SURVEY OF THE BOOTES VOID

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ABSTRACT. Radial velocities have been measured for 231 galaxies chosen by apparent magnitude from 282 small fields spanning the area on the sky thought to contain the Bootes void. The galaxy distribution exhibits a spherical volume 6000 km/s in diameter in which no objects are found. The rms velocity difference of close pairs in our sample is less than 180 km/s.

INTRODUCTION

Based on an apparent-magnitude limited radial velocity sample of galaxies in just three fields, separated from each other by typically 30° on the sky, we supposed that a large volume of space in the direction (α, δ) = (14h40m, +50°) might be empty of galaxies in the velocity range from 12,000 to 18,000 km/s (Kirshner, Oemler, Schechter and Shectman, 1981). In this case, much of the area of the sky between our three fields should exhibit the same gap in the distribution of galaxy radial velocities.

OBSERVATIONS

In order to effectively sample the galaxy distribution in such a large volume, we have conducted a new survey in 282 small fields distributed on the sky between the original three. Each new field has an area of .0625 sq. deg.

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Photographic enlargements of the 282 fields, made at Kitt Peak from glass copies of the red Palomar Sky Survey plates, were distributed to the 4 collaborators. The fields were chosen in two batches, 122 for the 1981 observing season and 160 for 1982. For each batch, each of us compiled a list of galaxies in order of estimated apparent magnitude. An averaging procedure was used to produce a master list of galaxies ranked in order of brightness. Because of the increased contrast of the photographic enlargements, there is a tendency to overestimate the luminosity of galaxies of lower surface-brightness. Variations in photographic sensitivity, both on the original plates and in the copying process, also contribute scatter to the final rankings.

Radial velocities for galaxies on the lists were measured from optical spectra obtained with the cassegrain spectrographs at the Palomar 5-meter telescope, with the Reticon photon-counting detector, and at the Kitt Peak 2.1-meter telescope, with the IIDS. The velocity sample is roughly complete above the limiting rank. The overall distribution of velocities is not very different from more rigorously chosen photometric samples, with a moderate enhancement of low velocity, low surface-brightness galaxies.

Figure 1a shows the positions on the sky of the 282 fields. The 1981 fields were evenly distributed on a grid in the sampled area. Based on the results from the first 102 velocities, the 1982 sample was chosen to double the field density of the original grid and quadruple the density of fields in the central region where the hole in the galaxy distribution appeared to be most conspicuous.

RESULTS

The distribution on the sky of galaxies with measured velocities is shown in Figure 1b, c, and d for three ranges in radial velocity which contain in all 156 galaxies. The remaining 32 percent of the sample lies closer than 6,000 km/s or more distant than 24,000 km/s. The absence of galaxies from the central part of Figure 1c, between 12,000 and 18,000 km/s, is most conspicuous just where the density of survey fields is highest.

Note that two galaxies in Figure 1c at (14h10m, +48°) and (14h10m, +42°) have velocities of 17,910 and 12,060 km/s respectively. A sphere 6,180 km/s in diameter, centered at 15,000 km/s and (14h48m, +47°), contains no measured velocities.

The empty sphere intersects the line of sight from 164 of the 282 survey fields. Judging from the smoothed velocity distribution of the sample, the expected number of galaxies in the spherical volume is 23. This estimate is conservative in the sense that we have not yet tried to delineate a larger but irregularly shaped empty volume, or one of reduced, but not zero, density. Such a larger volume is indicated by the lines of sight to our original three fields, which lie entirely

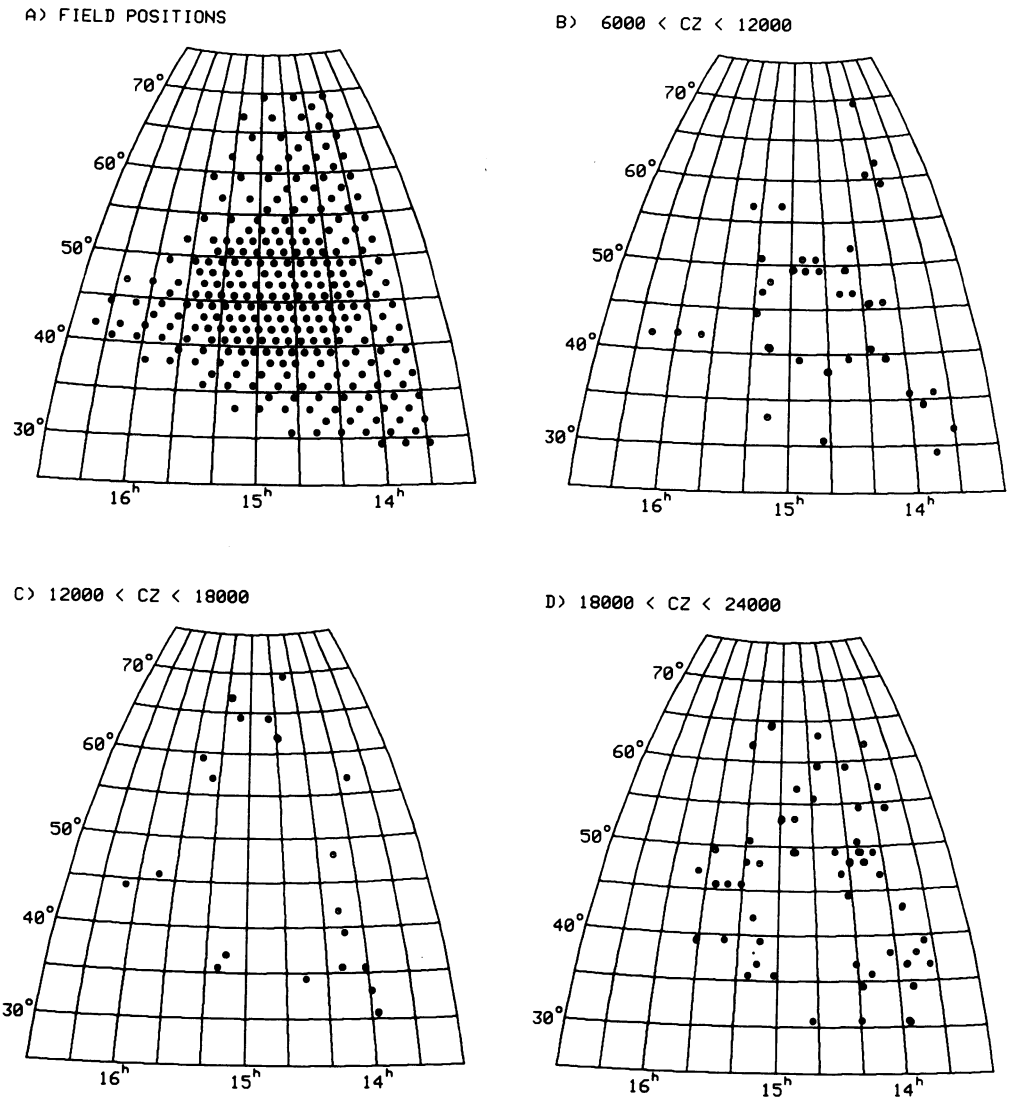

Figure 1-(a) Positions on the sky of 282 survey fields; (b), (c), (d) Positions of galaxies with measured velocities in three ranges from 6,000 to 24,000 km/s.

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outside the boundary of the present empty sphere, yet exhibit a strong galaxy deficit in the same velocity interval.

One advantage of a survey conducted in fields of such small size is that the correlation of galaxy velocities is much lower. In our previous survey, velocities occur in groups of typically three or four. In the present survey, groups or small clusters tend to appear in single fields. A list of all groups of velocities which occur in single fields, where the redshift difference is less than 1000 km/s, contains 144 single objects, 29 doubles, 7 triples, and 2 quadruples. The average number of velocities in each group is only 1.3. The 23 velocities missing from the empty sphere would be expected to occur in 18 such groups.

The probability of observing no events when 18 are expected is only 1.5×10^{-8}. Some allowance must be made for additional correlation of velocities between neighboring fields, and also for choosing the empty sphere after the fact. Since the entire sample contains 231 galaxies, there are only of order 10 independent ways to find an empty volume of this size. Thus, the void is very unlikely to be a statistical artifact. There is a probability of at least a few percent, however, that the density of galaxies in the empty sphere is as high as 0.25 times the average density.

The distribution of velocity differences within single fields is itself remarkable. If the galaxies in our velocity sample were distributed at random, 15 such pairs would be expected with velocity differences less than 1000 km/s. In fact, there are 62 such pairs in our sample (1 in each double, 3 in each triple, 6 in each quadruple). However, only 9 of the pairs have velocity differences between 400 and 1000 km/s--just the number expected by chance. The rms velocity difference of the remaining pairs, correcting for the 6 expected at random, is only 180 km/s. This value can be taken as an upper limit since there is no reason to believe that the measurement error is much lower.

REFERENCE

Kirshner, R. P., Oemler, A., Schechter, P. L., and Shectman, S. A.: 1981, Ap. J. (Letters), 248, L57.

Discussion

Inagaki: How does the size of the void depend on the luminosity of galaxies?

Shectman: A population of fainter galaxies could exist in the empty volume. Such galaxies would not show up in our apparent magnitude limited sample.

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Huchra: Are any of the galaxies in the sample of Weedman and Balzano (Markarian galaxies) or Sanduleak and Pesch in your empty sphere?

Shectman: No, Balzano and Weedman, in particular, consider an even larger area on the sky than that occupied by the empty sphere.

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