. W., & Tonry, J. 1991, ApJS, 75, 935

da Costa, L. N., *et al.* 1988, ApJ, 327, 544

da Costa, L. N., Pellegrini, P. S., Willmer, C., & Latham, D. W. 1989, ApJ, 344, 20

da Costa, L. N., Willmer, C., Pellegrini, P. S., & Chincarini, G. 1987, AJ, 93, 1338

Davis, M., Huchra, J., Latham, D., & Tonry, J. 1982, ApJ, 253, 423

de Vaucouleurs, G. 1975, in Stars and Stellar Systems, Vol. 9, edited by A. Sandage, M. Sandage, and J. Kristian (University of Chicago Press, Chicago), p. 557

de Vaucouleurs, G., de Vaucouleurs, A., & Corwin, H. G. 1976, Second

Reference Catalog of Galaxies (University of Texas Press, Austin)
Dressler, A. 1988, ApJ, 329, 519
Dressler, A. 1991, ApJS, 75, 241
Dressler, A., & Faber, S. M. 1990, ApJ, 354, L45
Faber, S. M., & Burstein, D. 1988, in Large-Scale Motions in the Universe, edited by V. C. Rubin and G. C. Coyne (Princeton University Press, Princeton), p. 115
Fairall, A. P., & Jones, A. 1991, Publ. Astron. Dept. UCT, 11, 1
Fairall, A. P., *et al.* 1992, AJ, 103, 11
Fairall, A. P., Vettolani, G., & Chincarini, G. 1989, A&AS, 78, 269
Felten, J. E. 1985, Comm. Ap, 11, 53
Feudling, W., da Costa, L. N., & Pellegrini, P. S. 1994, MNRAS, 268, 943
Geller, M. J., & Huchra, J. P. 1983, ApJS, 52, 61
Geller, M. J., & Huchra, J. P. 1989, Science, 246, 897
Giovanelli, R., & Haynes, M. P. 1991, ARA&A, 29,499
Haynes, M. P., & Giovanelli, R. 1988, in Large-Scale Motions in the Universe, edited by V. C. Rubin and G. C. Coyne (Princeton University Press, Princeton), p. 31
Hopp, U., & Materne, J. 1985, A&AS, 61, 93
Huchra, J. P. 1989, private communication
Huchra, J. P., Davis, M., Latham, D., & Tonry, J. 1983, ApJS, 52, 89
Huchra, J. P., & Geller, M. J. 1982, ApJ, 257, 423
Huchra, J. P., Latham, D. W., da Costa, L. N., Pellegrini, P. S., & Willmer, C. N. A. 1993, AJ, 105, 1637
Hudson, M. J. 1993, MNRAS, 265, 43
Kauffmann, G., & Fairall, A. P. 1991, MNRAS, 248, 313 (KF)
Kraan-Korteweg, R. C. 1992, in Variable Stars and Galaxies, ASP Conf. Ser. Vol. 30, edited by B. Warner (Brigham Young University, Provo), p. 235
Lauberts, A. 1982, The ESO/Uppsala Survey of the ESO(B) Atlas, (ESO, Garching)
Lauberts, A., & Valentijn, E. A. 1989, The Surface Photometry Catalogue of the ESO-Uppsala Galaxies (ESO, Garching) (ESO-LV)
Lucey, J. R., Currie, M. J., & Dickens, R. J. 1986, MNRAS, 221, 427
Lucey, J. R., Lahav, O., Lynden-Bell, D., Terlevich, R. J., & Melnick, J. 1989, in Large-Scale Structures and Peculias Motions, ASP Conf. Ser., Vol. 15, edited by D. W. Latham and L. N. da Costa (Brigham Young University, Provo), p. 31
Lynden-Bell, D., Faber, S. M., Burstein, D., Davies, R. L., Dressler, A., Terlevich, R. J., & Wegner, G. 1988, ApJ, 326, 19
Lynden-Bell, D., Lahav, O., & Burstein, D. 1989, MNRAS, 241, 325
Maia, M. A. G., da Costa, L. N., & Latham, D. W. 1989, ApJS, 69, 809
Mathewson, D. S., Ford, V. L., & Buchhorn, M. 1992, ApJS, 81, 413
Maurellis, A., Fairall, A. P., Matravers, D., & Ellis, G. F. R. 1990, A&A, 229, 75
Pellegrini, P. S., da Costa, L. N., Huchra, J. P., Latham, D. W., & Willmer, C. N. A. 1990, AJ, 99, 751
Rhee, G., & Katgert, P. 1992, AJ, 103, 1438
Richter, O. G. 1987, A&AS, 67, 237
Sandage, A. 1975, ApJ, 202, 563
Saunders, W., *et al.* 1991, Nature, 349, 32
Shectman, S. A., Schechter, P. L., Oemler, A. A., Tucker, D., Kirshner, R. P., & Lin, H. 1992, in Clusters and Superclusters of Galaxies, edited by A. C. Fabian (Kluwer, Dordrecht), p. 351
Strauss, M. A., Davis, M., Yahil, A., & Huchra, J. P. 1992a, ApJ, 385, 421
Strauss, M. A., Huchra, J. P., Davis, M., Yahil, A., Fisher, K. B., & Tonry, J. 1992b, ApJS, 83, 29
Tully, R. B., & Fisher, J. R. 1987, Nearby Galaxies Atlas (Cambridge University Press, Cambridge) (TF87)
Tully, R. B., Scaramella, R., Vettolani, G., & Zamorani, G. 1992, ApJ, 388, 9
Vorontsov-Velyaminov, B. A., Krasnogorskaya, A. A., & Arkhipova, V. P. 1962–1968, Morphological Catalogue of Galaxies, Parts 2–4 (Moscow University, Moscow)
Willmer, C. N. A., Focardi, P., Chan, R., Pellegrini, P. S., & da Costa, L. N. 1991, AJ, 101, 57
Winkler, H. 1983 MNASSA, 42, 74
Zwicky, F., Herzog, E., Wild, P., Karpowicz, M., & Kowal, C. 1962–1968, Catalog of Galaxies and Clusters of Galaxies (Caltech, Pasadena)