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New H I-detected Galaxies in the Zone of Avoidance

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ABSTRACT

We present the first results of a blind H I survey for galaxies in the southern Zone of Avoidance with a multibeam receiver on the Parkes telescope. This survey is eventually expected to catalog several thousand galaxies within Galactic latitude $|b| < 5°$, mostly unrecognised before due to Galactic extinction and confusion. We present here results of the first three detections to have been imaged with the Australia Telescope Compact Array (ATCA). The galaxies all lie near Galactic longitude 325° and were selected because of their large angular sizes, up to 1°.3. Linear sizes range from 53 to 108 kpc. The first galaxy is a massive $5.7 \times 10^{11} M_{\odot}$ disk galaxy with a faint optical counterpart, SGC 1511.1–5249. The second is probably an interacting group of galaxies straddling the Galactic equator. No optical identification is possible. The third object appears to be an interacting pair of low column density galaxies, possibly belonging to an extended Circinus or Centaurus A galaxy group. No optical counterpart has been seen despite the predicted extinction ($A_B = 2.7 - 4.4$ mag) not being excessive. We discuss the implications of the results, in particular the low H I column densities ($\sim 10^{19}$ atoms cm^{-2}) found for two of the three galaxies.

Subject headings: surveys – galaxies: distances and redshifts – galaxies: fundamental parameters – radio lines: galaxies

1. INTRODUCTION

Within a Galactic latitude of ±20°, extinction and foreground confusion can considerably affect the quality of optical studies of galaxies. Within ±10°, most optical observations are

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challenging, and observations at infrared wavelengths become competitive with optical observations for the purposes of galaxy identification (e.g. Saunders et al. 1994). Within $\pm 5^\circ$ of the Plane, even infrared observations are impossible for most extragalactic studies. However, in this latitude range, H I observations at 21 cm wavelength have been used with considerable success, since the Galactic neutral hydrogen has optical depth only over the narrow velocity range covered by its emission. Blind searches in the Galactic Plane, or Zone of Avoidance (ZOA), were pioneered by Kerr & Henning (1987) and a survey with the Dwingeloo 25 m telescope has been successful in discovering several new nearby galaxies, including Dwingeloo-1 (Kraan-Korteweg et al. 1994; Henning et al. 1998).

In the past, large-area blind H I surveys have had limited sensitivity because of the time it takes to scan significant areas of sky. However, the new Parkes 21 cm multibeam receiver with its array of 13 feed horns (Staveley-Smith et al. 1996) allows much more rapid mapping of the nearby Universe. We have begun a survey with this receiver for galaxies within $\pm 5^\circ$ of the southern Galactic Plane. This survey should eventually produce a list of several thousand new galaxies behind the Plane, and give us information about massive nearby galaxies such as Dwingeloo-1 (Kraan-Korteweg et al. 1994) and Circinus (Freeman et al. 1977) which may have been previously overlooked. It will also help fill in our knowledge of the structure of the Centaurus-Pavo and Abell 3627 superclusters (Fairall 1988, Kraan-Korteweg et al. 1996) and the Puppis and Vela regions (Kraan-Korteweg & Huchtmeier 1992, Lahav et al. 1993, Kraan-Korteweg & Woudt 1994, Yamada et al. 1994) as they disappear behind the Galaxy, as well as uncover unknown large-scale structure across or behind the Galactic Plane.

In this paper, we present results for three galaxies found during the course of the survey. These galaxies are selected from a preliminary list of ~ 50 galaxies found near longitude 325° (Juraszek et al. 1998). Each of the galaxies is resolved in the $14'$ beam of the Parkes telescope, and thus must be fairly nearby. In § 2, we describe the Parkes survey observations for the three galaxies. In § 3, we present the more detailed ATCA observations and optical CCD observations. Finally, in § 4, we discuss the implications of the findings.

2. MULTIBEAM SURVEY OBSERVATIONS

The ZOA survey began at the Parkes telescope[5] on 1997 March 22, and is expected to be completed by early 1999. The survey will map the southern ZOA between longitudes 212° and 36°, and between latitudes -5° and $+5^\circ$. Data are taken by scanning the telescope in Galactic longitude. Each scan is of length 8° with the position angle of the multibeam receiver lying nominally at 15° from the Galactic equator. The final survey will be heavily oversampled in the

[5]The Parkes Telescope and the Australia Telescope are funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.

spatial domain.

Property	J1514 − 52	J1532 − 56	J1616 − 55
RA (J2000)†	$15^h14^m34^s$	$15^h32^m43^s$	$16^h16^m49^s$
DEC (J2000)†	$-52°59'25''$	$-56°07'30''$	$-55°44'57''$
Galactic longitude †	323.°59	324.°07	329.°06
Galactic latitude †	4.°04	−0.°02	−3.°67
Heliocentric velocity, cz (km s^{-1}) *	1452	1383	421
Velocity width at 50% (km s^{-1}) *	441	90	55
Distance ($H_\circ = 75$ km s^{-1}Mpc^{-1}) (Mpc)	17.0	16.0	3.7
H I Diameter (kpc) †	53	108	86
Peak H I column density (atoms cm^{-2}) *	16.3×10^{19}	2.0×10^{19}	0.8×10^{19}
H I mass ($M_\odot$) *	8.4×10^9	2.1×10^9	8.9×10^7
Inclination †	62°	–	–
Position Angle †	156°	–	–
Absorption, A_B(dust)	4.3 mag	57 mag	2.7 mag
Absorption, A_B(gas)	3.4 mag	16 mag	4.4 mag
Type	SBb?	Interacting?	Interacting LSB?

Table 1: The three large H I-detected galaxies with multibeam and ATCA data. Parameters measured from the multibeam data are indicated with an asterisk (*); those from the follow-up ATCA data with a dagger (†). Velocity widths are measured at the 50% level from spatially integrated and Hanning-smoothed spectra (26 km s^{-1} resolution). H I diameters are measured at 1 M$_\odot$ pc^{-2} (1.26×10^{20} cm^{-2}) for J1514 − 52, and at 10% of the peak ATCA column density for J1532 − 56 and J1616 − 55 (1.0×10^{19} cm^{-2}, and 2.1×10^{18} cm^{-2}, respectively). The optical absorption estimates are based on the data of Schlegel et al. (1998) (dust) and Dickey & Lockman (1990) (gas).

The multibeam correlator has a bandwidth of 64 MHz and covers the frequency range 1362.5 to 1426.5 MHz. This corresponds to a velocity (cz) range of approximately −1200 to 12700 km s^{-1}. The channel spacing is 13 km s^{-1}, but to suppress ringing caused by the strong narrow-band Galactic H I emission, the data shown here are Hanning smoothed to a resolution of 26 km s^{-1}. The average FWHP beamwidth of the multibeam receiver is 14′, though the gridding process increases this to 17′. The average system temperature is 20 K. The data used here have an rms noise of about 15 mJy beam^{-1}, corresponding to an H I column density of around 7×10^{17} atoms cm^{-2} in each 26 km s^{-1} resolution element. The data were calibrated and baseline-subtracted

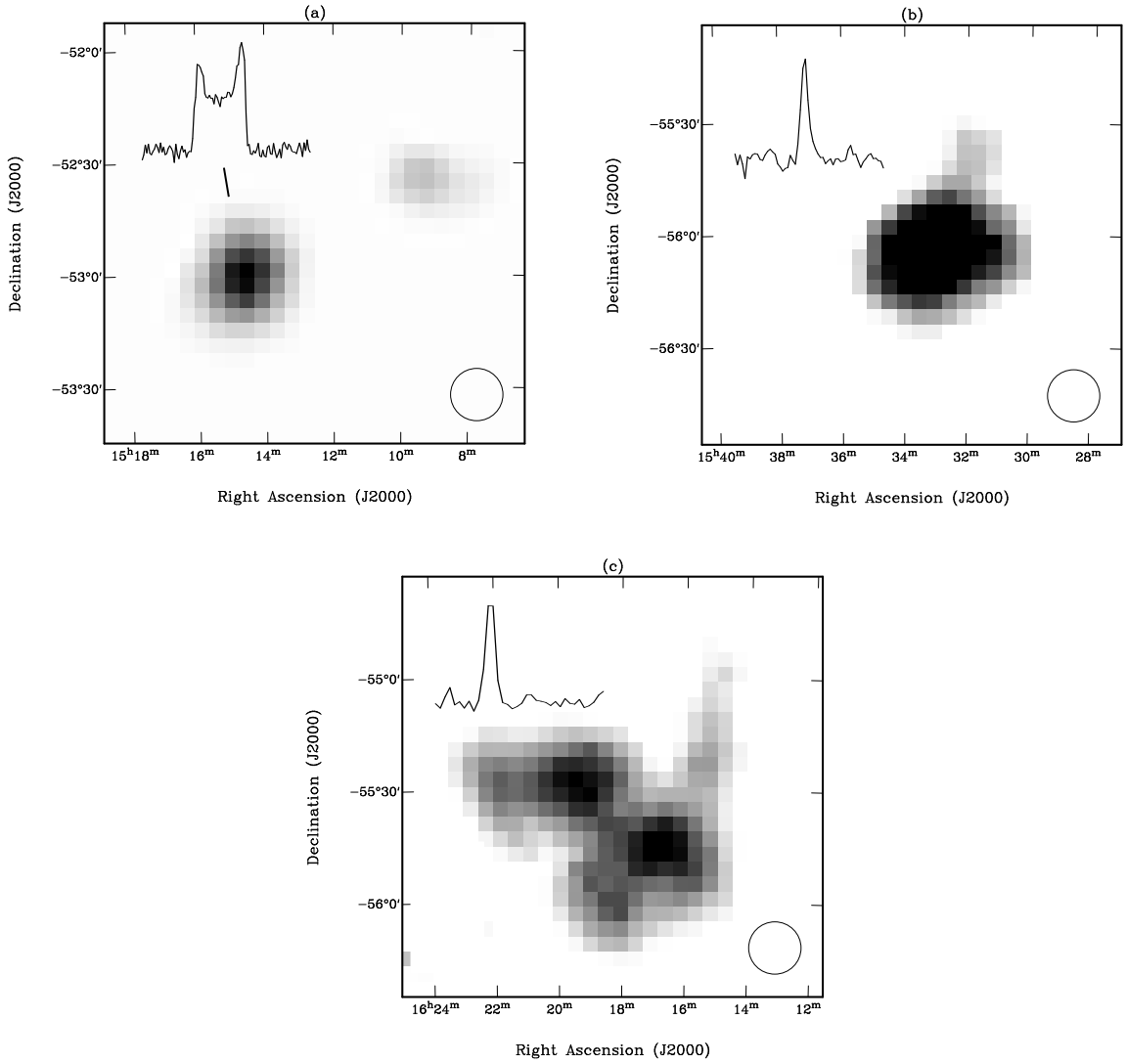

Fig. 1.— Parkes multibeam column density images, with velocity contours overlayed, for the three galaxies: (a) J1514 − 52 (note the companion, ESO 223-G012 to the northwest); (b) J1532 − 56, and (c) J1616 − 55. The field size is 1.°9 in each case. The integrated velocity profiles for the objects is overlayed at the top left of each panel, and the Parkes beam is drawn in the lower right. The peak column densities range from 8×10^{18} to 2×10^{20} atoms cm^{-2} (see Table 1).

using a real-time system based on aips++ (Barnes et al. 1997). Cubes were also made using specially developed aips++ routines (Barnes 1997). Miriad, aips and aips++ were used for cube concatenation, Hanning smoothing and making moment maps. All spectral calibration and cube-forming routines use robust statistics. In combination with high oversampling of the sky, this allows enormous suppression of any non-continuous interference.

The galaxies chosen for follow-up observations are shown in Table 1 together with positions and other measured properties. The column-density images for J1514 − 52, J1532 − 56 and J1616 − 55 from the multibeam survey are shown in Figure 1. All the galaxies are near $\ell = 325°$ and are well-resolved, implying large overall sizes. Only J1514 − 52, at $b = 4\overset{\circ}{.}04$ has a previously identified optical counterpart, SGC 1511.1 − 5249 (Corwin et al. 1985). J1514 − 52 is also notable for having a close companion, ESO 223–G 12, visible in the multibeam image (Figure 1). The companion has an almost identical velocity and velocity width to J1514 − 52. The H I masses of the three new galaxies range from $9 \times 10^7 M_\odot$ (J1616 − 55) to $8 \times 10^9 M_\odot$ (J1514 − 52) and peak column densities from 8×10^{18} atoms cm^{-2} (J1616 − 55) to 2×10^{20} atoms cm^{-2} (J1514 − 52) (at the multibeam resolution). The linewidths range from 55 km s^{-1} (J1616 − 55) to 441 km s^{-1} (J1514 − 52). The large H I mass and linewidth for J1514 − 52 are typical of a massive spiral galaxy. The low H I mass and linewidth for J1616 − 55 are typical of a low-mass dwarf system. However, the large linear size (86 kpc, see below) and low column density of J1616 − 55 is not typical of an H I-rich dwarf galaxy, a point to which we return in § 4.

3. RADIO AND OPTICAL FOLLOW-UP OBSERVATIONS

	J1514 − 52	J1532 − 56	J1616 − 55
Observation Date(s)	97/06/08	97/06/08, 97/10/01	97/06/06, 97/07/16
Array(s)	750A	750A, 375	750A, 122B
Integration time (h)	4	4.5+9	13+12
Bandwidth (MHz)	8	8	8
Number of pointings	1	1	12
Velocity resolution (km s^{-1})	6.6	6.6	6.6/26.4
Synthesised beamwidth	$1\overset{'}{.}4 \times 0\overset{'}{.}8$	$2\overset{'}{.}2 \times 2\overset{'}{.}2$	$4\overset{'}{.}5 \times 4\overset{'}{.}5$
Position angle	31°	0°	0°
Combined with multibeam data?	×	×	√

Table 2: ATCA journal of observations.

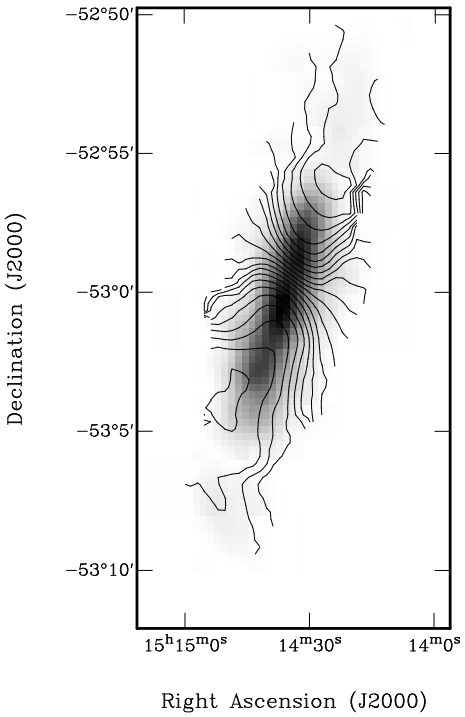

Fig. 2.— ATCA column density map of J1514 – 52 with contours of equal velocity overlayed. The peak brightness is 6.81 Jy beam^{-1} km s^{-1}, corresponding to a column density of 1.8×10^{21} atoms cm^{-2} (higher than the multibeam value, due to higher spatial resolution). The velocity contours are in intervals of 20 km s^{-1} starting from 1240 km s^{-1} in the northwest and finishing at 1640 km s^{-1} in the southeast. The beam size is $1\farcm4 \times 0\farcm8$ (natural weighting).

High-resolution H I and optical CCD observations were made of the multibeam-detected galaxies. Table 2 lists the observing parameters for the ATCA H I observations. The CCD observations are discussed in the text.

3.1. J1514 – 52

The ATCA column density image is shown in Figure 2. J1514 – 52 is clearly resolved and is a highly inclined, rotating disk galaxy. The H I mass measured from the primary-beam-corrected ATCA column density image is 4.8×10^9 M$_\odot$. This is only 60% of the H I mass measured in the multibeam observations (8.4×10^9 M$_\odot$, Table 1). The difference is due to the lack of short spacings in the 750A array, and primary beam attenuation[6] which forces the signal below the threshhold

[6]The FWHP primary beamwidth of the ATCA at 21 cm is 34′.

level for detection of significant H I. The diameter at a projected H I surface density of 1 $M_\odot$ pc^{-2} (1.26×10^{20} cm^{-2}) is 53 kpc (Table 1). However, the total H I extent is much larger. A tilted ring analysis (which gives the rotation curve shown in Figure 3) extends to a radius of 55 kpc. Given the relatively short observation and the fact that the ATCA primary beam correction is significant, the galaxy may extend considerably further still. The kinematically derived inclination is 62° and the pa is 156°. The dynamical center is given in Table 1, and is only 6″ from the precise optical position listed by Woudt & Kraan-Korteweg (1998).

An approximate decomposition of the rotation curve into an exponential disk, H I disk, and dark halo is reasonably successful (Figure 3). The portion of the rotation curve due to H I was fixed according to the measured ATCA H I density profile (corrected for primary beam attenuation) but normalised so that the H I mass agrees with the multibeam mass in Table 1. It is assumed that the H I lies in a flat, infinitely thin disk. A 30% (by mass) He contribution was also allowed for. The steep initial rise in the rotation curve was well-fitted by an infinitely thin exponential disk with a scale length of 8 kpc and central density 500 $M_\odot$ pc^{-2} (and total mass 2.0×10^{11} $M_\odot$). Finally, a pseudo-isothermal halo (e.g. Walsh et al. 1997) with a core radius of 30 kpc and central density of 10^{-3} $M_\odot$ pc^{-3} was required to fit the outer part of the rotation curve.

J1514 – 52 is therefore a very massive system. The mass of the dark halo within a radius of 60 kpc is 3.6×10^{11} $M_\odot$. The combined mass of the halo and both disk components is 5.7×10^{11} $M_\odot$. The gentle decline of rotation velocity even at the largest radii suggests that the extent and total mass of the galaxy are significantly larger.

Optically, this galaxy is quite visible on sky-survey plates despite its Galactic latitude of 4°.04. An I-band image taken with the Mount Stromlo and Siding Spring Observatories (MSSSO) 40-inch telescope on 1997 July 4 is shown in Figure 4. The exposure time is 16 min, and the pixel size (after 3×3 binning) is 1″.8. The maximum optical diameter of J1514 – 52 on Figure 4 is 220″ (17 kpc). Woudt & Kraan-Korteweg (1998) list this galaxy as WKK 4748 in their catalog and give a diameter of $212'' \times 56''$ and a magnitude of $B_J = 13.9 \pm 0.5$ mag. The Galactic column density of 4.6×10^{21} atoms cm^{-2} (Dickey & Lockman 1990) gives rise to an estimated absorption $A_B = 3.4$ mag. More recent reddening estimates based on modelling of IRAS and DIRBE far-infrared data (Schlegel et al. 1998) suggests $A_B = 4.3$ mag (Table 1) and therefore an absolute magnitude $M_B \approx -21.6$ mag. The corresponding H I mass-to-light ratio $M_H/L_B \approx 0.13$ is below the median value of 0.20 – 0.21 for the Sab/Sb samples listed by Roberts & Haynes (1994), but well within the range of these galaxies. The rotation curve analysis above also gives a reasonable value for the disk mass-to-light ratio $M_{\rm disk}/L_B \approx 3.1$.

With its optical size, J1514 – 52 should have been be included in the Lauberts (1982) ESO catalog. However, it seems to have first been listed as a galaxy by Corwin et al. (1985) who catalog it as SCG 1511.1-5249. Improved coordinates are given by Spellman et al. (1989). It is a very strong infrared source (IRAS 15109-5248) with a 100μm flux density of 60 Jy. Its far-infrared luminosity of $1.0 \times 10^{10} L_\odot$ lies in between two other moderately active galaxies: Circinus

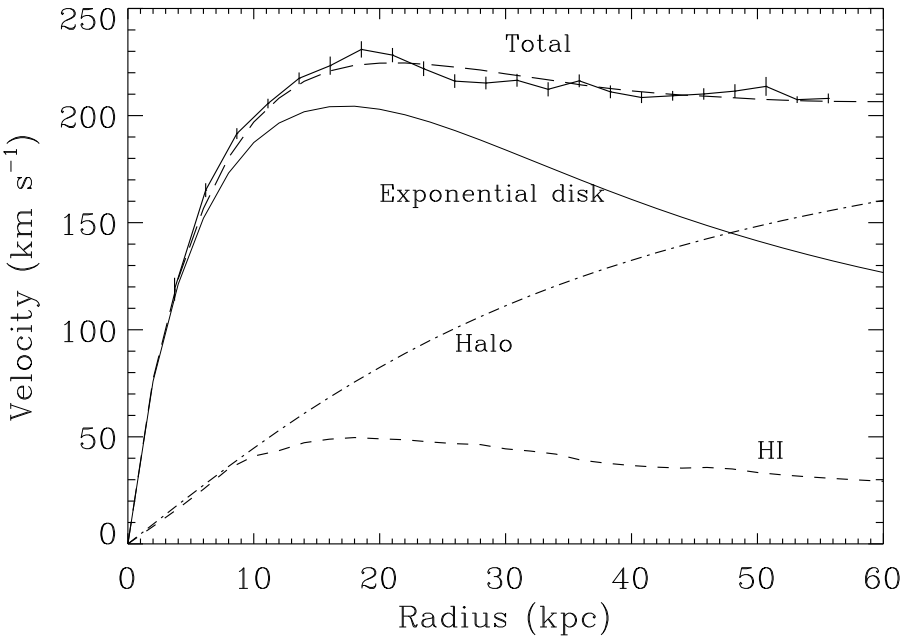

Fig. 3.— Observed rotation curve for J1514 – 52 (thick solid line with error bars) compared with a model (long dashed line) which comprises: an exponential disk of scale length 8 kpc (thin solid line), an H I +He (mass ratio 1:0.3) disk (short dashed line), and a pseudo-isothermal dark halo of core radius 30 kpc. The total mass of all components within a radius of 60 kpc is 5.7×10^{11} $M_\odot$.

($5.7 \times 10^9 L_\odot$) and NGC 253 ($1.3 \times 10^{10} L_\odot$). The far-infrared luminosity may be indicative of nuclear activity, possibly triggered by the nearby companion, ESO 223-G012, which also appears in Figure 1. J1514 – 52 has also been listed as a galaxy candidate by Yamada et al (1993), Weinberger et al. (1995) and Takata et al. (1996).

3.2. J1532 – 56

J1532 – 56 required more ATCA integration time and a shorter array to detect (see Table 2). The column-density image is shown in Figure 5. In H I, J1532 – 56 is resolved into a relatively bright region at RA $15^h32^m43^s$, DEC $-56°07'30''$ (J2000) which is surrounded by a diffuse H I halo and a bright extension of length $\sim 6'$ (28 kpc) at pa 150°. At the southern end of the extension, an arm-like feature twists back in a manner reminiscent of the tidal tails in the M81 group of galaxies (Yun et al. 1994). In the ATCA image, the overall system appears to have a diameter of 108 kpc at 10^{19} atoms cm^{-2}, which is very similar to the 105 kpc diameter of the M81/M82/NGC3077 system as measured by the VLA (Yun et al. 1994). The extent of J1532 – 56

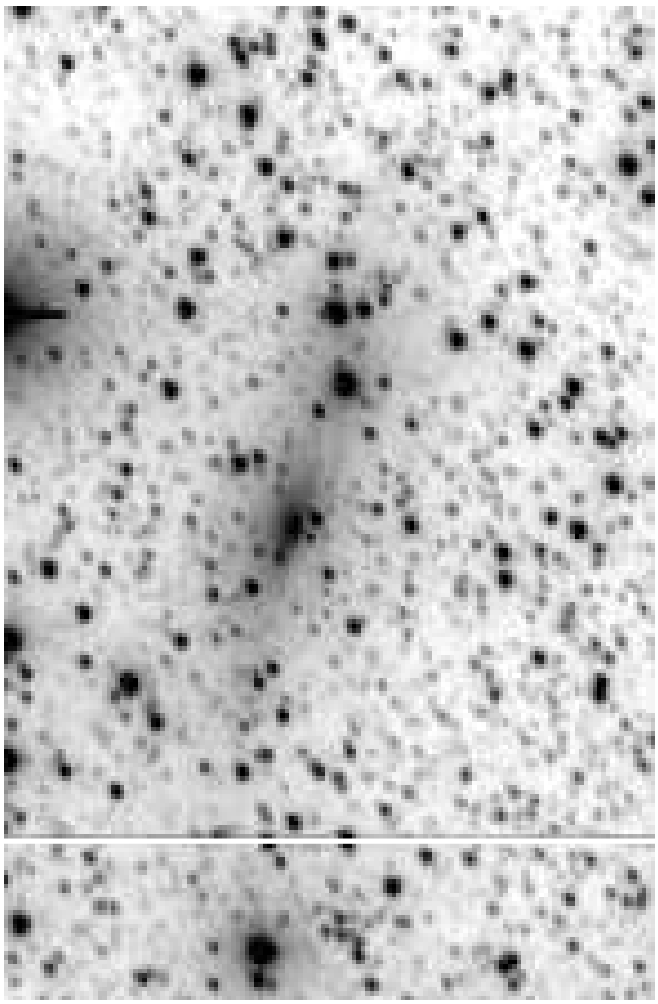

Fig. 4.— I-band image of J1514 – 52 taken with the MSSSO 40 inch telescope. North is up, east to the left.

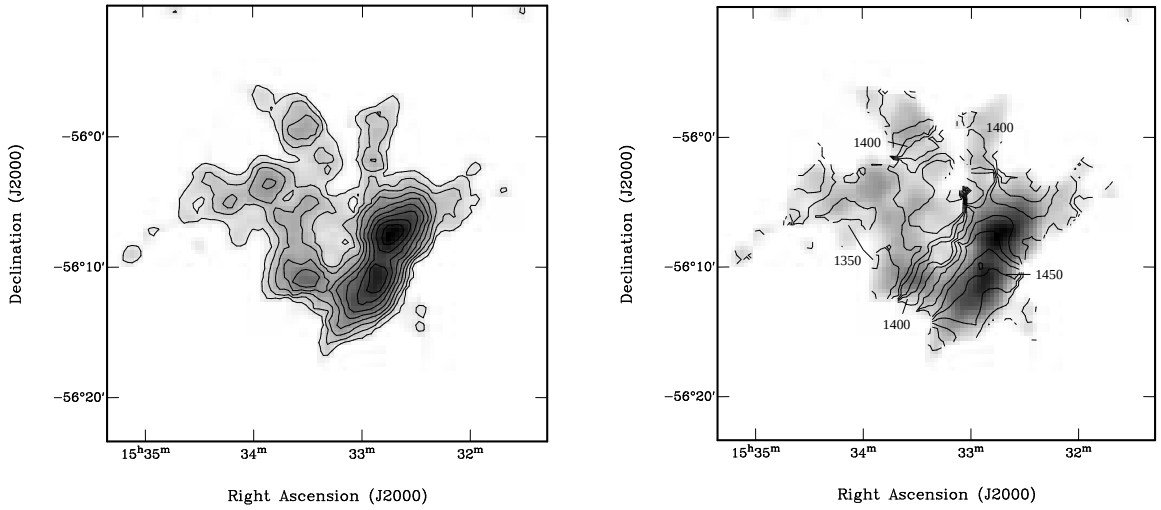

Fig. 5.— Column density images of J1532 − 56 with contours of H I column density (left) and velocity (right) overlayed. The column density contours are in interval of 0.16 Jy beam^{-1} km s^{-1} starting from 0.16 Jy beam^{-1} km s^{-1} (10^{19} atoms cm^{-2}). The peak column density is 1.0×10^{20} atoms cm^{-2}. The velocity contours are spaced by 10 km s^{-1}. The highest velocities occur in the south (1480 km s^{-1}) and north (1440 km s^{-1}); the lowest velocities in the east (1360 km s^{-1}). Contour values are marked at 50 km s^{-1} intervals. The ATCA beam is 2.′2.

is probably underestimated by the ATCA observations because of the primary beam cutoff. The multibeam data suggest a value as high as 200 kpc. The ATCA peak column density is 10^{20} atoms cm^{-2} and the average column density in the tail is 3×10^{19} atoms cm^{-2}. Both these values are around two orders of magnitude smaller than for the M81 group, though some of this is may be due to the large resolution difference.

J1532 − 56 lies at $(\ell, b) = (324.^{\circ}07, -0.^{\circ}02)$ where the estimated absorption is $A_B = 16 - 57$ mag (Table 1), thus making optical and IR detection unlikely. An 843 MHz radio continuum image from the Molonglo Observatory Synthesis Telescope (MOST, Green et al. 1998) in Figure 6 reveals a close proximity (separation 15′) to the extended H II region G324.147+0.231, and even closer to the compact H II region G324.192+0.109 (Caswell & Haynes 1987). This and the fact that the heliocentric velocity of 1380 km s^{-1} corresponds to a frequency (1413.9 MHz) which is reasonably close to the H263δ recombination line rest frequency (1413.6 MHz) prompted us to check whether were being confused by Galactic emission. However, within the 64 MHz bandwidth of the multibeam data, we failed to find any other recombination lines. The absence of sufficient continuum emission at the position of J1532 − 56 also makes this explanation untenable.

More interestingly, Figure 6 also shows J1532 − 56 to be close to an elliptical ring listed as a Galactic supernova remnant (SNR) candidate by Whiteoak & Green (1996). However, we think it

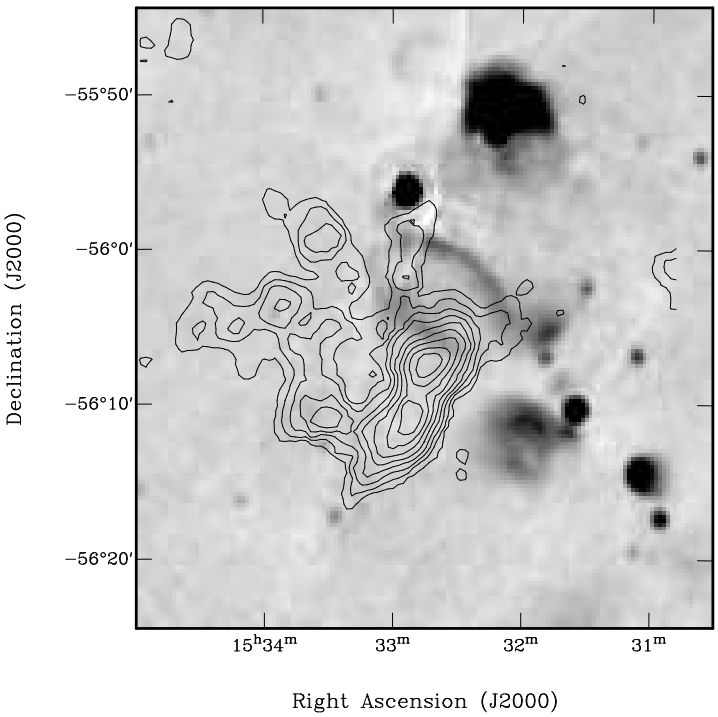

Fig. 6.— An 843 MHz MOST image (Green et al. 1998) of the region around J1532 − 56, with the ATCA H I column-density map superimposed (contours as in Fig. 5). The galaxy lies close to a probable SNR, MSC 324.1+0.1 (the elliptical ring) (Whiteoak & Green 1996), and to the H II regions G324.192+0.109 (the bright source north of J1532 − 56) and G324.147+0.231 (the extended object at Dec −55°50′). The other extended source at RA 15^h32^m, Dec −56°12′ is unidentified.

is unlikely that J1532 − 56 is a high-velocity cloud (HVC) associated with an expanding SNR. The velocity of J1532 − 56 in the Galactic rest frame is 1251 km s^{-1}, which is well outside the range, ±314 km s^{-1}, quoted by Stark et al. (1992) for Galactic HVCs. A search for molecular gas may help to evaluate this possibility.

3.3. J1616 − 55

This object required even an even longer integration and a more compact ATCA configuration to detect successfully with the ATCA. J1616 − 55 is large, so a mosaic of 12 pointing positions each separated by 15′, was required.

This object was imaged by making a dirty mosaic cube and beam cube following the method of Sault et al. (1996). Natural weighting was used. The cube was then re-gridded to the velocity spacing of the multibeam data (which in turn was re-gridded to the pixel size of the ATCA data)

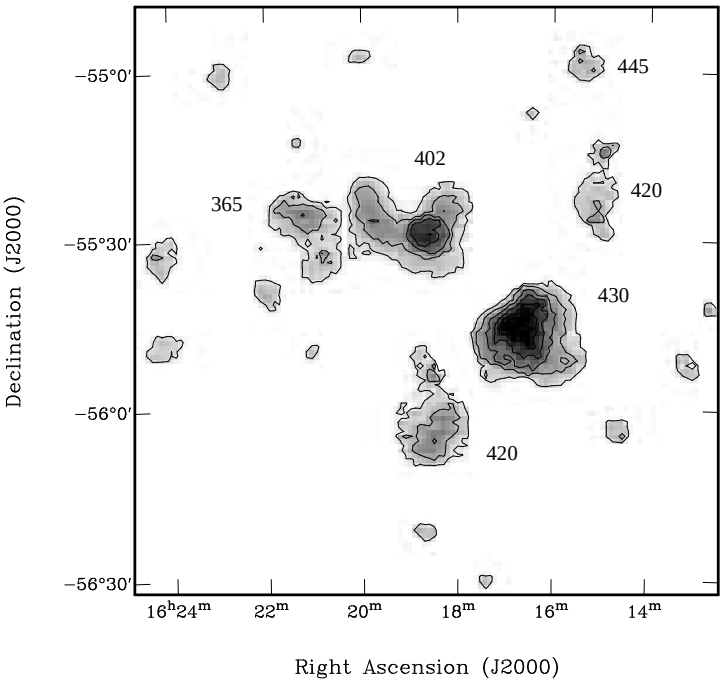

Fig. 7.— The ATCA column density image for J1616 − 55 (natural weighting) with contours at intervals of 0.2 Jy beam^{-1} km s^{-1}, starting at 0.2 Jy beam^{-1} km s^{-1} (3×10^{18} atoms cm^{-2}). The peak column density is 2.1×10^{19} atoms cm^{-2} with the restoring beam used of 4.′5. This image is a 12 point mosaic with the ATCA and incorporates the Parkes multibeam data in that the latter is the default maximum entropy model. Approximate heliocentric velocities in km s^{-1} are marked beside each significant component in the image.

and deconvolved using a maximum entropy task in MIRIAD. The multibeam data were used as the 'default image', thereby constraining the final deconvolved image to be consistent with the ATCA data on small spatial scales, while being consistent with the multibeam data on large spatial scales. The resolution of the restored cube is 4.′5. Column-density and velocity images were made by applying a flux cutoff of 7 mJy beam^{-1} to a smoothed version of the cube. The final column-density image is shown in Figure 7.

The ATCA observations show that the object appears to be resolved into two bright components, at least four fainter components and, most probably, a diffuse halo (Figure 7). The brightest component lies in the southwest at RA $16^{\rm h}16^{\rm m}49^{\rm s}$, DEC $-55°44'57''(\pm 1')$ (J2000). A fainter 'butterfly' feature lies about 25′ to the northeast at RA $16^{\rm h}19^{\rm m}05^{\rm s}$, DEC $-55°29'08''$ (J2000). The velocities agree with the multibeam observations: 430 km s^{-1} in the southwest and 402 km s^{-1} in the northeast. Because of the increased resolution, the peak column density is higher in the ATCA image – about 2.1×10^{19} atoms cm^{-2}.

The morphology of this system is unusual. It may be a single, very low column density galaxy where much of the disk has dropped below our detection level. However, we suspect that, like J1532 – 56, it is better explained by a tidal interaction between two smaller galaxies. The fainter outlying features in Figure 7 would then represent tidal debris. The combined H I mass of the whole system, if placed at 3.7 Mpc, is about a fifth of the mass of that of the Small Magellanic Cloud. The projected separation between the two main components is 27 kpc. The Galactic extinction in this region is between $A_B = 2.7$ and 4.4 mag (Table 1). This is low enough for a bright spiral such as J1514 – 52 to be seen, but could easily mask a lower surface brightness system. We have inspected Sky Survey plates of the region, and have taken MSSSO 40 inch CCD frames in V, R and Hα (exposure times 5 – 15 min) without obtaining an optical identification. Thus we propose that J1616 – 55 is an interacting pair of binary LSB galaxies not unlike, though lower in mass than, the H I cloud discovered by Giovanelli & Haynes (1989).

The J1616 – 55 system appears to have no immediate extragalactic neighbors. However, its heliocentric velocity (430 km s^{-1}, Table 1) is almost identical to that of the Circinus galaxy (439 km s^{-1}, Jones et al. 1998). Circinus lies at $\ell = 311\overset{\circ}{.}3, b = -3\overset{\circ}{.}8$, about 18° distant, or a distance of only 1.2 Mpc if both objects are 3.7 Mpc distant. Coincidentally, both galaxies lie at almost identical Galactic latitudes. It is therefore a possibility that that Circinus is not an isolated galaxy, but has the J1616 – 55 system as a distant companion. In turn, both galaxies in turn lie at the southern extremity of the Centaurus A group which also has a mean distance of ~ 3.5 Mpc (Coté et al. 1997).

4. DISCUSSION

The present sample is too small to predict the nature of the galaxies that will be found in the Parkes multibeam surveys of the Galactic Plane and the southern sky. It may, however, be significant that tidal interactions are hypothesised for two of the three objects discussed in this paper. Such systems are clearly under-represented in optical surveys. The Magellanic Stream, for which no stars appear to be associated (Wayte 1991), and the relatively recent discovery of the extent of the tidal interaction in the M81 group (§ 3.2, Yun et al. 1994), are good examples. The discovery of significant numbers of such systems may put on a firmer footing the relationship between tidal interactions, mergers and nuclear activity in nearby galaxies.

The same two objects (J1532 – 56 and J1616 – 55) are also significant in having low column densities – peaking at around 10^{19} cm^{-2} at the multibeam resolution of 14′ (17′ after gridding). This corresponds to < 0.08 M$_\odot$ pc^{-2} projected H I column density, which is more than an order of magnitude below the star-formation threshold proposed by Kennicutt (1989). The properties of the new galaxies are compared in Figure 8 with the optically selected sample of 'normal' galaxies observed by Broeils & van Woerden (1994, hereafter BW) in a search for extended H I disks. The BW sample, which includes a wide range of morphological types, H I masses and luminosities, has a narrowly defined range of mean H I surface densities – around 3 M$_\odot$ pc^{-2}. J1514 – 52 has

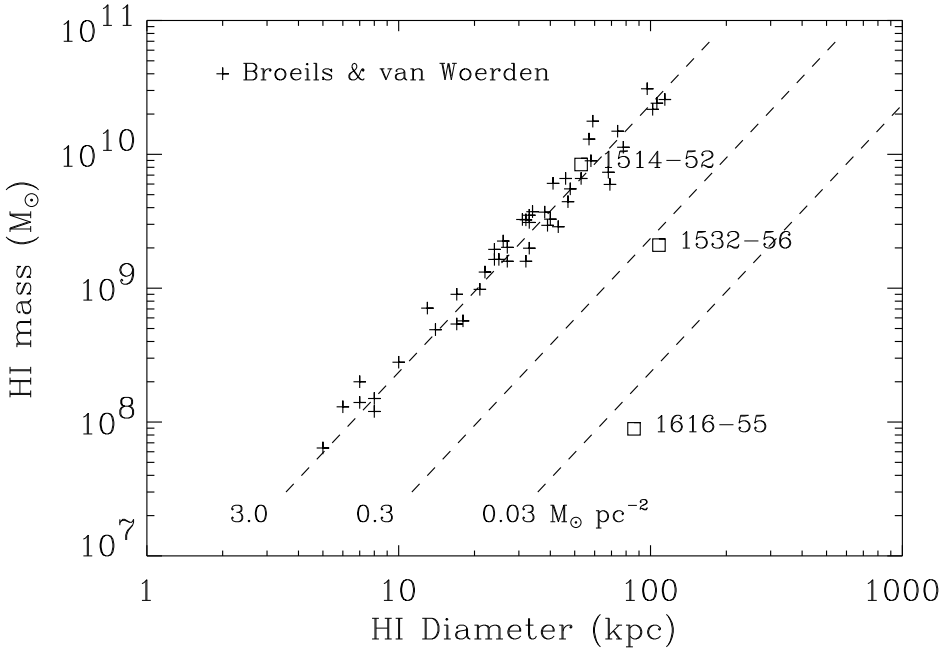

Fig. 8.— H I mass against H I diameter for J1514 − 52, J1532 − 56 and J1616 − 55 compared with the Broeils & van Woerden (1994, BW) sample of large H I-rich galaxies. Most of the BW sample and J1514 − 52 lie near the line representing an average surface density of 3 $M_\odot$ pc^{-2} . J1532 − 56 and J1616 − 55 have surface densities a factor of 13–200 smaller. Diameters for J1514 − 52 and the BW galaxies are measured at a surface density of 1 $M_\odot$ pc^{-2}. The peak column density of J1532 − 56 and J1616 − 55 lies beneath 1 $M_\odot$ pc^{-2}, so these were measured at 10% of their peak surface densities, or 0.080 and 0.017 $M_\odot$ pc^{-2}, respectively.

an H I mass and an H I diameter (which has been measured at the same surface density of 1 $M_\odot$ pc^{-2} – Table 1) close to the high end of the BW sample. It therefore has a similar mean (deprojected) surface density, ~ 3.8 $M_\odot$ pc^{-2}. In contrast, J1532 − 56 and J1616 − 55 have mean surface densities of 0.23 and 0.015 $M_\odot$ pc^{-2}, respectively. The diameters of these objects are hard to compare with their bright counterparts as their peak surface density does not exceed the 1 $M_\odot$ pc^{-2} level. Similarly, the BW data is too insensitive to measure diameters at a fainter level (i.e. BW would not have been able to detect J1532 − 56 and J1616 − 55 with their observing parameters). Instead, we note that 1 $M_\odot$ pc^{-2} is reasonably close to 10% of the peak surface density for galaxies in the BW sample, and use this criterion to define diameters for J1532 − 56 and J1616 − 55. This level corresponds to contours at 0.080 and 0.017 $M_\odot$ pc^{-2}, respectively.

What is the reason for the low H I surface densities in J1532 − 56 and J1616 − 55? Are these rare tidal systems? Or are these common objects, akin to the optical low surface brightness galaxy population (e.g. McGaugh 1996)? Morphologically, it appears that the systems chosen may

have had a strong tidal influence. However, it should be noted that even the central H I surface densities are extremely low. For example, the peak (projected) surface density of J1616 – 55 is a factor of 18 below the *mean* surface density (~ 3 $M_\odot$ pc^{-2}) of the BW sample. The answer to these questions awaits further multibeam observations. However, the resolution of the Parkes telescope ($14'$) is such that the numbers of low column-density galaxies which are close enough to be resolved may be small.

5. SUMMARY

Three large galaxies have been found in a blind multibeam H I survey of the southern Galactic Plane. These galaxies are the first of several thousand expected detections. One of them is a bright spiral (or would be except for the several magnitudes of optical extinction) and has been noted before by several authors. The remaining two are new discoveries for which we have been unable to find optical/IR counterparts, even with targeted observations. One of the new objects lies precisely on the Galactic equator.

High-resolution (ATCA) H I observations as well as optical CCD observations have helped to reveal the nature of the three galaxies:

1. J1514 – 52 (SGC 1511.1-5249 = WKK 4748) is an inclined (62°) disk galaxy with a flat rotation curve which extends to a radius of almost 60 kpc. The H I mass is 8.4×10^9 $M_\odot$ and the total mass is 5.7×10^{11} $M_\odot$. This galaxy appears to have a moderately active nucleus $L_{\rm FIR} = 1.0 \times 10^{10}$ $L_\odot$. This activity may be associated with having a nearby companion, ESO 223-G012.

2. J1532 – 56 appears as a very large (200 kpc) system in the multibeam images, although the ATCA diameter is 108 kpc. Its complex velocity field suggests the presence of more than one galaxy, a view which seems to be supported by the ATCA images which show the system to have morphological similarities with other tidally interacting systems such as the M81 group. The Galactic equator cuts through the middle of this system, thus demonstrating the effectiveness of the blind H I technique for finding galaxies even in the deepest obscuring layer of the Milky Way.

3. J1616 – 55 is the closest, lowest column density, and lowest mass of all the objects studied here. It appears to be a binary pair of LSB galaxies. A high (optical) surface brightness galaxy would probably have been seen at this position, where the predicted obscuration is $A_B = 2.7$ to 4.4 mag (although predictions such as these, based on IRAS data and Galactic H I column densities, are extremely uncertain). This system is also interacting, and is possibly associated with the Circinus galaxy and/or the Centaurus A group.

We speculate that interacting and low-column-density galaxies may be found in significant

numbers in blind H I surveys with the Parkes multibeam receiver and other systems.

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REFERENCES

Barnes, D.G., 1997, ADASS VII, in press (San Francisco: ASP)

Barnes, D.G., Staveley-Smith, L., Ye, T., and Oosterloo, T. 1997, ADASS VII, in press (San Francisco: ASP)

Broeils, A.H., and van Woerden, H. 1994, A&A Suppl., 107, 129 (BW)

Caswell, J.L., and Haynes, R.F. 1987, A&A, 171, 261

Corwin, H.G., de Vaucouleurs, A., and de Vaucouleurs, G. 1985, Southern Galaxy Catalogue, The University of Texas Monographs in Astronomy no. 4 (Austin: Univ. of Texas)

Coté, S., Freeman, K.C., Carignan, C., and Quinn, P.J. 1997, AJ, 114, 1313

Dickey, J.M., and Lockman, F.J. 1990, ARA&A, 28, 215

Fairall, A.P. 1988, MNRAS, 230, 69

Freeman, K.C., Karlsson, B., Lynga, G., Burrell, J.F., van Woerden, H., and Goss, W.M. 1977, A&A, 55, 445

Giovanelli, R., and Haynes, M.P. 1989, ApJ, 346, L5

Green, A.J., Cram, L.E., Large, M.I., and Ye, T.-S. 1998, ApJ(submitted)

Henning, P.A., Kraan-Korteweg, R.C., Rivers, A.J., Loan, A.J., Lahav, O., and Burton, W.B. 1998, AJ, 115, 584

Jones, K.L., Koribalski, B.S., Elmouttie, M., and Haynes, R.F. 1998, MNRAS, (in press)

Juraszek, S. et al., (in preparation)

Kennicutt, R.C. 1989, ApJ, 344, 685

Kerr, F.J., and Henning, P.A. 1987, ApJ, 320, L99

Kraan-Korteweg, R.C., and Huchtmeier, W.K. 1992, A&A, 266, 150

Kraan-Korteweg, R.C., Loan, A.J., Burton, W.B., Lahav, O., Ferguson, H.C., Henning, P.A., and Lynden-Bell, D. 1994, Nature, 372, 77

Kraan-Korteweg, R.C., and Woudt, P. 1994, 9^{th} IAP Astrophysics Meeting and 3^{rd} Meeting of the EARA on 'Cosmic Velocity Fields', eds. F. Bouchet and M. Lachièze-Rey, (Gif-sur-Yvette: Editions Frontières), p.557

Kraan-Korteweg, R.C., Woudt, P.A., Cayatte, V., Fairall, A.P., Balkowski, C., and Henning, P.A. 1996, Nature, 379, 519

Lahav, O., Yamada, T., Scharf, C., and Kraan-Korteweg, R.C. 1993, MNRAS, 262, 711

Lauberts, A. 1982, The ESO/Uppsala Survey of the ESO(B) Atlas (Garching: ESO)

McGaugh, S.S. 1996, MNRAS, 280, 337

Roberts, M.S., and Haynes, M.P. 1994, ARA&A, 32, 115

Sault, R.J., Staveley-Smith, L., and Brouw, W.N. 1996, A&A Suppl., 120, 375

Saunders, W., et al. 1994, in Unveiling Large-Scale Structures behind the Milky Way, ASP Conf Ser. 67, eds Balkowski, C., and Kraan-Korteweg, R.C. (San Francisco: ASP), p.257

Schlegel, D.J., Finkbeiner, D.P., and Davis, M. 1998, ApJ500, 525

Spellman, K., Madore, B.F., and Helou, G. 1989, PASP, 101, 360

Stark, A.A., Gammie, C.F., Wilson, R.W., Bally, J., and Linke, R.A. 1992, ApJS, 79, 77

Staveley-Smith, L. et al. 1996, Publ. Astr. Soc. Australia, 13, 243

Takata, T., Yamada, T., and Saito, M. 1996, ApJ, 457, 693

Walsh, W., Staveley-Smith, L., and Oosterloo, T. 1997, AJ, 113, 1591

Wayte, S.R. 1991, in The Magellanic Clouds, IAU Symp 148, eds Haynes, R., and Milne, D. (Dordrecht: Kluwer), p.447

Weinberger, R., Saurer, W., and Seeberger, R. 1995, A&A Suppl., 110, 269

Whiteoak, J.B.Z., and Green, A.J. 1996, A&A Suppl., 118, 329

Woudt, P.A., and Kraan-Korteweg, R.C. 1998, (in preparation)

Yamada, T., Takata, T., Djamaluddin, T., Tomita, A., Aoki, K., Takeda, A., and Saito, M. 1993, ApJS, 89, 57

Yamada, T., Tomita, A., Saito, M., Chamaraux, P., and Kazes, I. 1994, MNRAS, 270, 93

Yun, M.S., Ho, P.T.P., and Lo, K.Y. 1994, Nature, 372, 530

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