Outlining the Local Void with the Parkes HI ZOA and Galactic Bulge Surveys

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1 The Local Void

The Local Void (LV) was first identified by Tully [11] as a very local region ($cz \lesssim 3000\,\mathrm{km\,s^{-1}}$) devoid of galaxies located next to the Galactic Bulge $0° \lesssim \ell \lesssim 90°$ within Galactic latitudes of $|b| \lesssim 30°$. The lack of galaxies in that area must partly be influenced by the high foreground extinction and star density. Nevertheless, the reality of the void was never doubted as it extends beyond the optical and near-infrared Zone of Avoidance (ZOA) and can be traced to relatively high latitudes (see Figs. 1 and 2). The continuity of low galaxy density across the opaque part of the ZOA was recently corroborated by HIPASS [5, 9, 14], which is unaffected by extinction or star density.

The actual size, extent and so-called "emptiness" of the Local Void has remained a matter of much debate. Some suggest the LV to be larger and extend to the more distant Microscopium (or Sagittarius) Void at $cz \sim 4500\,\mathrm{km\,s^{-1}}$ (e.g. [2]), while others identified filamentary structures at larger longitudes ($\ell \sim 60°$) that separate off two distinct smaller voids (Delphinus and Cygnus [10, 2, 1]), hence reducing the size of the LV. Independently, careful scrutiny of sky survey plates in Hercules/Aquila did reveal various dwarf galaxies [4] suggesting that the LV might not be quite as galaxy-free as previously thought.

The interest in this nearest of voids recently escalated again with the claims on dynamical grounds, that the LV must be much larger (of the order of 50Mpc) and extremely empty – if not filled with Dark Energy – to explain the repulsive peculiar motion of the LV on the Milky Way of $\sim 260\,\mathrm{km\,s^{-1}}$ with respect to the Local Supercluster restframe [12, 13]. In addition to that, the large peculiar motion recently found for the dwarf galaxy ESO461-36 in the LV seems to suggest that it is being catapulted out of the Local Void with $\sim 230\,\mathrm{km\,s^{-1}}$ [12].

2 The Parkes ZOA HI Surveys

Better and tighter observational constraints on the size and census of the Local Void can only be achieved through deep HI surveys. Three systematic deep HI surveys performed with the Multibeam Receiver of the 64 m Parkes radio telescope cover a large fraction of the LV. Their integration time is a factor 4−5 longer than HIPASS [9, 14] and reach sensitivities of $rms \sim 6$ mJy [1, 6, 8]. The instantaneous velocity range is -1200 to $12\,700\,\mathrm{km\,s^{-1}}$ as in HIPASS. These are the deep southern ZOA survey (ZOA) [6, **?**] plus northern extension (NE) [1] which encompass the Galactic longitude range $196° \leq \ell \leq 52°$ for latitudes of $|b| \leq \pm 5°$, plus a recent extension towards higher latitudes in the Galactic Bulge region, made because of the interest in large-scale structures such as the Local Void, the Great Attractor and the Ophiuchus (super)cluster.

The Galactic Bulge extension (GB) has an average of 20 scans, hence slightly lower compared to the 25 scans of the ZOA and NE surveys. It extends to Galactic latitudes of $\pm 10°$ for the longitude range $332° \leq \ell \leq 36°$, reaching up to higher positive latitudes ($+15°$) for $348° \leq \ell \leq 20°$. The combined survey area is outlined in Fig. 2.

3 Outlining the Local Void

The distribution of the galaxies detected in the deep HI surveys are displayed in Fig. 1 in a redshift cone out to $6000\,\mathrm{km\,s^{-1}}$ (ZOA+NE with dark (blue) large dots; GB red (lighter) large dots for $5° < |b| < 10°$ resp. $+15°$ including galaxies from the shallower HIPASS for $-10° < b < 15°$ (smaller dots; cyan). The redshift cones on the right-hand side reflect the galaxy distribution above (top) and below (bottom) the ZOA, for $5° < |b| < 30°$ respectively, based on published redshifts as in LEDA.

When discussing the various features of the LV, the reader is also referred to Fig. 2 which illustrates sky projections (in gal. coordinates) of redshift intervals of widths $\Delta v = 1000\,\mathrm{km\,s^{-1}}$. Note that the data outside the outlined HI survey region depends on availability of redshift data in the literature (LEDA) and constitutes an uncontrolled data set.

While the galaxy density in the longitude range of the LV ($\sim 330° - 45°$) is clearly lower than the rest of the sky (Fig. 1), it is by no means as devoid of galaxies as previously thought. It is in fact quite striking that the LV area based purely on the deep HI data set (left) – which is sensitive to low-mass (gas-rich) dwarf galaxies – is much more populous compared to the LV region at higher latitudes (right panels) for which no deep HI survey is available.

The overall under-dense region seems to extend to about $6000\,\mathrm{km\,s^{-1}}$ (see both Figs. 1 & 2), hence supportive of Tully's larger void. However, a filament is visible around $3000\,\mathrm{km\,s^{-1}}$ which clearly seems to divide this larger under-dense region into a nearer and distant void (previous LV and Microscopium Void). But neither of these two voids appear well defined nor really empty.

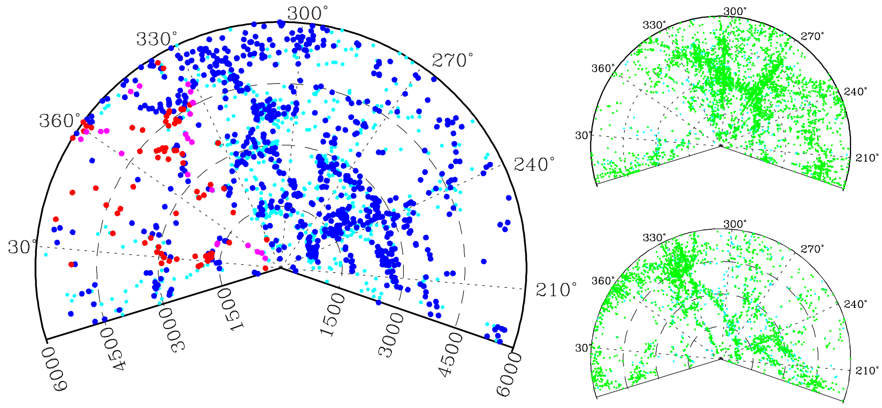

Fig. 1. Distribution of HI galaxies along the ZOA out to 6000 km/s detected in the deep Parkes HI ZOA and NE surveys ($|b| \leq 5°$; blue), the GB extension ($\pm10°$ resp. $+15°$ for $332° \leq \ell \leq 36°$, and $348° \leq \ell \leq 20°$) as well as galaxies from HIPASS (shallower) for $-10° \leq b \leq 15°$ (small lighter dots). The boundaries of the LV lie somewhere within $330° \lesssim \ell \lesssim 60°$. For visualisation of continuation of LSS, pie diagrams above (top) and below (bottom) the GP ($5° < |b| < 30°$) based on redshift data in the literature (LEDA) are shown on the right.

Within the nearer LV there seems to exist a protrusion into that void at about $1500\,\mathrm{km\,s^{-1}}$(prominent in both Fig. 1 & 2), while an extension that crosses the Great Attractor Wall at the location of the Norma cluster seems to cut into the more distant Microscopium void at $\ell \sim 350°, v \sim 4500\,\mathrm{km\,s^{-1}}$ and $340°, 5000\,\mathrm{km\,s^{-1}}$.

It can be argued that the larger LV consists of a huge under-dense region out to $cz \lesssim 6000\,\mathrm{km\,s^{-1}}$ from about $345° - 45°$ in longitude and $-30°$ to about $+45°$ in latitude, which possibly is connected to the Cygnus and Delphinus voids at slightly higher longitudes (see e.g. [1]). However, various filamentary features criss-cross and divide this larger LV into smaller voids. And these smaller voids are not empty either. Even within the nearest part of the LV ($cz \lesssim 1500\,\mathrm{km\,s^{-1}}$) some – very low mass – galaxies have been detected with the HI surveys.

A project has begun to systematically study the global properties of the galaxies in and around these voids based on their HI-masses and near-infrared morphology and luminosity. The latter is being obtained with the InfraRed Survey Facility (IRSF) at the SAAO (instantaneous JHK_s bands). Preliminary inspection of some of the LV galaxies seem to suggest that the galaxies in the voids are extreme low-mass, faint galaxies while the ones making up the borders of the smaller voids seem more consistent with normal luminous spiral galaxies.

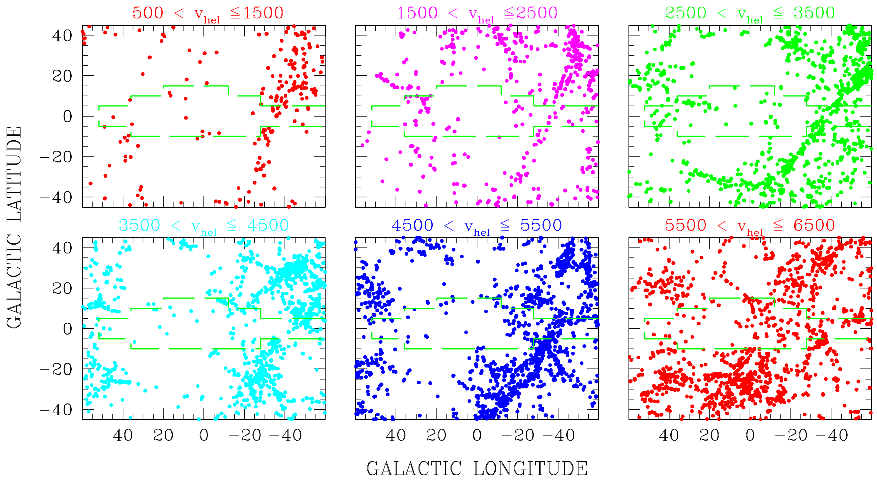

Fig. 2. Six redshift slices of widths $\Delta v = 1000\,\mathrm{km\,s^{-1}}$ ranging from $500 - 1500\,\mathrm{km\,s^{-1}}$ to $5500 - 6500\,\mathrm{km\,s^{-1}}$ centered on the GB, respectively the LV based on the deep Parkes HI surveys (ZOA+NE+GB; the combined HI survey area is marked) as well as published redshifts in the literature (LEDA).

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