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An H I Survey of the Great Attractor Region

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Abstract. A blind H I survey using the Parkes telescope at $|b| < 5°$ $300° < \ell < 332°$ has so far revealed 305 galaxies, most of which were previously unknown. These galaxies are used to map out the distribution of filaments and voids out to 10^4 km s^{-1}. A preliminary measurement of the galaxy overdensity suggests only a moderate overdensity is present, and that the excess mass (above the background density) is $\sim 2 \times 10^{15}\Omega_\circ$ M$_\odot$. This is below the mass predicted in POTENT reconstructions of the local velocity field, and implies that the 'Great Attractor' (GA) is not as massive as these reconstructions indicate, or does not lie hidden in the region investigated.

1. Introduction

As described elsewhere in these proceedings, the Zone of Avoidance (ZOA) provides a formidable obstacle to the study of galaxies and to the completion of our picture of large-scale structure in the local Universe. The southern ZOA obscures dynamically important structures in the Puppis, Vela, Norma and Ophiuchus regions (Lahav 1994, Kraan-Korteweg & Woudt 1994, Kraan-Korteweg et al. 1996, Wakamatsu et al. 1994). Density fields inferred from complete redshift surveys such as PSCz (Saunders et al., these proceedings) and peculiar velocity reconstructions (Kolatt, Dekel, & Lahav 1995) indicate that the most massive structure, usually dubbed the 'Great Attractor' (GA), probably lies near the Galactic equator close to $\ell = 320°$.

Surveys of galaxies down to moderately low latitudes are possible with some difficulty at optical and infrared wavelengths. However, quantitative studies which involve measurements of luminosity or size are very hard to make with any precision because of the obscuration problem. The blind 21-cm approach as pioneered by Kerr & Henning (1987) offers a neat solution to the problem, in that flux densities are unaffected by dust. Moreover, with the H I Parkes

All-Sky Survey (H I PASS) now complete, measurements of galaxy overdensity in previously obscured regions can be compared with very large control samples.

This paper describes some preliminary results from a deep survey with the multibeam receiver on the Parkes telescope. Over 300 galaxies were detected in this survey, which is an extension of the survey begun by Juraszek et al. (2000). The survey is dense enough to recognise several coherent structures and to begin to measure actual overdensities in order to quantify excess mass in this region.

2. The Survey

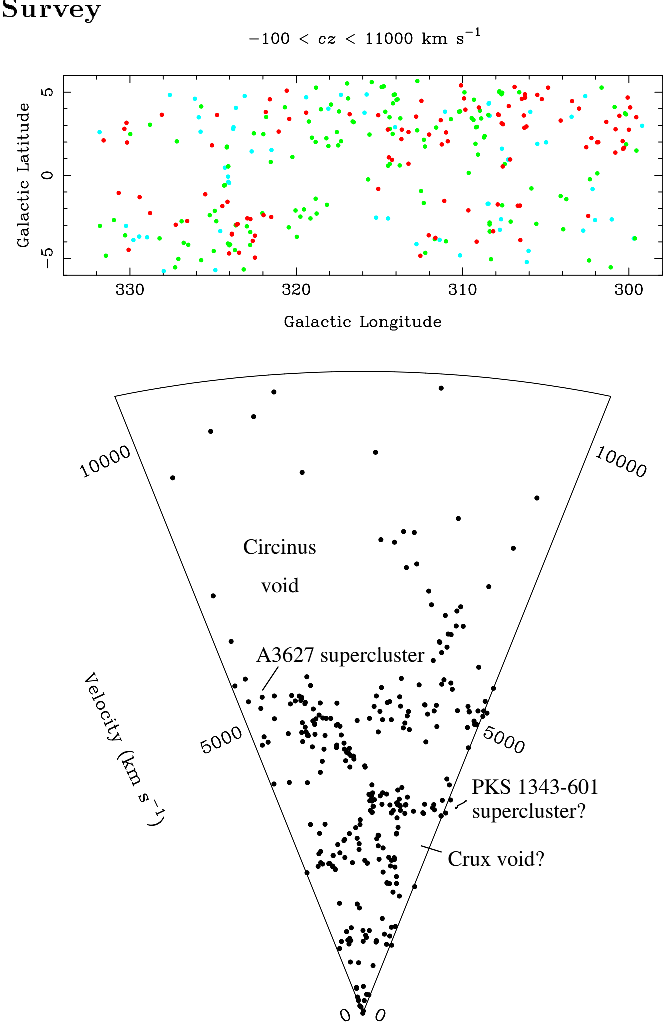

Figure 1. *Top:* angular distribution of galaxies $|b| < 5°$ and $300° < \ell < 332°$. *Bottom:* wedge diagram showing velocity (Local Group frame) as a function of longitude. Several coherent structures are identified, following Fairall (1998).

The H I survey presented here is part of the ongoing Parkes ZOA survey (Staveley-Smith et al. 1998, Juraszek et al. 2000, Henning et al. 2000). The aim is to cover the southern ZOA to deeper levels than afforded by H I PASS

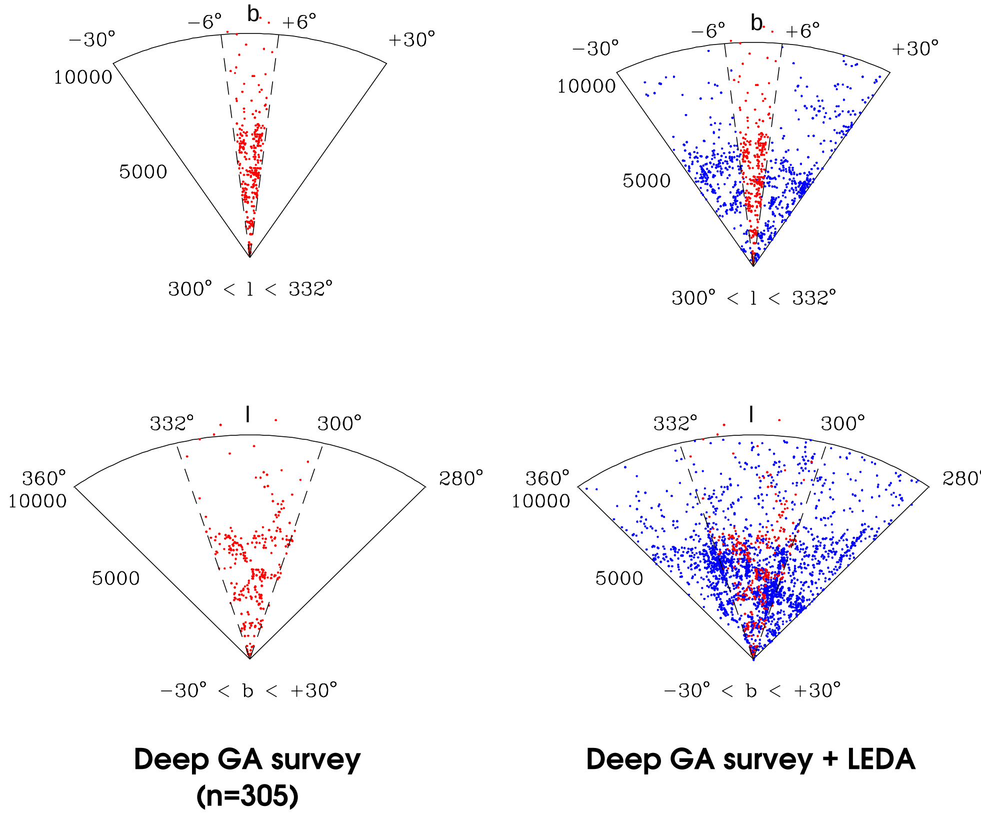

Figure 2. *Left:* distribution of the newly detected galaxies in Galactic latitude and Galactic longitude. *Right:* including LEDA galaxies with known redshifts.

alone. The data presented here comprises the full-sensitivity data for the region $300° < \ell < 332°$ and $|b| < 5°$, or nearly a fifth of the southern ZOA.

The total integration time is 230 hrs, with the final sensitivity being 5 mJy beam^{-1}. The angular and velocity resolutions are $15\farcm5$ and 18 km s^{-1}, respectively. The velocity coverage is -1200 to 12700 km s^{-1}.

A total of 305 galaxies were found by visual inspection of the data cubes from two independent searches (SJ and RKK). The cubes have some residual baseline ripple near continuum sources, which it is planned to correct for at a later stage. The limiting flux density for inclusion in the catalogue was dependent on the velocity width of the H I profile approximately according to $W_{50}^{-0.7} \int SdV > 0.05$. In other words, a galaxy with a profile width $W_{50} = 150$ km s^{-1} will be included if its flux integral exceeds 1.7 Jy km s^{-1}.

3. Galaxy Distribution

The distribution of the 305 galaxies on the sky and in redshift is shown in Fig. 1. There is clear structure in the galaxy distribution, with several coherent features visible. There appear to be at least two voids both of which (Circinus and Crux) are identified by Fairall (1998) from existing galaxy redshift surveys above and beneath the Plane. At $\ell \approx 330°$, $cz = 5000$ km s^{-1} there is a large overdensity of galaxies. This redshift coincides closely with the ACO 3627 cluster, and its spiral-rich subcluster (Woudt 1998), suggesting that the structure is part of an extended supercluster or cloud of galaxies around the main cluster. This whole structure appears to be the low-redshift boundary of the Circinus void and to extend at least $50h^{-1}$ Mpc to $\ell \approx 300°$.

Extending between $\ell = 300°$ and $\ell = 314°$ at $cz = 3400$ km s^{-1} (Local Group frame), and forming the high redshift side of the Crux void is a coherent structure which may be associated with PKS B1343-601, a radio galaxy with a Local Group redshift of 3641 km s^{-1} (West & Tarenghi 1989). The existence of a coherent structure at this redshift would tend to confirm the existence of a cluster around PKS B1343-601 as suggested by Kraan-Korteweg & Woudt (1999). We see no direct evidence for the actual cluster, though it may be spiral-poor.

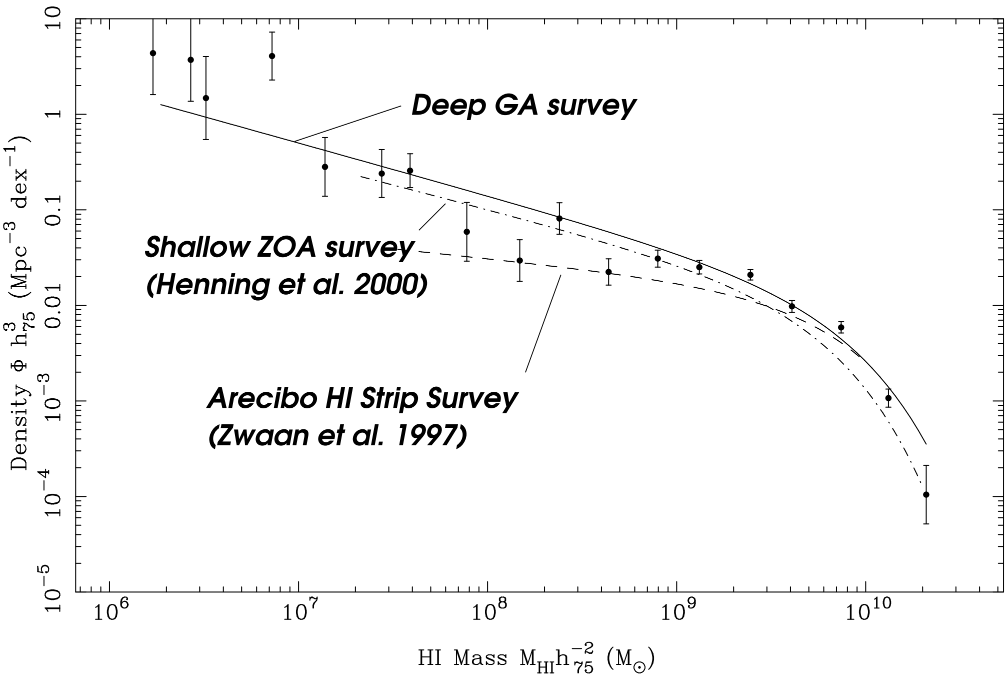

Figure 3. The H I mass function of the galaxies in the GA region formed using the $\Sigma V_{\rm max}^{-1}$ method. A Schechter function (solid line) is fit to the data. An overdensity of galaxies relative to the Zwaan et al. (1997) (dashed line) and Henning et al. (2000) (dot-dashed line) H I mass functions is apparent.

Figure 2 shows the distribution of the same galaxies in latitude-velocity and longitude-velocity wedges, similar to those presented by Juraszek et al. (2000). The plots on the right include galaxies in the Lyon/Meudon Extragalactic Database and together with the multibeam galaxies give the most complete census of nearby galaxies in the range $\ell = 300°$ to $332°$, $|b| < 30°$.

4. Mass Overdensity

The ability to measure H I fluxes and masses without uncertain extinction corrections means that, assuming neutral gas traces total mass on a large scale, we can measure densities and masses. A straightforward way of doing this is to measure and integrate the H I mass function using the selection function noted above.

In Fig. 3, we calculate the volume density for galaxies in a given H I mass interval (0.25 dex bins) using the $\Sigma V_{\rm max}^{-1}$ method. The resultant mass function is fitted with a Schechter function, and compared with the results from the shallow ZOA survey of Henning et al. (2000) and the Arecibo H I Strip Survey (AH ISS) of Zwaan et al. (1997). The present 'deep GA' survey shows a mass excess compared with both other surveys. This is particularly true at low H I masses where there is an almost order of magnitude disagreement between the present results and Zwaan et al. (1997)[1]. Integrating the data points in Fig. 3 yields a total H I density of 8.0×10^7 M$_\odot$ Mpc^{-3}, compared with 5.9×10^7 M$_\odot$ Mpc^{-3} for the shallow ZOA survey and 4.0×10^7 M$_\odot$ Mpc^{-3} for the summation $(\Sigma M_{\rm H\,I}/V_{\rm max})$ (H$_\circ$ = 75 km s^{-1} Mpc^{-1}) over the AH ISS galaxies.

The shallow ZOA and AH ISS control samples are not ideal. The shallow ZOA survey itself includes the GA region as well as the Local Void and is smaller than the present survey. The AH ISS sample is smaller still. The errors in calculating overdensity are therefore dominated by the control samples. Until H IPASS solves this particular problem, we will use a value for the GA overdensity of $\delta\rho/\rho_\circ = 0.5 \pm 0.2$. This is less than the overdensity of ~ 1.2 predicted by POTENT at 4000 km s^{-1} (Kolatt et al. 1995). Around half the H I mass lies between 10^9 and 10^{10} M$_\odot$. At this mass, the average maximum distance is ~ 90 Mpc, and the weighted sample volume $(n/\Sigma V_{\rm max}^{-1})$ is $\sim 2 \times 10^4$ Mpc^3. Therefore, the excess H I mass in this region is 5.3×10^{11} M$_\odot$. Assuming H I traces total mass, the excess total mass is $\sim 2 \times 10^{15} \Omega_\circ$ M$_\odot$.

Although the H I in the GA region appears to trace significant excess mass, the amount involved is no more than is likely to be present in the ACO 3627 cluster, which has a mass of $\sim 10^{15}$ M$_\odot$ (Woudt 1998; Böhringer et al. 1996). The combination is well short of the 5×10^{16} M$_\odot$ invoked to explain local galaxy dynamics (Lynden-Bell et al. 1988).

5. Where is the Great Attractor?

We now consider alternative hiding places and alternative hypotheses to the GA:

First, galaxy clusters tend to be deficient in neutral gas, so H I surveys are not efficient cluster detectors. Could the GA consist of 10-50 clusters hidden within this region? Unfortunately, Fig. 1 shows that the massive superclusters around rich clusters such as ACO 3627 are difficult to hide, and that only a few such superclusters can be present in this region.

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[1] In the low H I-mass regime, which does not dominate the total H I mass, the $\Sigma V_{\rm max}^{-1}$ method is sensitive to local overdensities.

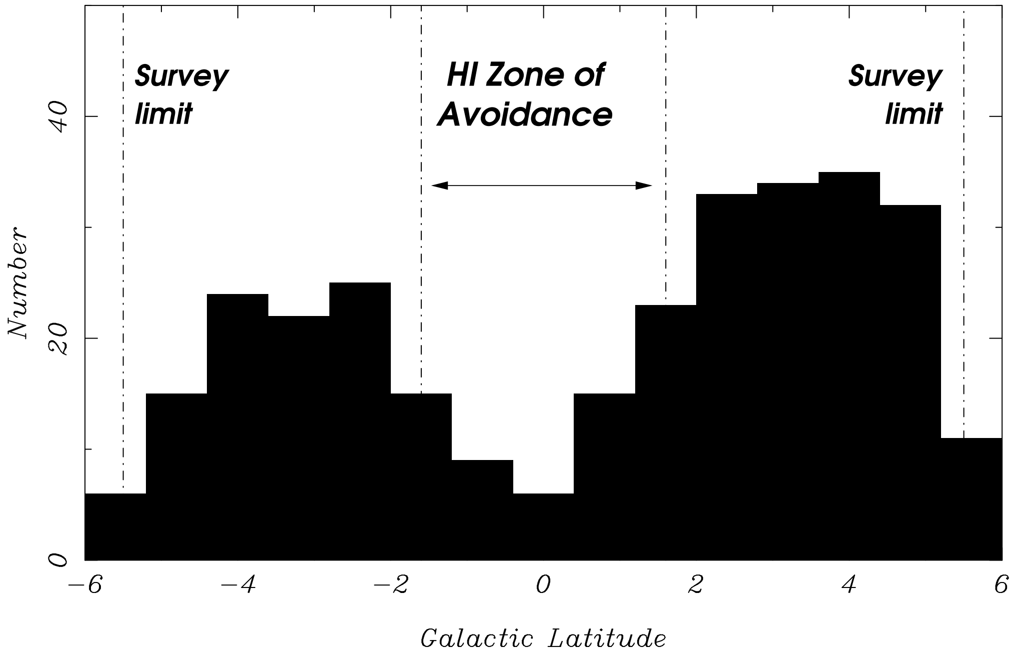

Figure 4. The distribution of galaxies in Galactic latitude shows an excess of galaxies on the northern side of the Plane relative to the southern side, and a deficit of galaxies within 1°.6 of the Plane. The deficit is due to increased system temperature and excess baseline ripple which reduce sensitivity.

Second, the sensitivity of the current survey is lowered near the Plane due to increased noise and baseline curvature due to Galactic continuum sources. How wide is this region and would it be able to hide significant mass? Figure 4 shows the distribution, in Galactic latitude, of the 305 galaxies. Although galaxies are present at $b = 0°$, there appears to be a real deficit (by a factor of ~ 2) at $|b| < 1°.6$. This deficit is accounted for in the mass function, but there is nevertheless some room for hiding a compact cluster. At a distance of ~ 70 Mpc, the remaining hidden zone corresponds to a projected diameter of ~ 4 Mpc. As already mentioned, further suppression of continuum is planned in order to reduce the remaining ZOA. At this stage, however, there seems little chance that important structures have been entirely missed.

Third, could the GA be located outside the present area, or be more extensive than the region surveyed so far? There is certainly room for hiding massive structures near the Plane at $\ell < 332°$ and $\ell > 300°$, which have not yet been completely observed by the Parkes telescope. A GA of around 20$\times$ the extent of the present volume, or lying beyond the redshift of maximum sensitivity would also help. However, regions away from the Plane are adequately mapped by IRAS redshift surveys (Saunders et al., these proceedings) which already fail to completely explain the degree of overdensity predicted by POTENT.

Finally, there remains the possibility that properties such as bias parameter and galactic mass-to-light ratios vary on a large-scale in such a way as to mimic dynamical effects. Comparison of a number of different distance indicators tends to suggest this is not the case, and that the issue may be errors and biases. It is notable that the most accurate distance indicator in the redshift range considered here, the surface brightness fluctuation method, appears to favour low values for large-scale bulk flow and a low value for the Great Attractor mass ($\sim 9 \times 10^{15}$ $M_\odot$, Tonry et al. 2000), which is much more in accord with the results presented here.

6. Summary

An ongoing deep survey with the Parkes telescope has so far found 305 galaxies deep in the Zone of Avoidance at Galactic latitudes $|b| < 5°$, longitudes $300° < \ell < 332°$. These galaxies fill in the main missing gap in our knowledge of structure in the local Universe out to 10^4 km s^{-1} in the 'Great Attractor' region. The excess mass found, $\sim 2 \times 10^{15} \Omega_\circ$ $M_\odot$, is significant but much less than that predicted by some reconstructions of the non-Hubble velocity field (Kolatt et al. 1995). Several structures (filaments, voids and superclusters) are identified.

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