Seeing Through the Dust: The Detection of HI and the Exploration of the ISM in Galaxies
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The H I Parkes All-Sky Survey (HIPASS)

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Abstract. The H I Parkes[1] All-Sky Survey is the largest survey of neutral hydrogen gas to date, covering the whole southern sky with a velocity range from −1200 to 12700 km s^{-1}. With the northern extension to HIPASS completed, 70% of the sky has been scanned for neutral hydrogen gas. Among the many highlights of the survey are a catalog of high velocity clouds, maps of the Magellanic System and a growing inventory of external galaxies, more than 10% of which were previously uncatalogued. Intergalactic gas clouds are rare at the sensitivity level of the survey.

1. Introduction

We are celebrating 50 years of H I exploration since the first discovery of the 21-cm line by Ewen & Purcell (1951) in the Milky Way. The emission was first detected on March 25, 1951, then confirmed by Muller & Oort (1951) on May 11 and Christiansen & Hindman on July 12. The year 1953 marked the first H I detection in the Magellanic Clouds by Kerr & Hindman (1953). By 1975 about 140 galaxies had been measured in H I (see Roberts 1975). The first comprehensive H I catalog was compiled by Huchtmeier & Richter (1989) and contains ∼9,500 galaxies. To-date the Lyon-Meudon and the NASA/IPAC Extragalactic Databases hold 13,841 (LEDA) and 17,753 (NED) objects with H I line flux measurements. Most of these H I measurements were obtained for galaxies selected from optical catalogues, which are biased against galaxies with low optical surface brightness and incomplete in regions of high optical extinction. Blind H I surveys are therefore necessary to obtain a census of the neutral hydrogen gas in the local Universe. Since H I surveys are biased against galaxies with small amounts of hydrogen gas, e.g. elliptical galaxies (see Sadler 2001), optical and H I surveys complement each other.

Recently several blind H I surveys have been conducted, generally increasing with time in both volume and number of detections. Using the Arecibo telescope Spitzak & Schneider (1998) catalogued 75 galaxies (40 new) within 55 degrees^2, followed by Rosenberg & Schneider (2000) who found 265 galaxies (81 new) within 430 degrees^2. With the advent of a 21-cm multibeam system at the 64-m

[1]The Parkes telescope is part of the Australia Telescope which is funded by the Commonwealth of Australia for operation as a National Facility managed by CSIRO.

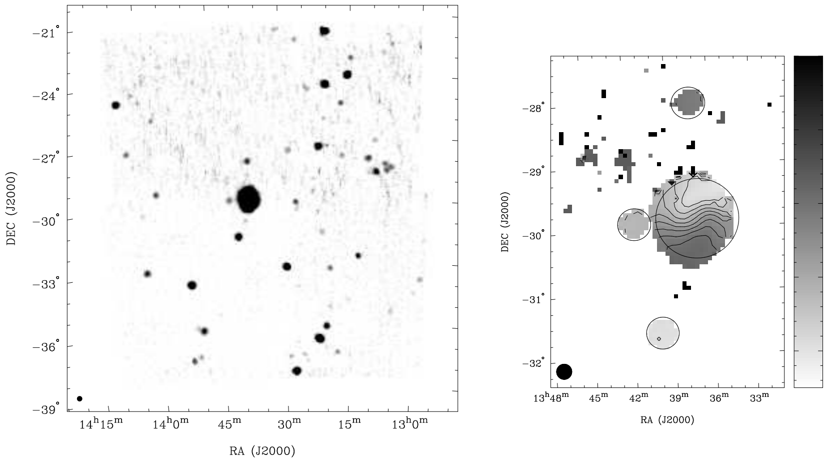

Figure 1. —**Left:** Example HIPASS field, centred on the nearby galaxy NGC 5236 (M 83), composed of four regular HIPASS cubes resulting in a total size of 16° × 16°. The H I distribution is shown in the velocity range from 250 to 2500 km s^{-1}. About 50 galaxies can be identified. —**Right:** HIPASS mean velocity field of M 83 (see also Park et al. 2001)and nearby surroundings. The circles mark the optical positions of NGC 5236, NGC 5264, ESO 444–G084, and NGC 5253. — The Parkes beam is displayed at the bottom left of each figure.

Parkes telescope (see Staveley-Smith et al. 1996) as well as new observing and data reduction software (Barnes et al. 2001), much larger and deeper surveys are now possible.

The H I Parkes All-Sky Survey (HIPASS; $\delta < +2°$) and the northern extension to HIPASS ($\delta = +2$ to $+25°$) are now complete and together cover 70% of the sky. An example HIPASS field around M 83 is shown in Fig. 1. The H I Jodrell All-Sky Survey (HIJASS; $\delta > +25°$) which just commenced (see Kilborn, these proceedings) will cover the remaining sky within the next couple of years. The Parkes southern Zone-of-Avoidance (ZOA) survey and its northern extension are also complete ($|b| < 5°$; $l = 196°$ to $52°$); a bulge extension to ZOA is on-going. Both the HIPASS and ZOA surveys cover a velocity range from –1200 to 12700 km s^{-1}. The HIPASS sensitivity is about 40 mJy beam^{-1} (3σ) which gives a column density limit of about $N_{\rm HI} = 4 \times 10^{18}$ cm^{-2} and an H I mass limit of about $M_{\rm HI} = 10^6 \times D^2_{\rm Mpc}$ M$_\odot$ (assuming $\Delta v = 100$ km s^{-1}). The 3σ ZOA survey sensitivity is $\sim$20 mJy beam^{-1}, but can be much worse in regions of high 20-cm radio continuum emission. For more details see Staveley-Smith et al. (2000a).

2. HIPASS and ZOA Highlights

As subsets of the data get analysed by various groups and individuals (especially PhD students), more and more highlights emerge from a large range of topics, e.g. a catalog of high velocity clouds, new views of the Magellanic System, gas dynamics in nearby galaxy groups, catalogs of various galaxy samples, and many previously hidden galaxies, revealed by *seeing through the dust* of the Zone-of-Avoidance (see also Staveley-Smith et al. 2001). In the following I summarise some recent highlights from the HIPASS and ZOA surveys:

- Only a large survey like HIPASS can capture the extent and beauty of the whole Magellanic System which covers a large fraction of the southern sky (see e.g. Putman 2000a). The Large and Small Magellanic Cloud, which are connected by a tidal bridge of hydrogen, strongly interact with each other and with our own Galaxy. The Magellanic Stream and recently discovered Leading Arm (Putman et al. 1998) allow us to study the nature of their interaction (see also Staveley-Smith, and, Brüns, these proceedings).

- Banks et al. (1999) and Knezek (1999) discovered a number of new galaxies in the first blind H I survey of the Centaurus A group (search area: $\sim$600 degrees^2, $200 < v_{\rm hel} < 1000$ km s^{-1}). The most gas-rich new group member is ESO 174–G?001 ($v_{\rm hel}$ = 680 km s^{-1}) with an H I mass of 2.1×10^8 M$_\odot$. The extended H I emission of NGC 5128 (Centaurus A) was missed because of a strong baseline ripple generated by its bright radio continuum emission (see Koribalski et al. 2002).

- HIPASS J1712–64 ($v_{\rm sys} \sim$ 460 km s^{-1}), which appears to be an extragalactic H I cloud with no optical counterpart was discovered by Kilborn et al. (2000). ATCA images resolve the cloud into two components similar to, but much less massive than, H I 1225+01 (the Virgo cloud). The discovery of another, very large H I cloud in its vicinity, HIPASS J1718–59 ($v_{\rm sys} \sim$ 400 km s^{-1}; Koribalski 2001), suggests a more local origin. Detailed studies are still under way.

- Since May 2000 HIPASS spectra are available from an on-line database (see *www.atnf.csiro.au/research/multibeam/*) as described by Staveley-Smith, Engel, & Webster (2000). Recent studies which have made use of the HIPASS database are by Huchtmeier et al. (2001), Helmboldt et al. (2001), and Davies et al. (2001).

- The most recent catalog emerging from HIPASS is that of the South Celestial Cap (SCC) region (Kilborn 2000, Kilborn et al. 2002). It is a major sample of 536 galaxies (114 new) at declinations $\delta < -62°$. The SCC catalog includes a small population of low-velocity H I clouds, whose origins and significance are under investigation. The catalog represents a small subset (11% in area) of the final HIPASS catalog, for which we have preliminary galaxy counts of $\sim$6000 galaxies.

- The High Velocity Cloud (HVC) Catalog (Putman 2000b, Putman et al. 2002) is a major compendium of various classes of southern H I clouds with anomalous velocities in the range $-500 < v_{\rm LSR} < +500$ km s^{-1}. Whereas most of the HVCs have a filamentary morphology and are loosely organised into large complexes, some are compact and relatively isolated.

- The "HIPASS Bright Galaxy Catalog" (hereafter HIPASS BGC; Koribalski 2001, Koribalski et al. 2002) is another major product of the multibeam

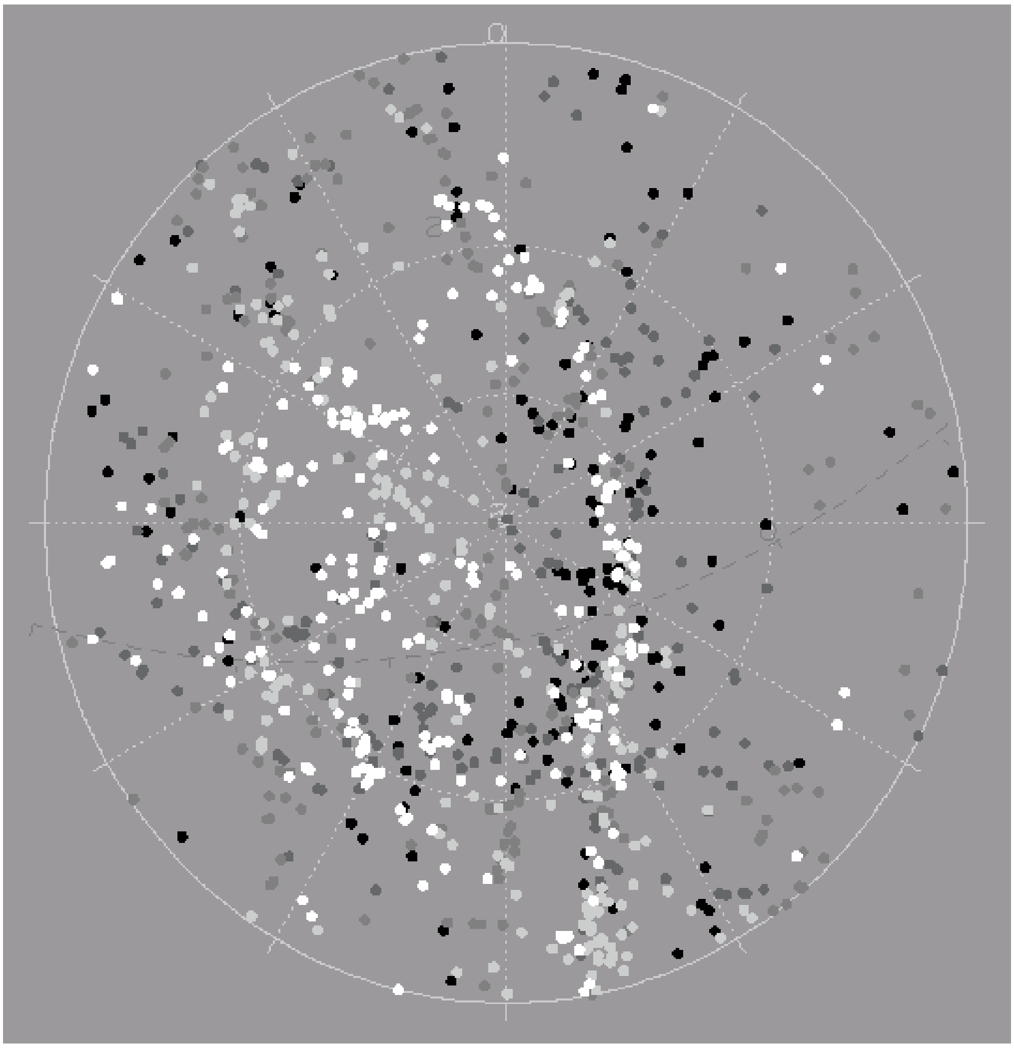

Figure 2. The “HIPASS Bright Galaxy Catalog” (Koribalski et al. 2002) contains the 1000 H I-brightest galaxies in the southern sky. The distribution of these galaxies on the sky is shown as a stereographic projection onto the South Pole (RA is increasing anti-clockwise in steps of 2 h). The displayed Local Group velocity ranges are as follows: $v_{\rm LG}$ < 1000 (white), 1000 – 1500 (light grey), 1500 – 2000 (grey), 2000 – 2800 (dark grey), > 2800 km s^{-1} (black). Nearly 10% of the HIPASS BGC galaxies were previously uncatalogued. — The most prominent filament across the figure is the Supergalactic Plane (SGP), roughly perpendicular to the Galactic Plane (dashed line). Parallel to the SGP we find at least two further filaments which have previously been described as the toes of a dinosaur's foot (Lynden-Bell 1994); the toes are clearly connected to the dinosaur's heel near the Great Attractor. Also prominent is the Local Void ($v_{\rm LG} \lesssim$ 1500 km s^{-1}.

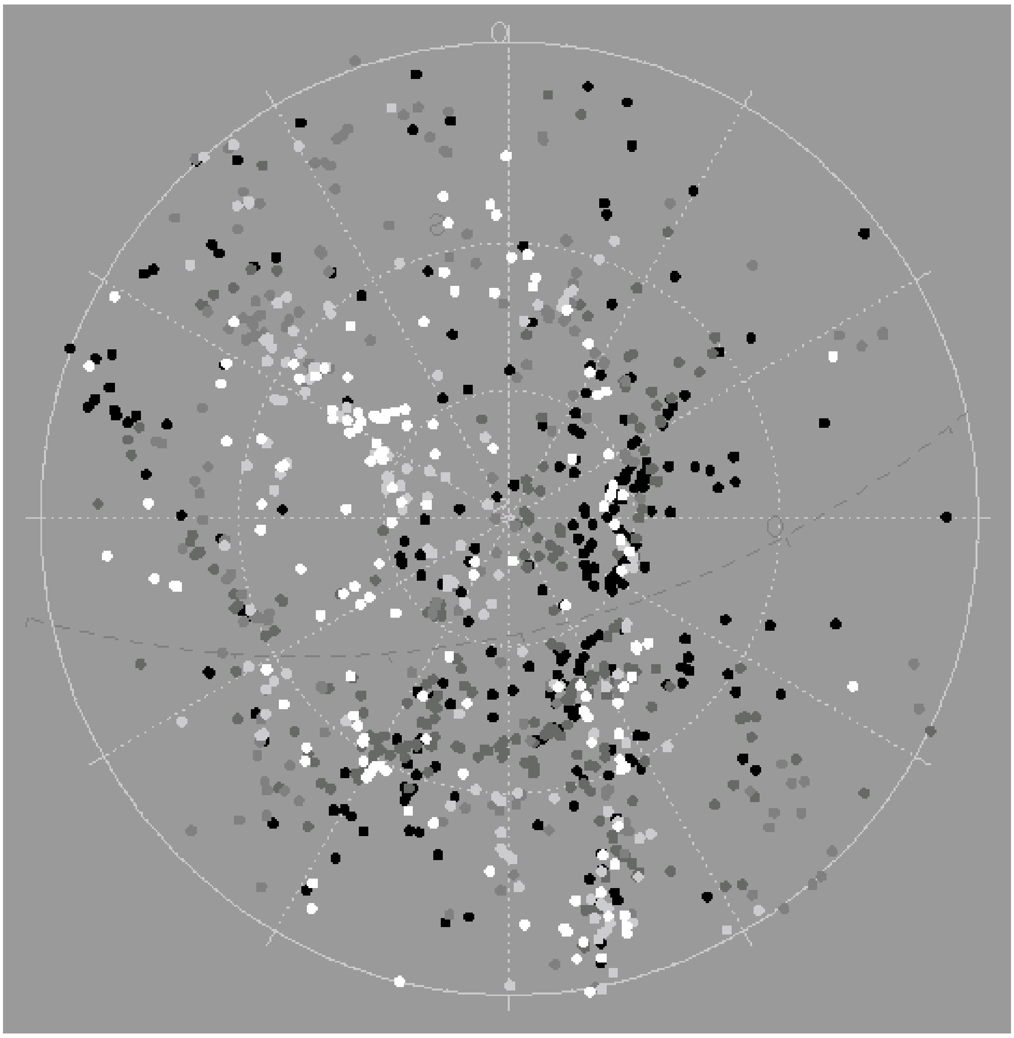

Figure 3. For comparison with Fig. 2 we show the distribution of the 1000 *optically*-brightest galaxies in the southern sky as obtained from LEDA (using $btc < 12.48$ mag, where btc is the mean total apparent corrected B-magnitude). For 309 of these galaxies no 21-cm magnitude (m21) is recorded in LEDA. — The HIPASS BGC and this LEDA sample have $\sim$400 galaxies in common. The main differences to Fig. 2 are: 1) the Zone-of-Avoidance is clearly seen as near horizontal gap in the data, and 2) galaxies appear more strongly clustered. Fig. 4 shows the galaxy type histograms for both samples. — The projection, coordinate grids and velocity ranges are the same as in Fig. 2.

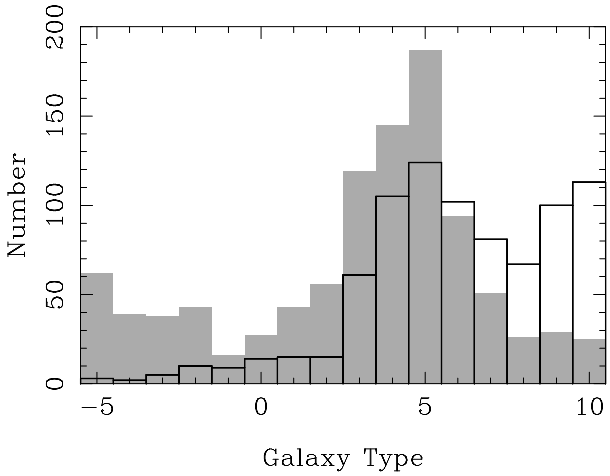

Figure 4. Galaxy type histograms for the HIPASS BGC (solid lines) and the LEDA sample (grey filling). LEDA parameters were only extracted for 850 BGC galaxies (see Jerjen et al. 2002).

surveys. It contains the 1000 H I-brightest galaxies in the southern sky (see Fig. 2), nearly 10% of which were previously uncatalogued. Most of the new galaxies lie, as expected, in the Zone-of-Avoidance; the remaining are mostly irregular dwarf galaxies (Ryan-Weber et al. 2002). For comparison, the 1000 *optically*-brightest galaxies are shown in Fig. 3. The differences in the two samples are remarkable and educating. Whereas large-scale structures like e.g. the Supergalactic Plane (SGP), the Fornax wall and the Local Void are prominent in both samples, the clustering of galaxies on smaller scales appears different. Fig. 4 emphasises the different galaxy types contributing to both samples.

- The discovery of a gas cloud, HIPASS J0731–69, near the asymmetric spiral galaxy NGC 2442 (Ryder et al. 2001) finally gives an important new clue regarding the galaxy's disturbed appearance. H I follow-up observations with the Australia Telescope Compact Array (ATCA) resolve the cloud into numerous blobs, none of which has an optical counterpart; CO observations with the SEST are underway. HIPASS J0731–69 is quite remarkable as it is the only such object in the HIPASS BGC (Koribalski et al. 2002).

- Using ATCA observations of a HIPASS sample of 36 galaxies across a large range of H I masses ($10^{7.5}$ to $10^{10.5}$ $M_{\odot}$) Ryan-Weber, Webster & Staveley-Smith (2002) find that the local column density distribution function, f($N_{\rm HI}$), is dominated by low H I mass galaxies in the range $3\times\ 10^{18} < N_{\rm HI} < 2\times\ 10^{20}$ cm^{-2}.

- A blind survey for the H I-bright galaxies in the southern Zone-of-Avoidance ($212° \leq l \leq 36°$, $|b| \leq 5°$) by Henning et al. (2000) revealed 110 galaxies. Of these 67 have no optical counterpart in NED. This 'H I Zone-of-Avoidance Shallow Survey' (HIZSS), which is composed of the first two out of 25 scans, represents the first stage of the now completed deeper search of the area with the multibeam system. Preliminary galaxy counts in the deep ZOA dataset exceed 1000 galaxies.

- An H I Survey of the Great Attractor region (l = 300° to 332°, $|b| < 5°$) by Staveley-Smith et al. (2000b) has so far revealed 305 galaxies, most of which were previously unknown (see also Juraszek et al. 2000). Assuming H I traces total mass, Staveley-Smith et al. find an excess total mass of $\sim 2\times\ 10^{15}\,\Omega_o\ M_\odot$, well below the $5\times\ 10^{16}\ M_\odot$ invoked to explain the local galaxy dynamics (Lynden-Bell et al. 1998).

Acknowledgments. The results summarised in this paper are based on a joint effort of members of the HIPASS and ZOA teams who are gratefully acknowledged.

We have made extensive use of the NED (http://nedwww.ipac.caltech.edu) and LEDA (http://leda.univ-lyon1.fr) databases; many thanks to George Paturel, Barry Madore and their teams.

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