NEW GALAXIES DISCOVERED IN THE FIRST BLIND H I SURVEY OF THE CENTAURUS A GROUP

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ABSTRACT

We have commenced a 21 cm survey of the entire southern sky (δ < 0°, −1200 km s−1 < v⊙ < 12,700 km s−1) that is “blind,” i.e., unbiased by previous optical information. In the present paper we report on the results of a pilot project that is based on data from this all-sky survey. The project was carried out on an area of 600 deg2 centered on the nearby Centaurus A (Cen A) group of galaxies at a mean velocity of v⊙ ∼ 500 km s−1. This was recently the subject of a separate and thorough optical survey. We found 10 new group members to add to 21 galaxies already known in the Cen A group: five of these are previously uncataloged galaxies, while five were previously catalogued but not known to be associated with the group. Most of the new members have H I masses close to our survey limit of 107 M⊙ at the assumed group distance of 3.5 Mpc. The new detection with the largest H I mass is ESO 174−G7001 with MHI = 2.1 × 108 M⊙. Prior to our survey this galaxy was an uncertain optical identification because of high Galactic extinction. We found optical counterparts for all the H I detections, most of them intrinsically very faint low surface brightness dwarf galaxies with H I profile line-widths suggestive of dynamics dominated by dark matter. The new group members add approximately 6% to the H I mass of the group and 4% to its light. The H I mass function, derived from all the known group galaxies in the interval 107 M⊙ < MHI < 109 M⊙, has a faint-end slope of 1.30 ± 0.15, allowing us to rule out a slope of 1.7 at 95% confidence. Even if the number in the lowest mass bin is increased by 50%, the slope only increases to 1.45 ± 0.15.

Subject headings: galaxies: clusters: individual (Centaurus A) — galaxies: distances and redshifts — galaxies: ISM — radio lines: galaxies — surveys

1. INTRODUCTION

Recent developments in technology make it possible to perform for the first time large-area sensitive blind surveys at 21 cm to search for extragalactic H I. This opens many scientific opportunities. Most importantly, the selection effect at high Galactic extinction. We found optical counterparts for all the H I detections, most of them intrinsically very faint low surface brightness dwarf galaxies with H I profile line-widths suggestive of dynamics dominated by dark matter. The new group members add approximately 6% to the H I mass of the group and 4% to its light. The H I mass function, derived from all the known group galaxies in the interval 107 M⊙ < MHI < 109 M⊙, has a faint-end slope of 1.30 ± 0.15, allowing us to rule out a slope of 1.7 at 95% confidence. Even if the number in the lowest mass bin is increased by 50%, the slope only increases to 1.45 ± 0.15.

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1. INTRODUCTION

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implying that they may add even more to the overall mass in the universe than to the light. Finally, any extragalactic survey in which every object is automatically tagged with its velocity-distance offers rare opportunities for statistical studies.

Blind 21 cm surveys have a long history, but their ambitions have been severely curtailed by technological limitations. Single-dish radio telescopes large enough to reach high sensitivity have had beam areas too small to survey large areas of sky, while interferometric surveys are still confined to relatively narrow velocity windows by the computer power required to carry out the necessary cross-correlations between every interferometer pair. Nevertheless, in recent times blind surveys have been carried out in the galaxy clusters Hydra by McMahon et al. (1993) and Hercules by Dickey (1997); in voids by Krumm & Brosch (1984) and Weinberg et al. (1991); behind the Galactic plane by Kerr & Henning (1987); and in the field by Henning (1995). Recently, narrow zenith-strip scans have been done at Arecibo (see below) by Spitzak & Schneider (1998) and Zwaan et al. (1997).

The most recent 21 cm survey is our H I Parkes All-Sky Survey (HiPASS), which started early in 1997 and is expected to be complete within ~3 yr. This project takes advantage of the new multibeam instrument at the 64 m radio telescope at Parkes (Australia) equipped with 13 separate beams (26 receivers) and enough correlator power in each beam to survey 1024 velocity channels simultaneously. The scientific aims of the project include a study of the Galactic H I and of the galaxy content of the local universe. For this purpose we scan the complete southern sky in the velocity range $-1200$ km s$^{-1}$ $< v_{\odot} < 12,700$ km s$^{-1}$.

For the purpose of testing the performance of HiPASS, the present limited study was carried out using the first set of HiPASS data completed to full sensitivity. The selected area covers a substantial fraction of the nearby Centaurus A (Cen A) group of galaxies. The main reasons for this choice are twofold: (1) the Cen A group is among the closest galaxy groups to the Local Group at ~3.5 Mpc (Hui et al. 1993; Sandage et al. 1994) and contains the richest population of different morphological galaxy types (de Vaucouleurs 1979), including the peculiar giant elliptical NGC 5128, the large disk galaxies M83 and NGC 4945, the S0 galaxy NGC 5102, and the active star-forming galaxy NGC 5253. All main group members appear disturbed in their morphology. It has been suggested (Graham 1979; van Gorkom et al. 1990) that the recent accretion of a population of gas-rich dwarfs could be the reason. The group lies in the super-galactic plane with its southern extension running down to low Galactic latitudes, making optical studies challenging because of high extinction. (2) The group has recently been the subject of a careful optical survey (Côté et al. 1997, hereafter C97) enabling comparison between contemporary optical searches for gas-rich type (irregular) galaxies and our “blind” H I survey.

Most earlier H I studies of groups of galaxies have been done based on previous optical identifications of candidate members. In the M81 group, van Driel et al. (1998) and Huchtmeier & Skillman (1998) have independently done 21 cm searches for optically selected dwarf candidates. Neither group detected any new members. Huchtmeier, Karachentsev, & Karachentseva (1997) followed up on potential dwarfs found on the Second Palomar Sky Survey (POSS II), and found one new candidate of the IC 342/Maffei group and three new dwarf members each in the NGC 6946 and NGC 672/IC 1727 groups. Maia & Willmer (1998) have studied the neutral hydrogen content of a number of “loose groups,” but they also used pointed observations of optical candidates.

Several H I searches of compact groups of galaxies have been done (Oosterloo & Iovino 1997; Williams & van Gorkom 1997; Williams, McMahon, & van Gorkom 1991); however, these groups are usually far enough away that both the spatial resolution and the sensitivity preclude the detection of dwarf galaxies. However, a few nearby groups have been surveyed blind at 21 cm, and they include M81, CVnI, and NGC 1023, in which Lo & Sargent (1979) found four previously uncatalogued members, and a part of the Sculptor group, studied by Haynes & Roberts (1979), who found uncatalogued H I objects thought to be group members.

The present paper is organized as follows: § 2 describes the 21 cm survey; the observations with results are given in § 3 and § 4. The optical follow-up on the newly detected galaxies and their optical properties are presented in § 5 and § 6. In § 7 we derive the H I Mass Function for the Cen A group. Finally, we discuss detection limits and future projects in § 8.

2. SURVEY

The Cen A group covers approximately 1000 deg$^2$ of sky down to and perhaps through the Galactic plane. Since it is also projected against the supergalactic plane, the area is rich in galaxies and therefore well suited to test the performance of HiPASS.

The comparison optical search for dwarf irregulars in the Cen A area by C97 covered 900 deg$^2$ between $12^h30^m < \alpha < 15^h00^m$ and $-50^\circ < \delta < -20^\circ$, whereas we have surveyed a smaller area of 600 deg$^2$, chosen because it fits into the HiPASS survey grid. C97 found 18 H I rich dIrr’s (two new), of which 14 were in our search-area. Adding AM 1321-304, found by Matthews & Gallagher (1996) and the six well-known bright group members NGC...
TABLE 1

| Galaxy | $\alpha$ (J2000) | $\delta$ (J2000) | $V_\odot$ (km s$^{-1}$) | $\int S\Delta V$ (Jy km s$^{-1}$) | $\Delta V_{10}$ (km s$^{-1}$) | $\Delta V_{30}$ (km s$^{-1}$) | H I Mass ($\times 10^8 M_\odot)$ |
|--------|-----------------|-----------------|-----------------------|-----------------------------|-----------------------|-----------------------|---------------------|
| ESO 321—G014$^a$ | 12 13 56 | -38 14 05 | 610 | 6.4 | 35 | 43 | 19 |
| ESO 381—G018$^b$ | 12 44 26 | -35 55 48 | 610 | 4.3 | 48 | 56 | 13 |
| ESO 381—G020 | 12 46 02 | -33 50 00 | 590 | 36 | 80 | 98 | 100 |
| CEN 5 | 13 03 25 | -49 32 48 | 130 | 5.9 | 21 | 46 | 17 |
| CEN 6 | 13 05 09 | -40 05 50 | 610 | 7.0 | 23 | 36 | 46 |
| NGC 4945 | 13 05 09 | -49 31 48 | 370 | 3.0 | 360 | 380 | 990 |
| ESO 269 | 13 10 33 | -46 59 52 | 400 | 7.2 | 62 | 84 | 21 |
| HiPASS 1321—31$^c$ | 13 21 06 | -31 32 25 | 570 | 8.4 | 31 | 46 | 24 |
| NGC 5102 | 13 21 55 | -36 38 18 | 470 | 110 | 200 | 220 | 320 |
| AM 1321—304 | 13 24 31 | -30 58 05 | 500 | 3.9 | 34 | 66 | 11 |
| IC 4247$^d$ | 13 26 34 | -30 22 16 | 420 | 6.3 | 33 | 49 | 18 |
| ESO 324—G024 | 13 27 44 | -41 29 45 | 520 | 43 | 68 | 95 | 120 |
| HiPASS 1328—30$^e$ | 13 28 26 | -30 26 32 | 200 | 8.5 | 33 | 54 | 324 |
| ESO 270—G017 | 13 34 48 | -45 32 53 | 830 | 260 | 150 | 160 | 740 |
| NGC 5236/M83 | 13 37 03 | -59 24 37 | 510 | 1700 | 260 | 280 | 3700 |
| HiPASS 1337—39$^f$ | 13 37 26 | -39 52 15 | 490 | 7.9 | 37 | 51 | 23 |
| NGC 5237 | 13 37 40 | -42 50 29 | 360 | 12 | 75 | 92 | 33 |
| NGC 5253 | 13 39 58 | -31 39 03 | 400 | 51 | 65 | 97 | 150 |
| NGC 5264 | 13 41 34 | -29 54 19 | 500 | 28 | 43 | 98 | 82 |
| ESO 325—G011 | 13 45 03 | -41 51 43 | 550 | 27 | 58 | 81 | 77 |
| ESO 174—G001$^g$ | 13 48 01 | -53 20 46 | 680 | 73 | 72 | 100 | 210 |
| HiPASS 1348—37$^h$ | 13 48 47 | -37 58 28 | 570 | 4.3 | 30 | 40 | 12 |
| ESO 383—G087 | 13 49 20 | -36 02 59 | 330 | 31 | 33 | 54 | 90 |
| HiPASS 1351—47$^e$ | 13 51 12 | -46 58 13 | 530 | 4.4 | 38 | 47 | 13 |
| NGC 5408 | 14 03 21 | -41 23 17 | 500 | 55 | 75 | 120 | 160 |
| UKS 1424—460 | 14 28 06 | -46 17 51 | 380 | 21 | 47 | 79 | 61 |
| ESO 222—G010 | 14 35 01 | -49 24 14 | 620 | 9.1 | 41 | 64 | 26 |
| ESO 274—G001 | 15 14 15 | -46 48 37 | 520 | 150 | 170 | 190 | 430 |
| NGC 5128$^i$ | 13 25 28 | -43 01 09 | 550 | ... | ... | ... | 490.0 |
| NGC 5206 | 13 33 44 | -48 09 04 | 570 | ... | ... | ... | <5.5 |
| ESO 272—G025$^j$ | 14 43 26 | -44 42 19 | 620 | ... | ... | ... | <5.5 |

Note—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

$^a$ Previously catalogued but not known to be group members.

$^b$ Not previously catalogued.

$^c$ High mass and line widths uncertain; galaxy profile confused with HVC.

$^d$ Undetected in HiPASS, as below our limiting sensitivity; $\alpha$, $\delta$, and heliocentric radial velocity obtained from NASA Extragalactic Database.

$^e$ Mass limit from RC3 (de Vaucouleurs et al. 1991).

$^f$ H I limit from C97, detected Hz.

5128, M83, NGC 4945, NGC 5102, NGC 5253, and ESO 270—G017, means there were in all 21 suspected group members in our 600 deg$^2$ search area prior to our survey, with another seven outside (see Fig. 1). Our search was confined to the velocity range 200 < $v_\odot$ < 1000 km s$^{-1}$, cut off at the lower end because of the possibility of confusion with high-velocity clouds (HVCs), which are numerous in the Cen A group direction (Wakker 1991). One group member, CEN 5 ($v_\odot = 160$ km s$^{-1}$), with a velocity lower than 200 km s$^{-1}$ has been previously claimed (C97), and there remains the possibility that other group members in our data remain excluded by the 200 km s$^{-1}$ restriction. If we exclude CEN 5 from the statistics, then there were in our search area, prior to this survey, 18 suspected group members with H I detections and two with Hz (NGC 5206 and ESO 272—G025).

3. OBSERVATIONS AND DATA REDUCTION

The 21 cm observations for this pilot study were carried out in 1997 February and March as part of the HiPASS survey, which is ongoing at the 64 m single-dish Parkes Radio Telescope. This data set comprises the first completed area observed to full sensitivity with HiPASS. The instrument is a multibeam system consisting of 13 beams, each with 2 orthogonal polarizations. The scanning rate across the sky is 1 deg minute$^{-1}$ at constant right ascension. The data from the 26 correlators are stored every 5 s. Each correlator has 1024 channels tuned to a velocity range of 1200 and 12,700 km s$^{-1}$, cut off at 100 km s$^{-1}$.

The observed spectra were smoothed on-line by applying a

The data from the 26 correlators are stored every 5 s. Each correlator has 1024 channels tuned to a velocity range of 1200 and 12,700 km s$^{-1}$, cut off at 100 km s$^{-1}$. For more details about the multibeam system we refer the reader to Staveley-Smith et al. (1996). The integration time per point on the sky is 450 s. The 5 $\sigma$ sensitivity of the HiPASS survey is measured at 70 mJy channel$^{-1}$ beam$^{-1}$. For more details about the multibeam system we refer the reader to Staveley-Smith et al. (1996). The observed spectra were smoothed on-line by applying a
The 21 cm spectra of the 28 detected objects centered on the coordinates given in Table 1. Note that the ordinates differ between spectra. A single asterisk denotes a catalogued object not primarily known as a group member; a double asterisk denotes an object that is not catalogued. The velocity range shown encompass the survey interval, which is between 200 and 1000 km s$^{-1}$. The spectrum of CEN 5 is included for completeness, but it is excluded from the statistics because its velocity is below our lower limit.
Three-dimensional data cubes (bandpass correction, can be found in Barnes et al. (1998). Consequently, the actual velocity resolution is 18.2 km s$^{-1}$.

Putting individual spectra onto a pixel grid of 4 x 4, the process accounts for a loss in velocity resolution of 37%. Galatic signal entering through spectral side lobes. This 25% Tukey filter to reduce “ringing” caused by the strong Galactic HVCs, because there is a clear overlap in velocity space between nearby galaxies and the system of HVCs of our Galaxy toward the Cen A group direction (Wakker 1991). Because of the number dominance of HVCs and because only one Cen A group galaxy is known below 200 km s$^{-1}$ to date (CEN 5, see Table 1), we restricted our study and optical follow-up program (see § 5) to detections with $v_\odot > 200$ km s$^{-1}$.

4. **H I PROPERTIES**

We determined the H I fluxes of our detections by making zeroth moment maps. A MIRIAD (Sault, Tenben, Wright 1995) Gauss fitting routine yielded an estimate of the object’s coordinates ($\alpha$, $\delta$, $v_\odot$) (cols. [2] and [3] in Table 1). Positional accuracy should equal the half-power beamwidth (14.8) divided by the signal-to-noise ratio, which corresponds to less than 3$'$ (3.2 kpc at the distance of Cen A) for all sources with a 5 $\sigma$ detection or better. A spectrum was extracted from the data cube at the sky position from which the heliocentric radial velocity, $v_\odot$ (col. [4]), was measured at the midpoint at 50% of the peak of emission, and the total flux was determined (col. [5]). Furthermore, we measured the velocity widths $\Delta V_{50}$ (cols. [6]) and $\Delta V_{20}$ (cols. [7]) at 50% and 20% of the peak, respectively. The H I mass (col. [8]) was computed by employing the standard formula:

$$\frac{M_{\text{HI}}}{M_\odot} = 2.356 \times 10^8 (D[Mpc])^2 \int S_\nu dV,$$

where $D$ is 3.5 Mpc, our assumed distance to the Cen A group.

The examination of the Hanning smoothed spectra (Fig. 2) reveal that none of the detections are marginal. All sources are found to have signals above 3.9 Jy km s$^{-1}$. The coordinates of the H I detections were cross-correlated with the NASA Extragalactic Database and compared with UK Schmidt films to find optical counterparts. Each source could be associated unambiguously with a galaxy (col. [1] of Table 1) that is located within the positional uncertainty of 3$'$ radius. In some cases more accurate position information were acquired with the Compact Array of the Australia Telescope (see Staveley-Smith et al. 1999) where the identifications were always confirmed.

Among the 28 detection we found 10 new Cen A group members. Five of these galaxies were previously catalogued but not known to be associated with the group, while the other five were previously uncatalogued galaxies and are
Fig. 5.—Optical B-band images of the 10 new Cen A group members, with asterisks as in Fig. 2. East is down; north is to the left, except for HI PASS 1351—47 (east down, north right) and ESO 174 — G7001 (north down, east right).

### TABLE 2

| Galaxy        | $\alpha$ (J2000) | $\delta$ (J2000) | $m_B$ (mag) | $D(B_B)$ (arcsec) | $\mu_B^{\alpha}$ (mag arcsec$^{-2}$) | $r_o$ (arcsec) | $r_o$ (kpc) |
|---------------|-----------------|-----------------|-----------|------------------|--------------------------------------|---------------|------------|
| ESO 321—G014  | 12 13 50        | −38 13 53       | 15.2      | ...              | ...                                  | ...           | ...        |
| ESO 381—G018  | 12 44 42        | −35 58 07       | 15.8$^*$  | 22               | 22.8                                 | 10           | 0.2        |
| ESO 269—G058  | 13 10 33        | −46 59 22       | 12.2 ± 0.2| 108              | 21.4                                 | 30           | 0.5        |
| HiPASS 1321—31| 13 21 08        | −31 31 48       | 17.1 ± 0.2| 8                | 24.2                                 | 10           | 0.2        |
| IC 4247       | 13 26 44        | −30 21 45       | 14.4      | ...              | ...                                  | ...           | ...        |
| HiPASS 1328—30| 13 28 55        | −30 29 32       | 17.0 ± 0.2| 16               | 23.4                                 | 10           | 0.2        |
| HiPASS 1337—39| 13 37 26        | −39 53 47       | 16.5 ± 0.3$^b$| ...              | ...                                  | ...           | ...        |
| ESO 174—G7001 | 13 47 50        | −53 20 45       | 14.2      | ...              | ...                                  | ...           | ...        |
| HiPASS 1348—37| 13 48 33        | −37 58 03       | 16.9 ± 0.2| 11               | 23.8                                 | 9            | 0.2        |
| HiPASS 1351—47$^c$ | 13 51 22       | −47 00 07       | 17.5 ± 0.3| ...              | ...                                  | ...           | ...        |

**Note.**—Units of right ascension are hours, minutes, and seconds, and units of declination are degrees, arcminutes, and arcseconds.

$^a$ $m_B$ values from RC3 (de Vaucouleurs et al. 1991)

$^b$ Calibrated with B-band data obtained from DSS

$^c$ Object is too faint (or low in the Galactic plane) to be fitted by a light profile.
identified according to the HiPASS survey nomenclature (HIPASS 1321−31 has recently been detected as 131820.5−311605 by Karachentseva & Karachentsev 1998).

The most gas-rich new group member is ESO 174−G?001 with a H I mass of $M_{\text{HI}} = 2.1 \times 10^8 M_\odot$, which is larger than the amount of H I observed, for instance, in NGC 5253 or NGC 5408. It is a LSB galaxy close to the Galactic plane ($b = 8\degree$), which may explain why its identification as a galaxy was previously uncertain (Lauberts 1982). CEN 5 was previously optically identified and classified as a group member candidate by C97, and so we include the spectrum for completeness, although it is excluded from the statistics by its low velocity ($< 200 \text{ km s}^{-1}$). Looking at the spectrum (Fig. 2), we see two peaks. However, the higher velocity signal is from the nearby galaxy NGC 4945, the complete profile of which can be seen in Figure 2.

For completeness reasons we also list in Table 1 the H I limits NGC 5206, ESO 272−G025, and NGC 5128, which remained undetected in this study: NGC 5206 is an early-type galaxy and ESO 272−G025 was classified as peculiar (Lauberts 1982). These two galaxies were also not detected in H I emission by C97, to a more sensitive detection limit. Since the multibeam failed to detect the powerful radio galaxy NGC 5128, the listed H I mass for this galaxy is taken from de Vaucouleurs et al. (1991), derived from absorbing gas.

In Figures 3 and 4 we compared the total fluxes and velocity widths ($\Delta V_{20}$) with the corresponding data measured by C97. In general, we found good agreement, showing HiPASS is achieving the expected sensitivity, although for three galaxies we measured larger integrated fluxes, suggesting that there may be a 21 cm signal outside C97’s chosen search areas.

5. OPTICAL PROPERTIES

We attempted to get CCD images in the optical photometric bands $B$ and $R$ for those galaxies without reliable photometry in the literature. The optical data was acquired as part of an extensive optical follow-up program of HiPASS galaxies. This program employs three telescopes: (1) the 1 m (40 inch) telescope at the Siding Spring Observatory, (2) the 1 m Swope Telescope at Las Campanas Observatory, and (3) the Curtis Schmidt telescope at Cerro Tololo Inter-American Observatory. We used 2048$^2$ CCDs with a ~24$\arcmin$ field of view and a pixel size of 0.7, except for the Siding Spring observations, where a 800$^2$ CCD was used with a ~ 8$\arcmin$ field of view and the same pixel size. For each
galaxy a series of six exposures of 300 s each were taken. The optical data were debiased and flattened with the standard Starlink CCDPACK (Draper 1993) reduction techniques, then calibrated using Landolt (1992) standards. The seeing was typically 1′. In the case of HiPASS 1337 − 39, we had to rely on the image from the Digitized Sky Survey (DSS; a similar method to that employed by Spitzak & Schneider 1998) to calibrate an image for which we had no calibrated CCD data.

Figure 5 shows B-band images of the newly identified Cen A group galaxies to illustrate the variety in optical morphology. Previously catalogued galaxies (single asterisks) are high surface brightness objects and thus likely to be visually identified as background galaxies. The uncatalogued galaxies (double asterisks), on the other hand, are faint, LSB galaxies with small angular size and very hard to see.

In Table 2 we list photometric parameters of the 10 new group members (col. [1]) drawn from various sources—either The Third Reference Catalogue of Bright Galaxies (RC3; de Vaucouleurs et al. 1991), the DSS, or from our own CCD data (if available). The coordinates (cols. [2] and [3]) are the optical positions either quoted in the literature or measured by us at the centroid of the optical image. When CCD data were available, the galaxy image was cleaned by removing superimposed foreground stars. Afterward, the total apparent magnitude $m_p$ (col. [4]) was determined by circular aperture photometry and fitting a growth curve. Otherwise the total apparent $B$ magnitude was taken from the literature. Where we could fit an exponential profile $\mu(r) = \mu_0^{exp} + 1.086(r/r_0)$ to our own optical data, we also quote the extrapolated central surface brightness $\mu_0$ (col. [6]) and the exponential scale length $r_0$ (cols. [7] and [8]). In some cases the galaxy was too faint or too obscured by stars for a reliable profile fit to be made.

6. RESULTS

To summarize our results, a shallow integration $H \alpha$ survey of the inner 600 deg$^2$ of the Cen A group and the velocity range $200 < v_c < 1000$ km s$^{-1}$ revealed 28 $H \alpha$ sources, all of which have been identified as Cen A group galaxies. All detections have integrated flux larger than 3.9 Jy km s$^{-1}$. Eighteen objects coincide with previously known group members. A further 10 are suggested as new group members. Of these 10, five coincide with previously catalogued galaxies, and five coincide with previously uncatalogued galaxies. Three main group members were not detected at our survey sensitivity of $10^3 M_\odot$ of $H \alpha$, assuming an $H \alpha$ velocity width of 50 km s$^{-1}$, but one (NGC 5128) is known as an $H \alpha$ source from absorption studies. All new galaxies detected in this study have optical counterparts.

Table 3 lists various intrinsic parameters for the new group members. The optical radius $R_{opt}$ (col. [2]) has been estimated by eye on the DSS images. The model-dependent total $B$ magnitudes, $m_B$ (col. [4]), have been calculated for each galaxy using the parameters of the exponential profile, $\mu_0^{exp}$ and $r_0$ (cols. [6] and [7], Table 2), using

$$m_B = \mu_0^{exp} - 2.5 \log (2\pi r_0^2).$$

However, this depends on an extrapolation to infinity, and so the model magnitudes should be compared with the $m_B$ values in Table 2 obtained from aperture photometry. The galactic extinction $A_B$ for each galaxy, given in column (4), has been obtained from the dust maps of Schlegel, Finkbeiner, & Davis (1998), wherein dust is mapped from the energy it emits in the far infrared as seen in the high spatial resolution observations made with IRAS and DIRBE. In the case of the highly obscured ESO 174−G001 we have checked that estimate by measuring the colors of neighboring background elliptical galaxies in our frames and find excellent agreement ($\pm 0.1$ mag).

Assuming a mean distance modulus of $(m - M) = 27.8$ for the Cen A group (Saha et al. 1995) and correcting for the extinction, we converted the absolute magnitude $M_B$ (col. [5]) and determined $M_{H\alpha}/L_B$ (col. [6]). The mass $M_*$, quoted in column (7) is arrived at by simply assuming a value of the stellar mass-to-light ratio $M_*/L_B = 1$ for such gas-rich dwarf galaxies, a result suggested by previous authors (e.g., Staveley-Smith et al. 1990 and de Blok, McGaugh, & van der Hulst, 1996). Finally, the ratio between indicative dynamical mass $M_i \equiv R_{opt}(AV_{50,core})^2/G$ (Roberts 1978) and photometric mass $M_*$ is given in column (8); $R_{opt}$ is the quoted optical radius, and $AV_{50}$ is the FWHM, corrected for inclination if the minor and major axes of the galaxy could be reliably determined.

Although $M_i$ may be a crude estimator of the true dynamical mass, it should provide a safe lower limit because $H \alpha$ radii are usually larger than the optical radii. For instance, Bosma (1978) suggests $H \alpha$ disks extend out to 1.5

| Galaxy     | $R_{opt}$ (arcmin) | $m_B$ (mag) | $A_B$ (mag) | $M_H$ (mag) | Inclination (deg) | $M_{H\alpha}/L_B$ | $M_*(10^8 M_\odot)$ | $M_i/M_*$ |
|------------|-------------------|-------------|-------------|-------------|-------------------|-------------------|---------------------|-----------|
| ESO 321−G0144       | 1.4 ± 0.2     | ... | 0.40       | −13.0       | 62                | 0.83              | 0.22                | 22−15     |
| ESO 381−G018       | 1.1 ± 0.2     | 15.8       | 0.27       | −12.2       | 55                | 1.1               | 0.11                | 77+20     |
| ESO 269−G058        | 3.8 ± 0.3     | 12.0       | 0.48       | −15.1       | 53                | 0.13              | 1.6                 | 32+14     |
| HiPASS 1321−31     | 0.7 ± 0.2     | 17.2       | 0.27       | −10.9       | 52                | 7.4               | 0.033               | 74+25     |
| IC 4247          | 1.2 ± 0.1     | ... | 0.24       | −13.6       | 63                | 0.44              | 0.40                 | 9+2       |
| HiPASS 1328−30     | 0.9 ± 0.1     | 16.4       | 0.32       | −11.0       | 57                | 8.4               | 0.038               | 84+15     |
| HiPASS 1337−39     | 0.5 ± 0.2     | ... | 0.37       | −11.5       | 42                | 3.8               | 0.060               | 61+15     |
| ESO 174−G001      | 2.7 ± 0.3     | ... | 2.11       | −15.6       | 76                | 0.80              | 2.6                 | 13±5      |
| HiPASS 1348−37     | 0.5 ± 0.2     | 17.0       | 0.33       | −11.2       | 64                | 2.7               | 0.042               | 37+22     |
| HiPASS 1351−47     | 0.6 ± 0.2     | ... | 0.65       | −10.9       | ...               | 3.9               | 0.033               | 59±30     |

16 The DSSs were produced at the Space Telescope Science Institute under U.S. Government grant NAG W-2166.
times the optical Holmberg radius, while for gas-rich galaxies, the ratio of H I to optical diameter can be much greater (e.g., van Zee, Haynes, & Giovanelli 1995).

The newly found group members fall in two main categories. Of the five previously catalogued galaxies, ESO 321-G014 (Fig. 5) and ESO 269-G058 (Fig. 5) are not in the C97 area: ESO 321-G014 is obviously a dwarf irregular, while ESO 269-G058 is a highly irregular object with obvious H II regions and strong dust lanes. For the latter galaxy, a wrong redshift (1853 km s\(^{-1}\)) is published in the literature (de Vaucouleurs et al. 1991). Our velocity for IC 4247 (418 km s\(^{-1}\)), Figure 5, is rather different from the value of 274 km s\(^{-1}\) published by da Costa et al. (1987) and now places it firmly in the Cen A group.

The five previously uncatalogued galaxies exhibit a quite different morphology. They are faint (~17 mag), LSB, inconspicuous objects picked up in a blind survey solely because they are anomalously rich in H I. The survey would not pick up objects as faint as \(m_B = 17\) unless they had \(M_{HI}/L_B\) ratios of 4 or more. Indeed, if we look at their ratios of \(M_{HI}/L_B\) uncorrected for Galactic extinction, we find they have values ranging between 4 and 10, with a median of 5.5. Higher values are known in the literature (e.g., Lequeux & Viallefond 1980; Bergvall & Jörsäter 1988; Brinks & Klein 1988; van Zee et al. 1995) but are very rare. If such objects have a stellar mass-to-light ratio then they do not pick up objects as faint as unless they had a very high \(M_{HI}/L_B\) ratio.

In Figure 6 we plot the H I mass function from the 27 detections of our survey, which have accurate H I masses.

In order not to overinterpret the data, we do not attempt to find a fit for \(M_{HI}^\text{max}\), only to find the faint-end slope \(x\). To do this we make a weighted linear least-squares fit of log \(\rho\) against log \(M_{HI}\), (where \(\rho\) is the number of sources per log \(10\) \(M_{HI}\) bin) for sources with \(M_{HI} < 10^9\) \(M_\odot\) (Fig. 6) and find log \(\rho = (-0.30 \pm 0.15)\) log \(M_{HI} + (3.21 \pm 1.20)\). Hence the Schechter faint-end slope is \(x = 1.30 \pm 0.15\), where the formal error on the slope (see Bevington 1969) arises from assuming purely Poisson statistics for the numbers in each log \(M_{HI}\) bin in Figure 6. Since the most likely systematic error is the loss from our lowest mass bin of sources, which did not make the first cut and were not remeasured more accurately, we can ask how \(x\) would change if we added 50% more sources to the 12 already in that bin. In fact, \(x\) rises to only 1.45 ± 0.15. Similarly, the formal error on the slope allows \(x = 1.45\) at 1 standard deviation. Our data therefore does not rule out a faint-end slope of 1.5, but we can exclude a slope as steep as 1.7 at the 95% level. Table 4 contains a comparison of our Cen A results with those from the three other H I M F surveys mentioned above.

### Table 4

| Survey | Number | Number less than \(10^9\) \(M_\odot\) | \(M_{HI}^\text{max}/M_\odot\) | \(x\) |
|--------|--------|--------------------------------|-----------------|-----|
| This work | 27 | 17 | ... | 1.30 ± 0.15 |
| Spitzak & Schneider (1998) | 79 | 4 | \(7 \times 10^9\) | 1.32 |
| Zwaan et al. (1997) | 66 | 4 | \(3.5 \times 10^9\) | 1.20 |
| Kilborn et al. (1998) | 99 | 1 | \(3 \times 10^9\) | 1.35 |
| Kilborn, Webster, & Staveley-Smith (1999) | 263 | 3 | \(3 \times 10^9\) | 1.20 |
| Kilborn et al. (1999)\(^a\)| 253 | 3 | \(5.5 \pm 1.7\) \(\times 10^9\) | 1.15 ± 0.17 |

\(^a\) \Sigma I/V\(_{\text{max}}\) method  
\(^b\) Maximum likelihood method
8. DISCUSSION

It is encouraging that the present comparatively shallow blind HI survey already increases the number of known galaxies of the Cen A group by 50%, i.e., from 20 to 30 in our search area. It is in particular interesting that this happened after the group was so carefully studied in the optical (C97).

A glance at the spectra (Fig. 2) confirms that none of our objects are marginal detections. All have signals above 3.9 Jy km s$^{-1}$, whereas the formal 5$\sigma$ noise limit for optimally smoothed sources that are 50 km s$^{-1}$ broad is closer to 1.5 Jy km s$^{-1}$. The dispersion in the velocity of the less significant peaks in our data map mimic the velocity distribution of the Cen A group galaxies, suggesting that many of them will also turn out to be real members of the group.

We find only one LSB galaxy with an HI mass of more than $10^8 M_\odot$—ESO174$-$G3001, which contains $2.8 \times 10^8 M_\odot$ of HI. It is 3$^\prime$ across, and its measured central surface brightness is 24.5 $\mu$Jy beam$^{-1}$, which is indeed low. However, it is the galaxy closest to the Galactic plane ($b = 8^\circ$) and turns out to have 2.1 mag of foreground blue extinction. When this is allowed for, the central surface brightness rises to 22.4 $\mu$Jy beam$^{-1}$, which is not very low; $M_{HI}/L_{B}$ drops to 0.8, and the absolute magnitude, $M_B = -15.6$. ESO174$-$G3001 was missed by previous studies simply because of the large extinction toward it. Despite its comparatively large size, ESO174$-$G3001 is still much smaller than the instrument beam. If there were a giant LSB galaxy in the group, i.e., one with a diameter larger than the projected beam (15 kpc), we could only have detected it, on signal-to-noise ratio grounds, if its projected mass were more than $10^8 M_\odot$ of HI per beam; thus it would need to have a column density, $N_{HI}$, of at least $10^{19}$ atoms cm$^{-2}$. In reality, our automatic baseline fitting procedure would at present almost certainly “remove” the signal from the data. Irrespective of telescope size, for sources that fill the beam there is a lowest column density, 

$$N_{HI} > 10^{18} T_{sys} \left( \frac{AV(km\,s^{-1})}{i_{obs}(s)} \right)^{-1} \, \text{cm}^{-2},$$

detectable by any radio telescope, set by receiver noise, where $AV$ is the projected line width in km s$^{-1}$ (e.g., Disney & Banks 1997). Extreme objects, close to this column density limit, are best found when they are matched to the beam. For example, an $L_*$ galaxy 10 times the radius of our own and containing the same amount of HI would have an $N_{HI} < 10^{19}$ atoms cm$^{-2}$ and would be found only in integrations significantly longer than HiPASS and most probably out near 6000 km s$^{-1}$. So the results from the present HI survey do not rule out the existence of extended LSB galaxies in the Cen A group. The present study is being followed by a much deeper HI survey in the same region, using the same instrument to address this issue.

Although our survey has increased the number of known Cen A group members by 50%, the new members add only 6% to the total HI, and 4% to its light. The HI mass function has a slope at the low-mass end of 1.33 $\pm$ 0.15, which is unlikely to be steeper than 1.5 because of either statistical or systematic effects.

The five newly catalogued dwarfs have indicative mass to stellar mass ratios (Table 3, col. [8]) between 40 and 80 (mean 63 $\pm$ 16). Such ratios probably underestimate the dynamical masses because they assume the HI radii ($R_{HI}$) are equal to the optical radii ($R_{opt}$). However, HI maps of similar objects by other authors generally show that $R_{HI} > R_{opt}$, the most striking example being the VLA observations of HI1225$+$01 (Chengalur, Giovanetti, & Haynes 1995; for comparison, the five new group members that are previously catalogued have a mean ratio of 14). The high ratios add to the accumulating evidence (e.g., Kormendy 1985) that HI-rich dwarfs have their dynamics controlled by dark matter.

This survey of the Cen A group was aimed chiefly at validating the performance of the wider HiPASS survey of the southern sky, which will be over 90% complete by the time this goes to press. It confirms that performance matches expectation, and that large-area blind HI surveys will open a new window onto the extragalactic sky. As to the Cen A group itself, we expect to find further new group members when we run the data through the automatic galaxy-finding algorithm now under development. We have also completed a much deeper survey ($t_{obs} = 12 \times$ HiPASS) of a limited region ($8\times4'$) in the area, to investigate the performance and promise of long multibeam integrations (Banks 1998).

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