REDSHIFTS AND LARGE SCALE STRUCTURES

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The effort to measure the geometry of space by experiment, that is, the determination of the Hubble Constant, H_0, and of the deceleration parameter, q_0, led toward the end of the first half of the century, to the classical paper by Humason, Mayall, and Sandage (1956). Their catalogue contains 920 redshifts collected over a twenty-year period (1935-1955). Further redshifts of galaxies were measured to refine such determinations and to study the dynamics of clusters (Zwicky 1933).

With the advent of fast optics, it became possible to systematically observe faint objects. Page (1960) and Burbidge (1975) attacked the problem of the determination of the masses of galaxies. Minkowski (1958), among others, obtained spectra of radio sources. Schmidt (1963) observed and interpreted the spectra of quasars; Mayall (1960) and Zwicky (1957), among others, called further attention to the dynamics of clusters of galaxies, etc. It was, however, only after the advent of panoramic intensified detectors, following the pioneering work of Lallemand (1962) that redshift surveys of large samples of galaxies became feasible. Some of these surveys, which had been planned to investigate the size of clusters of galaxies, naturally led to the problem of the large scale space distribution of galaxies.

As discussed by Professor Oort (1983) at this symposium, such surveys revealed a segregation in the distribution of redshifts, the presence of very large structures, $\gtrsim 50\ h^{-1}$ Mpc, and the presence of regions which, down to the limiting magnitude of the sample, are void of galaxies. Voids seem not to be in contradiction with gravitational clustering models (Aarseth and Saslaw 1982) and well accounted for in the work of Doroshkevich, Shandarin and Zeldovich (1982). Their dynamical effects as negative density fluctuations have been studied by Peebles (1982) and Salpeter (1983). They tend to form over density ridges and to cause small fluctuations in the velocity field of the order of 100 to 350 km/sec.

The presence of empty regions of space contradicts the concept of a uniform background density of galaxies as conceived by Hubble (1934) and, in a somewhat different form, by Zwicky (see Chincarini 1982). If

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such backgrounds exist, voids can be used to set an upper limit to the background density.

On purely observational grounds, we cannot exclude that such voids may be populated by faint galaxies (in this case, however, we would have to explain variations of the luminosity function on a scale size of the voids) or by other forms of matter.

In addition to surveys in selected regions of the sky, we need to understand: 1) the structure and dynamics of the local supercluster (see early maps by Shapley and Ames, 1932, and the work by de Vaucouleurs over the last 30 years, 1978, and references therein); 2) the distribution of galaxies over the whole sky; and 3) the discrepancies in the measurements of the density parameter, Ω, as derived from different samples and methods. Efforts in these directions have produced: 1) the 21-cm survey by Fisher and Tully (1981); 2) the survey by Sandage (see the revised Shapley-Ames catalogue of bright galaxies by Sandage and Tammann 1981); and 3) the Harvard Survey by Davis, Huchra, Latham and Tonry (1982). Other surveys, for instance the one by Rubin, Thonnard, Ford and Roberts (1976), have been very significant in supplying a useful data base, in measuring the anisotropy of the Hubble flow and in stimulating research in this direction. The Rubin-Ford effect is not yet fully understood.

All this work contributed to form a redshift data base that, according to the catalogue by Palumbo, Tanzella-Nitti and Vettolani (1982), updated to 1980, amounts to 13,672 redshift measurements of 8250 galaxies with cz $\leq$ 100,000 km/sec. Huchra is presently compiling a catalogue with entries for about 9000 galaxies, so that we can estimate we have at the present 12,000 to 14,000 published and unpublished redshifts of galaxies. A large contribution to this has been given by recent surveys, yet to be published, carried out in 21-cm at the Arecibo Observatory. Finally, according to M.P. Veron (1982), there are at present redshifts for about 1800 quasars.

Clusters as Markers of the Large-Scale Structure

Abell (1958) noticed that the distribution of clusters is not random and measured a cell size of about 40 h^{-1}. His catalogue and subsequent redshift measurements (Sarazin *et al*. 1982 list redshifts for about 329 clusters) have been the objects of various statistical analysis; among them are Kiang (1967), Kiang and Saslaw (1969), Hauser and Peebles (1973) and Rood (1976). Einasto and his collaborators (1980) used clusters to map large-scale structures, in particular the Perseus/Pisces region. Most recently, Bahcall and Soneira (1982) obtained the important result that clusters are correlated to separations of about 150 h^{-1} Mpc.

Clusters present, however, some limitations in the study of the large structures (superclusters) and in their use as markers of the distribution of matter. Clusters, in fact, define the density peaks of the large structures so that the information is limited to the location of the large density enhancements. Furthermore, as pointed out by Peebles (1980), the contrast in density for clusters is larger than the contrast in density for galaxies so that both clusters and galaxies cannot be good tracers of the large-scale mass distribution. The galaxies seem to be more reliable.

Galaxies allow one to map regions of low density, to study the effects of environmental conditions, and in a more reliable way to study the geometry of the large structures and to measure the deviations from the Hubble flow.

Geometry and Peculiar Motions

It is quite clear from the redshift-defined structures that their shape is highly asymmetric. In most cases, no limit of the structure has been found within the region of the sky sampled so that there may be continuity from one structure to the other. While the shape may partly depend on "how" we define the structure as mapped by the redshift surveys, filaments (often spaghetti-like?) seem to be quite common and I do not see much evidence of predominant pancake structures or of a defined cell size as suggested by Corwin (1981). On the other hand, within such structures a scale size can be defined by the two-point angular correlation function. This is in agreement with the slope of the cosmic correlation function derived by Peebles.

Evidence of the above statements is observed in the Her/A2197-99 supercluster which extends in the Serpens-Virgo region and may then continue toward Coma. Even more impressive is the sample in Perseus-Pisces and I refer to its discussion by Giovanelli (1983).

I find it quite interesting that some of these structures are very narrow, at least in one dimension. The velocity dispersion along the line of sight for Perseus-Pisces, Coma A1367 and Horologium is $\sigma \leq$ 500 km/sec. Selected features have velocity dispersions which are even smaller. The velocity dispersion may be partly contaminated by peculiar motions (however, away from concentration of matter - clusters - perturbations of the velocity field are expected to be small). Structures in Perseus-Pisces are thin, also, as seen projected on the celestial sphere. The Lynx-Ursa major supercluster observed by Giovanelli and Haynes (1982) has a projected width of only a few megaparsecs. It cannot be that in all cases we are observing projection effects in disk-like structures. Neither do I see evidence, at the present, that the geometry could be determined by the observational definition of a structure or by the limitation of the samples. The dispersed supercluster component (non-cluster galaxies) is not very luminous and is of about $5 \times 10^{10}\ L_{\odot}/\mathrm{Mpc}^2$. Determination of distances by the Tully-Fisher effect will allow deeper understanding of the geometry and possibly the measurement of non-Hubble velocities near noncluster density peaks. Such a program is now in progress.

Except for the local supercluster, little is known about peculiar motions. As is known, infall velocities in a local and fair (large enough) sample of the universe and measurements of the two-point angular correlation function in the direction parallel and perpendicular to the line of sight $\xi(\sigma,\pi)$ allow, following the method outlined by Peebles (1980), a measure of the density parameter Ω. Such determinations are unaffected by virialization (clusters) or evolutionary (q_o) problems and, assuming a fair sample, should give a realistic value of Ω. The value determined by the above methods oscillates, at present, in the range of 0.1 to 0.3 (Davis and Peebles 1982). It is such values that point to an open universe and yet they are too large to be consistent with the primordial helium abundance if the matter density is dominated by baryons ($\Omega b\ ho^2 \simeq 0.01$). To conclude, I see some of the future observational work aimed at: 1) better defining the geometry of the large structures; and 2) tackling the difficult problem of non-Hubble flow in selected structures. Advances and new experiments in high-energy physics will tell us whether the helium problem can be solved by massive neutrinos.

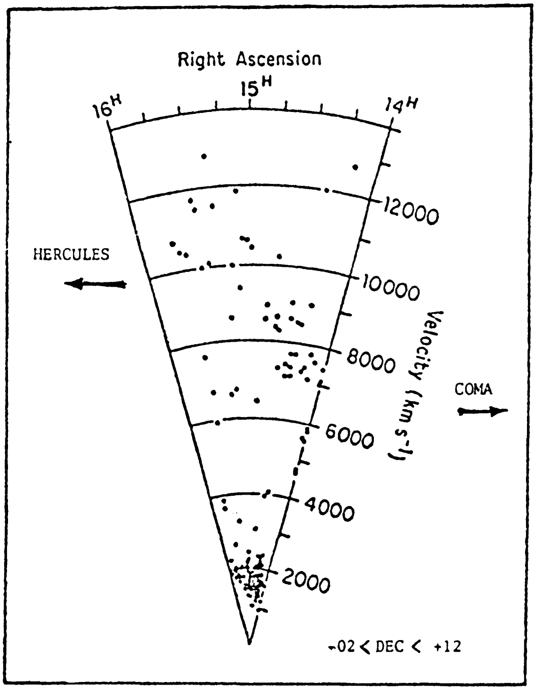

Fig. 1. Cone diagram of a sample of galaxies in the southern extension of the Hercules supercluster. It may be indicative of a connection to the Coma supercluster. (from Giovanelli Haynes, 1982)

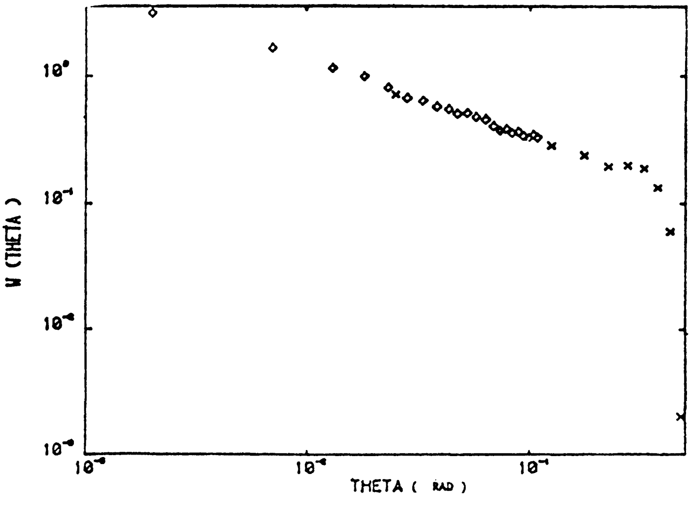

Fig. 2. Two-point angular correlation function for the Perseus-Pisces supercluster.

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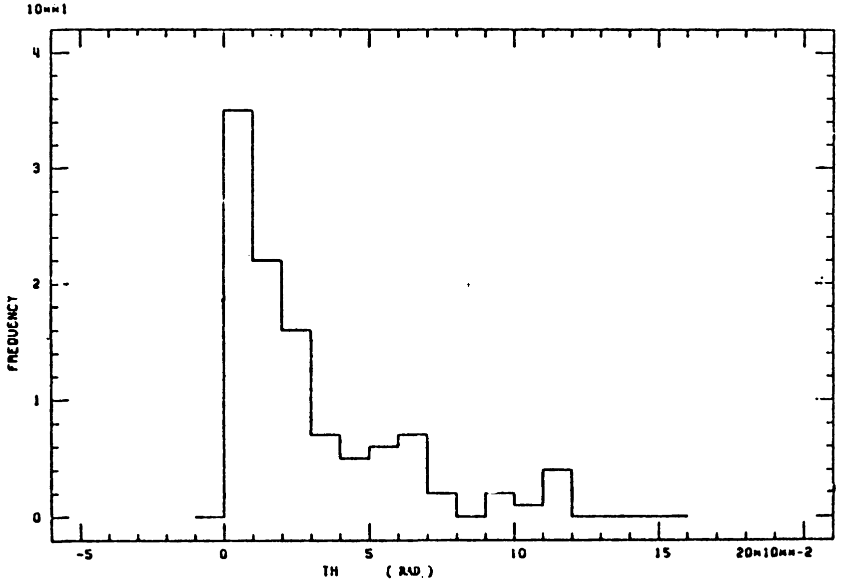

Fig. 3. Integrated width on the celestial sphere of the Perseus-Pisces supercluster (0.01 rad $\simeq$ 1 Mpc, H_o = 50 km/sec/Mpc).

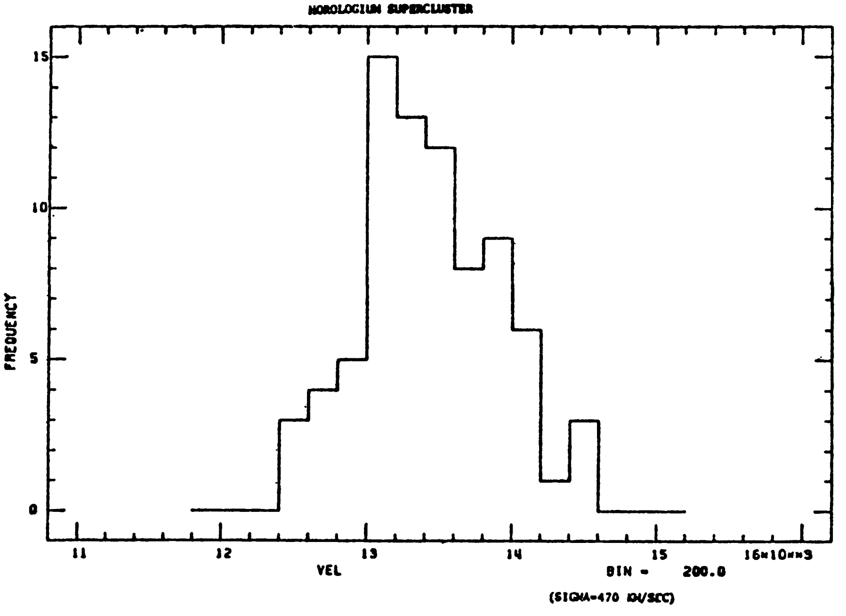

Fig. 4. Redshift distribution of the clump at V = 13436 in the Horologium supercluster.

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DISCUSSION

Inagaki: My question is similar to that of Prof. Dick Miller to Prof. Oort. Are there aggregations of galaxies ranging continuously from small groups to superclusters or are they hierarchical?

Chincarini: A cluster size can be defined dynamically or by using density criteria. Since clusters are embedded in superclusters with no discontinuity in the number density distribution of galaxies (see, for instance, Coma-A1367), clusters fade into superclusters, and a clear separation in the density distribution is not possible. In the redshift-defined large structures (for example, Coma-A1367 and Perseus-Pisces), supercluster clusters and groups are embedded in the structure and appear as density enhancements, which are probably bound. (For some groups the observations are equivocal, however.) I see no evidence of a purely hierarchical structure, groups of groups or clusters of clusters, independent of their supercluster environment.

Ellis: Would you comment on the existence of large structures as general features of the galaxy distribution? Redshift surveys in "interesting areas" may reveal such structures, but their significance as general features can be assessed only by performing deep surveys in randomly-chosen directions. The AAT survey (Bean et al., this symposium) do not show statistically convincing evidence for these large-scale features.

Chincarini: Certainly we need to have a fair sample of the universe, as you suggest. I believe that such samples are available. The observations I made with Martins (1975) refer to a noncluster region (Seyfert sextet). Structure is seen in the horologium sample (poster by Chincarini et al.), and especially in Perseus-Pisces, the Arecibo sample presented by Giovanelli (this covers a region of 30° in declination and 6h in right ascension), Hercules, and Coma-A1367. Finally, I refer to the work of Kirshner et al. and Davis et al. (Harvard Survey). If a sample does not show a similar structure, I am not surprised, since it may reflect the distribution of objects in that region and depend on various inclination effects of the structure. I am not familiar with your sample; it may reflect, however, a region of small density fluctuations. To use the correlation function analysis (your poster). You may possibly need a smooth distribution in depth. Finally, there seems to be no contradiction with some models in what is observed (see Shandarin, these proceedings). I hope deeper surveys will soon be available so that we can better understand the proposed geometry.