TWO QUESTIONS
ABOUT THE LARGE-SCALE DISTRIBUTION OF GALAXIES

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ABSTRACT. Observations and interpretation of the observations of the large-scale galaxy distribution prompt a number of profound questions to which we do not yet have clear answers. In this discussion I review two of the questions discussed during the symposium.

(1) *Are the properties of individual galaxies a strong function of the local density?*

We have known for a while that there is a relation between the morphology of a galaxy and the local density (Hubble and Humason 1931; Dressler 1980; Dressler 1984; Postman and Geller 1984). There are suggestions that the luminosity, mass and/or surface brightness of galaxies may also be correlated with local density (Davis and Djorgovski 1985; Haynes 1987). The search for some of these correlations has been prompted by cold dark matter models for the formation of large-scale structure (see e.g. Dekel and Silk 1986).

Riccardo Giovanelli's contribution to this symposium lays out evidence for a relationship between the luminosity of galaxies and the local density. This result is somewhat difficult to reconcile with the results of the Center for Astrophysics redshift survey (de Lapparent, Geller, and Huchra 1986; Huchra 1987). In this survey, we find that structures do not change as we change the magnitude limit. In other words, these surveys indicate that the distribution of galaxies is nearly independent of luminosity for $M_{B(0)} \lesssim -17.4$ (see also Postman, Huchra, and Geller 1986). It is important to reconcile the apparent discrepancy between these two conclusions and to determine the contribution of observational biases relative to genuine physical effects.

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Another closely related issue has also elicited discrepant results: is the surface brightness of individual galaxies a function of local density? Davis and Djorgovski (1985) published the first analysis of existing data and concluded that the data support a correlation. Later Bothun *et al.* (1986) and Thuan, Gott, and Schneider (1987) obtained new data and reached the opposite conclusion. Here again the problems may reside in the detailed properties of the catalogues of galaxies on which the analyses are based. Again resolution of the issue with better defined samples (especially in the photometric properties of the galaxies) is important for testing the predictions of the models.

A perhaps more extreme test is the distribution of neutral HI clouds in low density regions. As suggested by biased galaxy formation models, these clouds could be galaxies which failed to light up. Riccardo Giovanelli, Ed Salpeter, and Renzo Sancisi each commented briefly on the stringent limits placed by direct searches and by examination of off-beams in 21-cm redshift survey observations. HI clouds are certainly not abundant in regions of low galaxy density.

(2) *How good are limits on structures in the galaxy distribution larger than ~ 100 Mpc and how do we best approach the challenge of setting limits?*

One of the remarkable features of the surveys we have so far is that the largest structures we see are comparable with the depth of the survey. The first survey of Boötes (Kirshner *et al.* 1981) uncovered what was originally thought to be an unusually large structure. However, every other survey large enough to contain such a large structure does so. Large angular scale surveys in both the northern (de Lapparent, Geller, and Huchra 1986) and southern (da Costa *et al.* 1987) hemispheres reveal voids with diameters of 5000 km s^{-1}. Deep probes, though less constraining, indicate comparable or even larger structures (Koo, Kron, and Szalay 1987). The common occurrence of large voids has sobering implications for attempts to determine the mean properties of the galaxy distribution (de Lapparent, Geller, and Huchra 1987); for the two complete slices of the CfA survey extension (including 1761 galaxies) the uncertainty in the mean density is 25%.

The Meunster Redshift Project is an attempt to map the distribution of galaxies on very large scales by extracting redshifts from objective prism plates (Seitter 1987). The difficulty with this approach is that the errors in the redshifts are large, $\sigma_z \simeq 0.03$, larger than the diameters of the voids detected to date.

Deep number counts probably still provide the best limits on gigaparsec-scale inhomogeneities. Tyson's (1987) counts of galaxies in nine deep CCD fields provide no evidence for systematic number count variations over scales ~ 2000 h^{-1} Mpc.

Redshift surveys and counts of individual galaxies directly reveal structures on scales of order 100 h^{-1} Mpc and seem to rule out gigaparsec-scale inhomogeneities. Inhomogeneities in the range between $\sim$ 100 $^{-1}$ Mpc and a gigaparsec are poorly, if at all, constrained. A strategy to limit the existence of structures on these scales might include well-calibrated photometric surveys combined with deep, small angular scale redshift surveys. Effective design of these surveys is dictated by the character of the structures (de Lapparent, Geller, and Huchra 1987).

The distribution of rich clusters may also be a useful probe of structure on very large scales (c.f. Bahcall and Soneira 1984a; Postman, Geller, and Huchra 1986). The relationship between individual galaxies and clusters of galaxies as tracers of the large-scale matter distribution is not yet well understood. The amplitude of two-point cluster correlation function is an order of magnitude larger than one would predict naïvely from the galaxy correlation function. There also appears to be power on scales $\sim$ 100 h^{-1} Mpc in the cluster correlation function.

In addition to the general statistics, individual structures (voids and superclusters) identified in cluster catalogs seem to provide evidence for structure on scales of a few hundred megaparsecs (Bahcall and Soneira 1984b; Batuski and Burns 1985). However, the significance of these structures has been questioned by Otto *et al.* (1986). The problem is that clusters of galaxies are very sparse tracers of large-scale structure: the typical separation of the clusters is comparable with the scale of the identified structures. Further problems may result from inadequacies in the cluster catalogs themselves. The correspondence between "fingers" in redshift space and the cluster catalogs is less tight than one might hope (Huchra 1987).

The obvious solution to the problem of clusters as large-scale tracers is the acquisition of galaxy redshift survey data extensive enough to include many rich clusters. The completion of the CfA redshift survey extension to $m_{B(0)} = 15.5$ should make a significant contribution to the resolution of this issue.

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