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HIPASS Results on the Gaseous Environments of Galaxies

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Abstract.
The gaseous content and environment of nearby galaxies is explored using recent data from the HI Parkes All-Sky Survey (HIPASS). This paper looks at recent results relating to the HI mass content of the local Universe, the optical luminosity function of an HI-selected sample of galaxies, and the HI environment of the Milky Way. In the South Celestial Cap region, the HI density is $\sim 6 \times 10^7$ M$_\odot$ Mpc^{-3}, less than 10% of which is contributed by galaxies in the mass range $5 \times 10^6 < M_{HI} < 10^8$ M$_\odot$. On a larger scale, the distribution of galaxies towards and around the Great Attractor reveals an overdensity ~ 0.5, somewhat below than predicted by POTENT reconstructions of the peculiar velocity field.

1. Introduction

The gaseous environments of galaxies and their progenitors greatly influences the manner in which galaxies interact, evolve and form stars. Understanding this environment in the early Universe is of course vital for understanding the initial stages of galaxy evolution (Katz, these proceedings). Similarly, knowledge of the gaseous environments of galaxies at the present epoch is useful in letting us know how much gas has been processed into stars, and what amount of reprocessed, or primordial, gas remains available to form stars. Much of the diffuse, gaseous material around present day galaxies is likely to be in the form of hot, ionised halos and large-scale filamentary structures (Shull, Penton & Stocke 1999). Although the bulk of the present-day baryons may exist in such structures (Meiksin, these proceedings), this gas does not cool efficiently, and is largely unavailable for accretion onto galaxies.

The cooler, neutral gaseous environment of galaxies is more readily available for accretion and conversion into molecular gas and collapse into stars. This gas can readily be seen using the 21-cm line of neutral hydrogen and several useful studies have been conducted (Henning 1995; Zwaan et al. 1997; Spitzak & Schneider 1998). However, extensive surveys with sample sizes more than $\sim 10^2$ galaxies have been difficult because of observing time limitations. In this paper, we summarise the parameters of the new HI survey being conducted with

Table 1. Observing Parameters for the HI Parkes All-Sky Survey

Parameter	HIPASS value
Sky Coverage[a]	$\delta \leq 2°$
Integration time per beam	460 s
Average system temperature	21 K
Central beam efficiency	63%
Central FWHP beamwidth	$14'.0$
Gridded FWHP beamwidth[b]	$15'.5$
Velocity coverage (km s^{-1})	-1200 to 12700
Channel separation	13.2 km s^{-1}
Velocity resolution[c]	18.0 km s^{-1}
3-σ Positional accuracy	$3'.0$
3-σ detection limit	40 mJy beam^{-1}
3-σ HI mass limit[d]	$10^6 d^2_{\rm Mpc}{\rm M}_\odot$

[a] Northern extension is $2° <$ Decl. $< 25°$.
[b] See Barnes et al. (2000).
[c] After application of on-line Tukey 25% smoothing.
[d] For $\Delta V = 100$ km s^{-1}.

a multibeam receiver on the Parkes telescope, and discuss various new results pertaining to mass and luminosity functions and the general environment of galaxies. Other HIPASS results in these proceedings are discussed in separate contributions by Kilborn, Koribalski and Sadler.

2. HIPASS

The HI Parkes All-Sky Survey is a blind survey for galaxies over the whole sky as visible from the 64-m Parkes telescope. Started in 1997, the survey achieved completion in the Southern hemisphere early in 2000, and the data was released (see Fig. 1) in May 2000. The parameters for the survey are listed in Table 1. In terms of depth, HIPASS has a volume coverage two orders of magnitude greater than existing blind HI surveys (Schneider 1997), and is therefore important in establishing the HI properties of galaxies in the nearby Universe ($cz < 12700$ km s^{-1}, Table 1).

A major objective of HIPASS is to produce an HI-selected catalog of galaxies. Although this work is still proceeding (Koribalski, these proceedings), four smaller surveys in the Centaurus A group (Banks et al. 1999), the South Celestial Cap (Marquarding 2000, Kilborn et al. 2000) and in the Zone of Avoidance (Henning et al. 2000) have been completed.

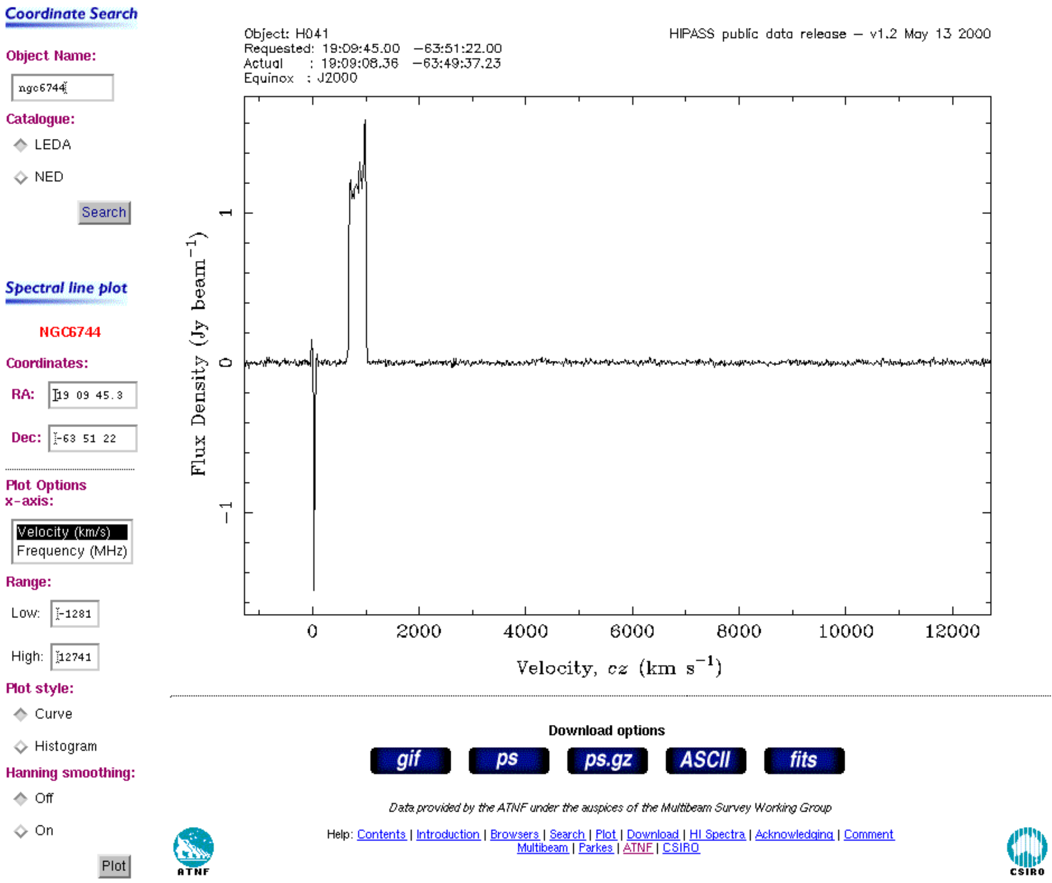

Figure 1. Public HIPASS spectrum of NGC 6744 from http://www.atnf.csiro/research/multibeam/release/

3. Luminosity and Mass Functions

Galaxies drawn from HIPASS reflect the HI-rich galaxy population: i.e. disk galaxies, spiral galaxies, LSB and dwarf galaxies. Many extragalactic HIPASS detections near the Galactic Plane are without an optical counterpart, due to extinction. Away from the Plane, only a few candidates for extragalactic HI clouds without optical counterparts exist (Kilborn et al. 2000).

To quantify the differences between optical and HI-selected samples, and to establish whether there are any substantial population differences, Marquarding (2000) studied a complete sample of 98 galaxies with $-90^\circ <$ Decl. $< -60^\circ$, $-1000 < cz < 2500$ km s^{-1}. Morphology was estimated mainly from ESO(B) survey plates. Photometry was taken from CCD data taken at Siding Spring Observatory and CTIO, Chile (22 galaxies) or the ESO-LV catalog (Lauberts & Valentijn 1989). Fig.2 shows the findings for disk galaxies. The luminosity function is reasonably well fit by a Schechter function with $M^* = -19.5$ mag or a Gaussian with a mean absolute magnitude -17.4 mag. The luminosity function

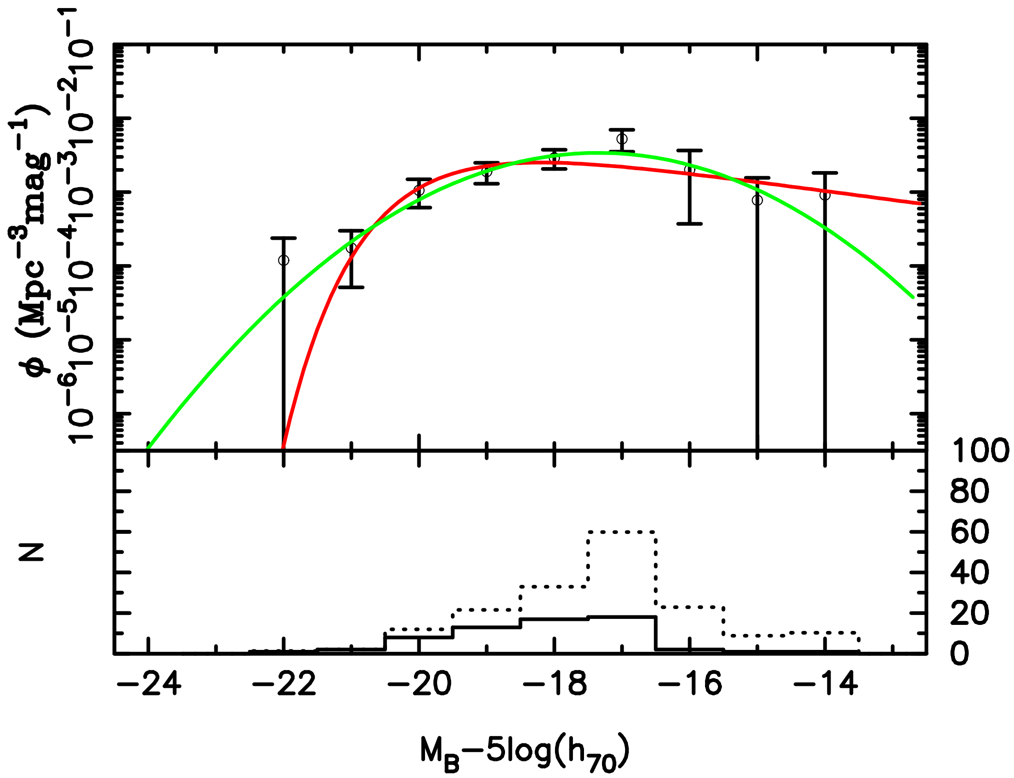

Figure 2. An optical luminosity function of HIPASS-selected *disk* galaxies in the South Celestial Cap (Marquarding 2000). A Gaussian fit (grey line) and Schechter fit (black line) are fit to the data points.

is constructed using $\Sigma V_{\rm max}^{-1}$ weighting derived from the HI sample properties (Marquarding 2000).

The apparent turnover in the disk-galaxy luminosity function fainter than absolute magnitude -17.4 mag reflects the paucity of dwarf disk galaxies. The optically-selected (Virgo and Centaurus) samples of Jerjen & Tammann (1997) exhibit similar trends, with a mean magnitude of -18.5 mag for spiral galaxies, which is slightly brighter but not substantially different. Somewhat more dramatic differences are apparent with later type Sdm-Irr samples, with many more faint galaxies turning up in HIPASS-selected samples compared with some, but not all (e.g. Loveday 1997) optically-selected samples. However, the sample size remains small.

The HI-only mass function, i.e. the density of galaxies of a given HI mass per decade of HI mass, is shown in Fig.3 for the South Celestial Cap sample of Kilborn (2000). The sample size is ~ 300 galaxies after stringent selection criteria are applied. The data points agree well with those of the shallow ZOA survey of Henning et al. (2000), though less well with the AHISS mass function of Zwaan et al. (1997) and the Ursa Major sample of Verheijen (these proceedings). The mass function is again constructed using the $\Sigma V_{\rm max}^{-1}$ method, so may be subject to some clustering bias. However, on the face of it, HIPASS finds many

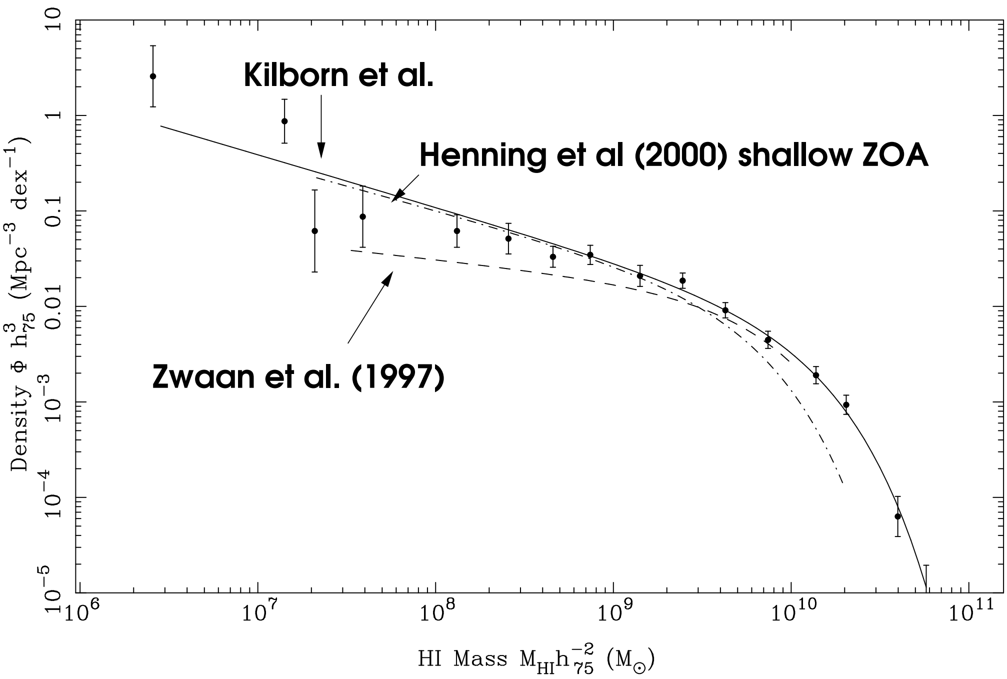

Figure 3. An HI mass function (and a Schechter fit) for galaxies in the South Celestial Cap (Kilborn 2000).

more low-mass galaxies than previous non-Parkes surveys, and finds a steeper faint-end slope when a Schechter function is fit to the data points (Fig.3).

The local HI density derived from the data points in Fig.3 ($\Sigma M_{\rm HI}\Phi(M_{\rm HI})$) is 6×10^7 M$_\odot$ Mpc^{-3}, which is about 50% more than the AHISS value of 4×10^7 M$_\odot$ Mpc^{-3}. Despite the numerical prominence of low-mass galaxies, the mass contribution of galaxies with HI masses $< 10^8$ M$_\odot$ is only $\sim 5 \times 10^6$ M$_\odot$ Mpc^{-3}, which is $< 10\%$ of the total HI mass. This limits the contribution of all clouds which HIPASS can resolve as separate objects (i.e. $\gtrsim$ 50 kpc from any companion), and therefore the contribution of any extragalactic HI clouds. Comparison with the HDF-derived luminosity density $L_B = 8.2 \times 10^8$ L$_\odot$ Mpc^{-3} (Driver 1999) also gives a *global* HI mass-to-light ratio $M_{\rm HI}/L_B = 0.08$ M$_\odot$/L$_\odot$.

4. The Environment of the Milky Way

In addition to the HVC population, discussed elsewhere in these proceedings, the nearest gas-rich neighbours of the Milky Way are the Magellanic Clouds which contain of the order 10^9 M$_\odot$ of HI. Though the interaction between the Clouds and the Milky Way is not on the same scale as other interacting systems (e.g. Hibbard & Yun 1999), it is nevertheless spectacular as shown in the HIPASS image of Fig.4.

The interaction between the Clouds and the Galaxy has resulted in a tidal tail, the famous Magellanic Stream, which stretches 100°across the sky, as well as a leading arm (Putman 2000). The mass contained in the Stream ($\sim 2 \times 10^8$

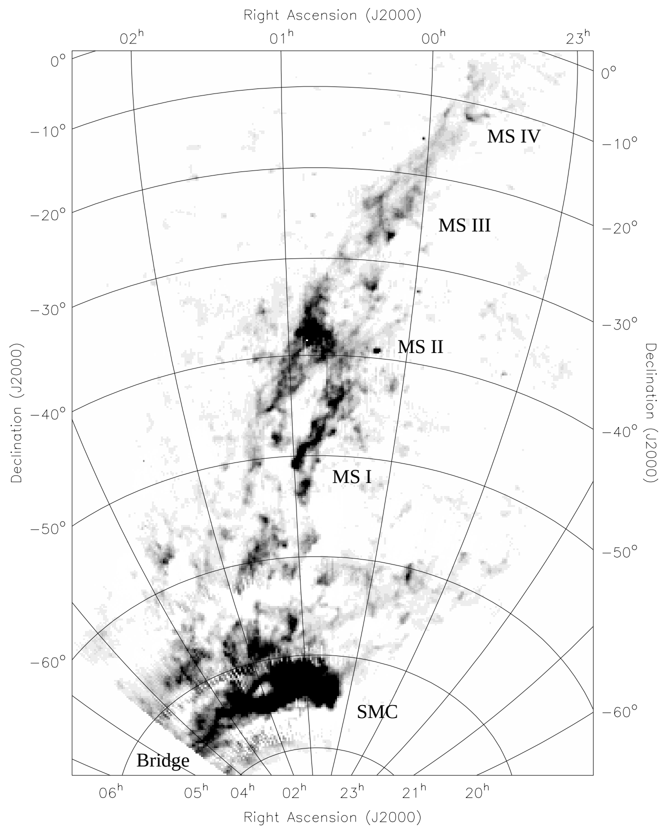

Figure 4. The Magellanic Stream is a tidal tail stretching from the SMC/Magellanic Bridge region for $\sim$ 100° into the Northern hemisphere (Putman 2000).

$M_{\odot}$) as well as that in the Clouds themselves is a substantial fraction of the existing gaseous mass of the Milky Way. Models suggest that much of this gas will accrete onto the Milky Way in a timescale of $\sim$ 1 Gyr. The data from HIPASS are currently being analysed in an attempt to understand the tidal forces at the head of the Stream, the relationship between the present Stream structure and the past orbital history of the Clouds, and the morphology and thermodynamic state of gas in the Stream.

5. The Great Attractor

One of the great attributes of a blind HI survey is insensitivity to the effects of dust obscuration. Nowhere has this been more of a problem than in the Great Attractor, a region of sky so-named because of its apparent influence on the peculiar velocities of galaxies within $\sim$ 5000 km s^{-1} (e.g. Kolatt, Dekel, & Lahav

1995). Preliminary results from an ongoing survey of the Zone of Avoidance in the region of the Great Attractor (Staveley-Smith et al. 2000) suggests that there may only be a moderate overdensity of galaxies, $\delta\rho/\rho_\circ = 0.5 \pm 0.2$. This survey applies to the region (in Galactic coordinates) $300^\circ < \ell < 332^\circ$ and $|b| < 5^\circ$, and to out to velocities of 10^4 km s^{-1} (and a weighted sample volume of $\sim 2 \times 10^4$ Mpc^3 for $H_\circ = 75$ km s^{-1} Mpc^{-1}).

This, in turn suggests that the amount of extra mass, over and above the background density, in the region is only $\sim 2 \times 10^{15}\Omega_\circ$ M$_\odot$. There are several possibilities for hiding more mass than this (since $\sim 5 \times 10^{16}$ M$_\odot$ is required to explain the canonical Great Attractor). Firstly, it may reside in clusters which are deficient in HI. Secondly, the remaining small region of reduced sensitivity near the ridge of Galactic continuum emission may mask some bright galaxies. Finally, the Great Attractor could be much more extensive than the region we have so far surveyed. These possibilities are discussed, though considered unlikely, in Staveley-Smith et al. (2000).

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