Local Structures as Revealed by HIPASS

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Abstract. The HI Parkes All-Sky Survey (HIPASS) gives an unprecedented view of the local large-scale structures in the southern sky. I will review the results from the HIPASS Bright Galaxy Catalog (BGC, Koribalski et al. 2004) and the first version of the deep catalog (HICAT, Meyer et al. 2004) with particular emphasis on galaxy structures across the Zone of Avoidance. Some previously hardly noticed galaxy groups stand out quite distinctively in the HI sky distribution and several large-scale structures are seen for the first time. Because HI surveys preferentially detect late-type spiral and dwarf galaxies, their distribution is less clustered than that of optically selected galaxies. HI surveys also significantly enhance the connectivity of large-scale filaments by filling in gaps populated by gas-rich galaxies.

1. The HIPASS Galaxy Catalogs

The HIPASS Bright Galaxy Catalog (BGC, Koribalski et al. 2004) contains the 1000 HI-brightest galaxies in the southern sky as obtained from the HI Parkes All-Sky Survey. These were selected by their HI peak flux density ($S_{\text{peak}} \gtrsim 116$ mJy) measured in the spatially integrated HIPASS spectrum. We note that a subset of $\sim 500$ galaxies is complete in integrated HI flux density ($F_{\text{HI}} \gtrsim 25$ Jy km s$^{-1}$). The HIPASS BGC is highly reliable ($S/N \gtrsim 9$) and contains accurate HI properties of all sources as well as optical identifications were available. Sources without cataloged optical (or infrared) counterparts, i.e. $\sim 10\%$ of the BGC, fall into two categories: (1) gas-rich galaxies in regions of high Galactic extinction or high stellar density, and (2) late-type dwarf and low surface brightness (LSB) galaxies. The latter are generally missed in optical catalogs because they are small in size or rather faint, but they are easily identified given the HI position. For details of the newly cataloged galaxies in the HIPASS BGC, 70% of which lie in the Zone of Avoidance ($|b| < 10^\circ$), see Ryan-Weber et al. (2001).

We found only one extragalactic HI cloud, HIPASS J0731–69 ($M_{\text{HI}} \sim 10^9$ M$\odot$), located at a projected distance of 180 kpc from the asymmetric spiral galaxy NGC 2442 (Ryder et al. 2001).

Fig. 1 shows the distribution of all sources in the HIPASS BGC and HICAT, divided into velocity bins of $\Delta v = 1000$ km s$^{-1}$. Fig. 2 shows the histogram of local group velocities in both catalogs. The deep HIPASS catalog (HICAT) contains 4315 HI sources, including a large fraction of the BGC. For the first time, we can trace local large-scale structures over the whole southern sky, unobscured by dust or foreground stars. A beautiful network of filaments, loops, groups and voids is revealed, creating a cellular web that gradually changes with redshift.
In particular, HIPASS uncovers previously obscured galaxy structures across the Zone of Avoidance. The most striking feature in the first velocity bin ($<1000$ km s$^{-1}$) is the — in this projection — nearly horizontal, well defined narrow filament which corresponds to the near-side of the Supergalactic Plane (SGP). It is very long, reaching from the Sculptor Group on the righthand side all the way past the CenA Group on the left, clearly continuing through the optical Zone of Avoidance (ZOA). The voids on both sides of the plane help to delineate it so clearly. Also visible is the near-side of the Fornax Wall whose full extend is seen in the next velocity bin ($1000 – 2000$ km s$^{-1}$), revealing another ZOA crossing. The criss-crossing of filaments (or walls) creates a remarkable cellular structure depicting regions of high galaxy density and voids. The local large-scale structures are further described in Section 3. Overall, we find that the filaments seen in HI appear well defined and continuous while optically outlined structures are generally much more clumpy (Koribalski et al. 2004). In other words, the correlation length of HI rich galaxies, most of which are late-type spiral galaxies (see Fig. 3) is much smaller than that of optically selected galaxies, which includes many more elliptical and early-type galaxies. This decrease of clustering from early- to late-type galaxies (Giuricin et al. 2001) affects our view of the local large-scale structure such that HI surveys reveal many previously unknown structures and enhance connectivity within known structures.

Fig. 4 also shows the distribution of galaxies on the southern sky, but here symbols indicate the galaxy morphological type. While optical identification of the HIPASS BGC sources revealed $\sim$90% cataloged galaxies (see Koribalski et
al. 2004), cross-identification for HICAT is still under way. The left side of Fig. 4 shows the optically identified BGC sources with their mean morphological type as obtained from the Lyon Extragalactic Database (LEDA) as well as all newly
cataloged sources. A preliminary match of all HICAT sources with velocities below 4000 km s$^{-1}$ was also carried out using LEDA; the result is shown on the right side of Fig. 4.

2. HI Observations

The HI Parkes All-Sky Survey (HIPASS) was carried out with the 21-cm multibeam receiver (Staveley-Smith et al. 1996) installed at the prime focus of the Parkes$^1$ 64-m telescope. HIPASS covers the whole sky up to declinations of +25°. While the southern sky has been thoroughly searched for HI sources, source finding in the northern data cubes is still under way. HIPASS covers a velocity range of $-1200 < \text{cz} < +12700$ km s$^{-1}$, at a channel spacing of 13.2 km s$^{-1}$. The velocity resolution is 18 km s$^{-1}$. After data reduction (see Barnes et al. 2001) the gridded Parkes beam is typically 15\′.5. HIPASS data was obtained by scanning the telescope across the sky in 8° strips in Declination ($\delta$). Five sets of independent scans were made of each region, resulting in a final sensitivity $\sim 40$ mJy beam$^{-1}$ (3$\sigma$) which corresponds to a column density limit of about $6 \times 10^{18}$ cm$^{-2}$ (for objects filling the beam) and an HI mass limit of about $M_{\text{HI}} = 10^6 \times D^2_{\text{Mpc}} \ M_\odot$ (assuming $\Delta v = 100$ km s$^{-1}$). Note that the HI Parkes survey of the Zone of Avoidance (Henning et al.; these proceedings) is five times deeper.

The advantages of HI surveys are numerous: with 21-cm multibeam receivers such as the Parkes 13-beam system we can now cover large volumes out to several hundreds of Mpc. We simultaneously measure HI source position and velocity, resulting in accurate systemic velocities, velocity widths and HI masses, as well as — supplemented by, e.g., the optical galaxy inclination — estimates of the rotation speed and therefore the total dynamical mass. HI observations are unaffected by dust extinction or foreground stars, resulting in an unobscured view of the nearby large-scale structure. Since LSB and dwarf irregular galaxies tend to be gas rich, these are easily detected in HI surveys. We emphasize that HI and optical (infrared) surveys are complementary, as the former favours gas-rich spiral and irregular galaxies while the latter are biased toward bright spiral and elliptical galaxies. The disadvantages of current HI surveys are that existing telescopes limit us to study the nearby galaxy structures and that single dish surveys have relatively low angular resolution, which means increasing source confusion at higher redshifts.

3. Local Large-Scale Structure

The galaxies detected in HIPASS give us the first view of the local Universe uninhibited by the foreground stars and dust from our own Galaxy. Numerous known large-scale structures can now be fully traced across the southern sky, the most prominent being the Supergalactic Plane, followed by the Fornax and

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Figure 2. Histograms of the Local Group velocities in the HIPASS BGC (grey) and HICAT (white).

Figure 3. Histograms of galaxy morphological types in the HIPASS BGC (left) and HICAT (right), for all optically identified galaxies as obtained from LEDA. Optical identification of HICAT sources is not yet complete and we only show a subset of galaxies with velocities less than 4000 km s$^{-1}$. The numerical galaxy types (de Vaucouleurs et al. 1991) are: –5 (E), –2 (S0), 1 (Sa), 3 (Sb), 6 (Sc), 8 (Sd), 9 (Sm), and 10 (Irr), plus intermediate types; note that 5 (S?) corresponds to galaxies with uncertain spiral type. In both samples there is, as expected, an abrupt decline in galaxy numbers for morphological types earlier than Sb.

Hydra Walls. Their extensions and connections across the optical Zone of Avoidance are clearly revealed in HIPASS (see Fig. 1). In addition, HIPASS provides a less clustered view of the local Universe by predominantly detecting late-type spiral and dwarf galaxies. These appear to trace large-scale structures in a much
Figure 4. Distribution of galaxies in the southern sky. The symbols indicate mean morphological types (when available) as obtained from LEDA: type < 2.5 (circles), 2.5–5.0, (crosses), 5.0–7.5 (stars), and 7.5–10 (black squares), roughly corresponding to Sab & earlier, Sb, Sc, and Sd/m & Irr, respectively. (Left) Optically identified galaxies in the HIPASS BGC plus newly cataloged galaxies (filled grey circles). (Right) Optically identified galaxies in the HIPASS BGC and HICAT. The latter are only included if reliably identified in position and velocity with $v_{\text{sys}} < 4000 \, \text{km s}^{-1}$.

more homogeneous way than optically selected galaxies. The SGP, Fornax and Hydra Walls create a giant three-pronged structure resembling the footprint of a dinosaur, as pointed out by Lynden-Bell (1994). HIPASS also allows a much improved delineation of voids as, for example, in the case of the Local Void.

At velocities below 1000 km s$^{-1}$ the most prominent features are the Supergalactic Plane (SGP), the Local Void next to the Puppis filament, the near side of the Fornax Wall and the Volans Void. The Supergalactic Plane (SGP) contains the greatest concentration of nearby groups and clusters of galaxies in the local Universe (see Lahav et al. 2000, and references therein). The SGP is very evident in HIPASS which reveals a distinct and continuous filamentary band — without a gap due to the ZOA — across the whole southern sky ending on the righthand side in the Southern Virgo Extension. The latter becomes quite prominent in the second velocity bin. The width of the SGP is no more than $\sim 10^\circ$; deviations of up to $10^\circ - 15^\circ$ from the supergalactic equator are apparent. HIPASS is also more stringent in defining the void sizes. The dominant void in the nearby Universe is the Local Void which can be seen as the empty region below the SGP.

At velocities between 1000 and 2000 km s$^{-1}$ we find the known clumpings of Fornax, Eridanus and the Southern Virgo Extension as well as two new galaxy groups which are not at all visible in the optical: the NGC 4038 and NGC 5084 Groups. For a detailed description see Koribalski et al. (2004).

In the next velocity bin (2000 – 3000 km s$^{-1}$) one prominent filament which stretches over a major fraction of the southern sky stands out clearly. It can be traced from the Indus and Pavo clusters crossing the ZOA to the Centaurus cluster in a linear structure, called the Centaurus Wall by Fairall (1998), at a
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slight angle with respect to the SGP. From there it bends over to the Hydra and Antlia clusters and folds back across the ZOA through Puppis where yet another spiral-rich new galaxy group is uncovered, Puppis G2. Also outstanding is the large-scale underdensity known as the Eridanus Void.

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