The Local Galaxy Population from the HIPASS survey

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Abstract. A new, sensitive HI survey is underway with a multibeam receiver on the Parkes telescope. The aim of the HI Parkes All-Sky Survey (HIPASS) is to blindly survey the southern sky out to a velocity of 12700 km s^{-1}. In this paper, we describe the parameters of the survey, summarise the current status, and present a collection of preliminary results on the Magellanic Clouds, new dwarf galaxies discovered in the Centaurus A group, and the HI mass function. These results have implications for our understanding of the population of nearby galaxies.

1 Introduction

The gaseous content of nearby galaxies depends on their past average rate of star-formation and the mass of baryonic material contained in the initial proto-galaxy. In general, more massive systems collapse earlier and contain the least gas relative to their baryonic mass at the present epoch. Understanding the evolution of galaxies and their gas consumption rate, and knowing the epoch of their formation is a fundamental goal in modern high-redshift astronomy. Present models (e.g. Pei & Fall 1995) are poorly constrained at high and low redshifts owing to uncertainties in gas content and star-formation rates. Some of these uncertainties arise from poorly constrained parameters at high redshifts, e.g. the correction for dust obscuration (Giavalisco et al. 1996, Calzetti 1997). However, there are significant uncertainties in local quantities such as the value for the space-averaged star-formation rate ($\dot{\Omega}_{\rm HI} = -3.7 \times 10^{-3}$ per Hubble time, Gallego et al. 1995) and the local gas density ($\Omega_{\rm HI} = 1.9 \times 10^{-4} h^{-1}$, Rao & Briggs 1993). Whereas local values for the star formation rate come from wide-area spectroscopic surveys, the local value for the gas density is dependent on targetted observations of optically-selected samples, and therefore may be biased. Moreover, the present cosmic star-formation rate is unsustainable for more than 0.5 Gyr unless there exists copious amounts of presently undetected HI or H_2 gas.

Blind surveys of neutral hydrogen (HI) in small regions of sky have been conducted and indicate some consistency with optically-selected samples (e.g.

Table 1. Summary of HIPASS parameters.

Parameter	Value
Sky Coverage	$\delta \leq 0°$
Integration time per beam area	500 s
Average system temperature	20 K
Central beam efficiency	63%
Central FWHP beamwidth	$14\overset{'}{.}0$
Velocity coverage (cz)	-1200 to 12700 km s^{-1}
Channel separation	13.2 km s^{-1}
Velocity resolution[a]	18.0 km s^{-1}
3-σ Positional accuracy[b]	$3\overset{'}{.}0$
3-σ detection limit[c]	30 mJy beam^{-1}
3-σ HI mass limit[d]	$10^6 d^2_{\rm Mpc} {\rm M}_\odot$

[a] After application of on-line Tukey 25% smoothing.
[b] Barnes (1998b); inversely proportional to signal-to-noise ratio.
[c] Measured value based on $r = 6'$ median gridding function.
[d] For $\Delta V = 150$ km s^{-1}.

Zwaan et al. 1997). However, there are strong selection effects operating against low column density galaxies which may not be optically prominent (e.g. Briggs 1990), and several surveys (e.g. Barnes et al. 1997) give only weak limits to the HI volume density of optically invisible galaxies. However the advent of the HIPASS survey, which is a sensitive all-sky survey of HI in the local Universe, will help to reduce some of the worst selection effects.

In this paper, we describe the parameters of HIPASS, and summarize a few preliminary results relevant to the population of nearby galaxies.

2 HIPASS parameters

The HI Parkes All-Sky Survey (HIPASS) is being conducted with a new multibeam receiver (Staveley-Smith et al. 1996) located at the prime focus of the Parkes telescope. Table 1 summarises the observational parameters of the survey which commenced on 1997 February 27. The sky is surveyed in 8° declination strips. The width of each observed strip on the sky is about $1\overset{\circ}{.}7$. However, this strip is slightly undersampled in Right Ascension, so strips are overlapped so that after five scans, each of the 13 beams makes a well-sampled survey of the sky. At the end of 1997, the survey was approximately 27% complete, with the sky coverage shown in Figure 1. Software reduction strategies are discussed in Barnes (1998a), and bandpass removal techniques are discussed in Barnes et al. (1998).

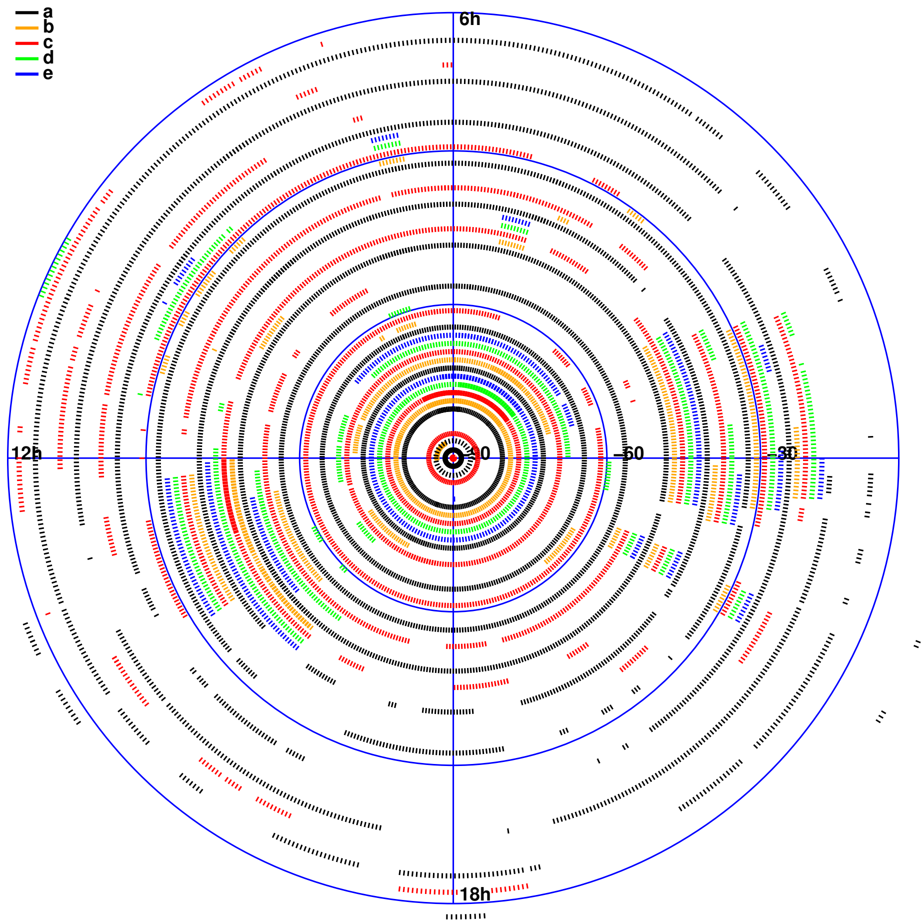

Fig. 1. A polar projection of HIPASS sky coverage obtained during 1997. Each of the five a-e scans is actually 8° long in declination (and not 1.°5 as plotted) and fully covers the sky.

3 Milky Way Dynamics

As can be seen from Figure 1, one of the best-sampled areas to date is the Southern Celestial Cap. This region contains our nearest gas-rich neighbours, the Magellanic Clouds. Although the velocity resolution and bandpass calibration schemes are not ideal for nearby extended objects, a large area around the Clouds has never been mapped with the full 14′ angular resolution of the Parkes telescope.

A brightness temperature image of an area 2400 deg^2 in extent and centred on declination $-90°$ is shown in Figure 2 (Putman et al. 1998). This mosaic nicely shows the nature of the interaction between the LMC and SMC as well as the beginning of the Magellanic Stream which appears to peel off from the SMC at the left-hand edge of the figure.

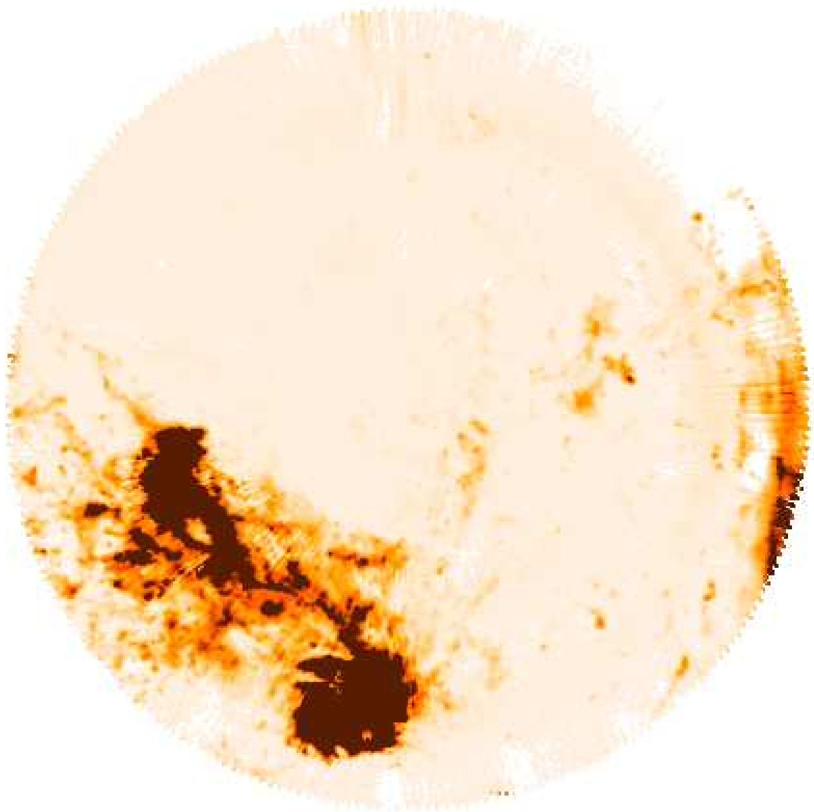

Fig. 2. A HIPASS view of the Southern Celestial Cap (Putman et al. 1998). This view contains the Large Magellanic Cloud (at the bottom), the Small Magellanic Cloud (towards the left) and the Bridge of gas connecting them. The southern Galactic Plane can be seen on the right-hand side. Many clouds of high velocity gas occupy the region between the Galaxy and the Clouds. The stripes in declination are scanning artefacts.

The wealth of new information apparent in this data is currently being used to re-examine the relationship between the LMC, SMC and the Galaxy in the context of various models describing their mutual interaction.

4 New Centaurus A neighbours

The Centaurus A group of galaxies (as opposed to the more distant Centaurus cluster) is the second most nearby group in the southern hemisphere (Côté et al. 1997) and allows a quick look at whether the mix of galaxy morphological types being detected by HIPASS is different from optically-selected samples, or not. Again, as Figure 1 shows, this group (at right ascension 13^h, declination $-35°$) was one of the early targets of the HIPASS survey.

Preliminary results (Banks et al. 1998) reveal a substantial number of previously unrecognised group members (around 10 with HI masses greater than 10^7 $M_\odot$). Although some of these are objects with previously unknown or incorrect velocities, a large fraction appear to be faint dwarf irregular galaxies. An example, HIPASS1351-47, is shown in Figure 3. Such galaxies are expected to be more prominent in HI-selected samples since, in general, they appear to have greater HI mass-to-luminosity ratios.

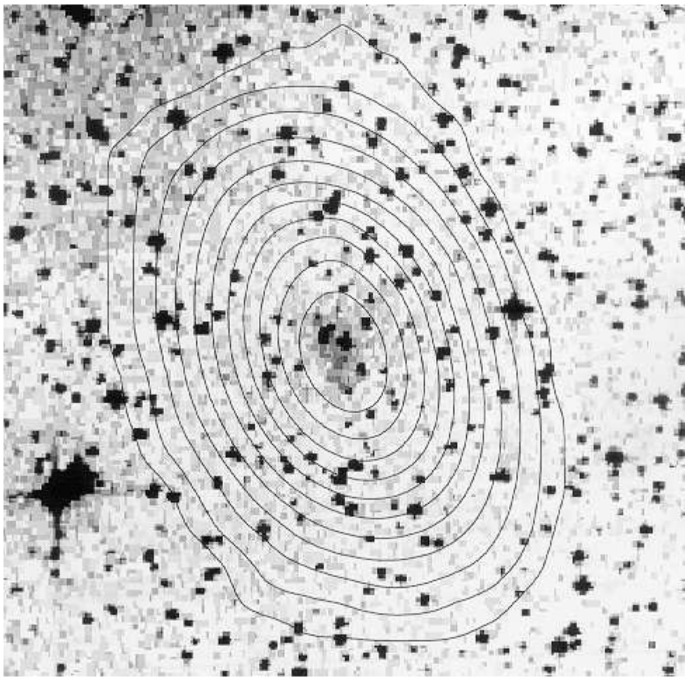

Fig. 3. Contours of HI column density overlayed on the Digitized Sky Survey for HIPASS1351-47, a new Centaurus A group member. The HI contours are from follow-up observations with the 375-m array of the Australia Telescope Compact Array taken on 1997 October 3.

Implications for the luminosity and mass distribution of Cen A galaxies, and the morphological mix of Cen A galaxies are discussed in Banks et al. (1998).

5 Field HI mass function

A more quantitative description of the density of galaxies in an HI-selected survey is given by the field HI-mass function. At the time of writing, the numbers of galaxies uniformly selected and measured from HIPASS data cubes in a systematic way is only ~ 200. However, this already exceeds existing surveys (e.g. Zwaan et al. 1997). Based on a flux-limited sub-sample of objects at declination $-74°$, Kilborn et al. (1998) have produced the HI mass function shown in Figure 4. The data points are overlayed with Schechter functions, with the best-fitting faint-end slope being -1.35. This is somewhat steeper than the slopes (~ -1.0) generally found in traditional optically-selected samples (e.g. Loveday et al. 1992), and indicates the greater contribution of low-mass galaxies to the cosmic density of gas.

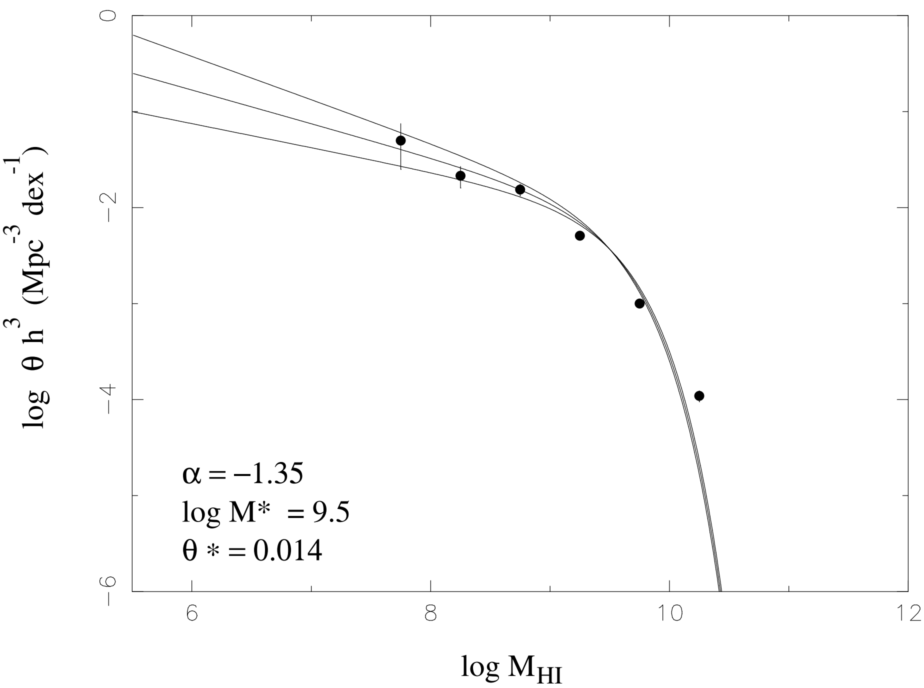

Fig. 4. A preliminary HI mass function from HIPASS using 99 galaxies from all HIPASS cubes in the $-74°$ declination zone. Three Schechter functions with faint-end slopes of -1.25, -1.35 and -1.45 are plotted.

Recent optical studies (e.g. Loveday 1997) suggest a possible upturn in the field luminosity function faintward of $M_B = -14$ mag. For an HI mass-to-luminosity ratio (in solar units) of unity, this corresponds to an HI mass of 6×10^7 $M_\odot$. Since this is approximately the lowest HI mass plotted in Figure 4, it will be interesting to see if there is any corresponding evidence for an upturn in the HI mass function as the amount of HIPASS data increases. Such an upturn would have dramatic consequences for our understanding of galaxy formation.

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