# The HI Parkes Zone of Avoidance Shallow Survey

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**Abstract**

The HI Parkes Zone of Avoidance Survey is a 21 cm blind search with the multibeam receiver on the 64-m radiotelescope, looking for galaxies hidden behind the southern Milky Way. The first, shallow (15 mJy rms) phase of the survey has uncovered 107 galaxies, two-thirds of which were previously unknown. The addition of these galaxies to existing extragalactic catalogs allows the connectivity of a very long, thin filament across the Zone of Avoidance within 3500 km s$^{-1}$ to become evident. No local, hidden, very massive objects were uncovered. With similar results in the north (The Dwingeloo Obscured Galaxies Survey) our census of the most dynamically important HI-rich nearby galaxies is now complete, at least for those objects whose HI profiles are not totally buried in the Galactic HI signal. Tests are being devised to better quantify this remaining ZOA for blind HI searches. The full survey is ongoing, and is expected to produce a catalog of thousands of objects when it is finished.

**Keywords: zone of avoidance - surveys - galaxies: HI - large-scale structure of the universe**

## 1 Introduction

The dust and high stellar density of the Milky Way obscures up to 25% of the optical extragalactic sky, creating a Zone of Avoidance (ZOA). The resulting incomplete coverage of surveys of external galaxies leaves open the possibility that dynamically important structures, or even nearby massive galaxies, remain undiscovered.

Careful searches in the optical and infrared wave bands can narrow the ZOA, (see Kraan-Korteweg, this volume) but in the regions of highest obscuration and infrared confusion, only radio surveys can find galaxies. The 21 cm line of neutral hydrogen (HI) passes readily through

the obscuration, so galaxies with sufficient HI can be found through detection of their 21 cm emission. Of course, this method will miss HI-poor, early-type galaxies, and cannot discriminate HI galaxies with redshifts near zero velocity from Galactic HI.

Here we describe an HI blind survey for galaxies in the southern ZOA conducted with the new multibeam receiver on the 64-m Parkes telescope. A survey of HI galaxies in the northern ZOA is underway with the Dwingeloo radiotelescope (Henning et al. 1998; Rivers et al. this volume).

# 2 The Shallow Survey

## 2.1 Observing Strategy

The HI Parkes ZOA survey covers the southern ZOA ($212\,\mathrm{deg} \leq l \leq 36\,\mathrm{deg}; |b| \leq 5\,\mathrm{deg}$) over the velocity range (cz) = $-1200$ to 12700 $\mathrm{km\,s^{-1}}$. The multibeam receiver is a focal plane array with 13 beams arranged in an hexagonal grid. The spacing between adjacent beams is about two beamwidths, each beamwidth being 14 arcmin. The survey is comprised of 23 contiguous rectangular fields which are scanned parallel to the galactic equator. Eventually, each patch will be observed 25 times, with scans offset by about 1.5 arcmin in latitude. The shallow survey discussed here consists of two scans in longitude separated by $\Delta$b = 17 arcmin, resulting in an rms noise of about 15 mJy, equivalent to a $5\sigma$ HI mass detection limit of $4 \times 10^6$ $\mathrm{d^2_{Mpc}\ M_\odot}$ (for a galaxy with the typical linewidth of 200 $\mathrm{km\,s^{-1}}$).

## 2.2 Data Visualization

After calibration, baseline-subtraction, and creation of data cubes, all done with specially developed routines based on aips++ (Barnes et al. 1998, Barnes 1998) the data are examined by eye using the visualization package Karma (http://www.atnf.csiro.au/karma/). The data are first displayed as right ascension – velocity planes, in strips of constant declination. Data cubes are then rotated, and right ascension – declination planes are checked for any suspected galaxies (eg. Figure 1).

# 3 Galaxies Found by the Shallow Survey

The shallow 21-cm survey of the southern ZOA has been completed, and 107 galaxies with peak HI flux densities $\geq$ about 80 mJy have been cataloged. Refinement of the measurement of their HI characteristics is ongoing, but the objects seem to be normal galaxies. However, of three large multibeam ZOA galaxies imaged in HI with the ATCA, two were seen to break up into complexes of HI suggestive of tidally-interacting systems (Staveley-Smith et al. 1998) Continued follow-up synthesis observations are planned to investigate the frequency of these interacting systems in this purely HI-selected sample.

Most of the galaxies are within 4000 $\mathrm{km\,s^{-1}}$, which is about the redshift limit for detection of normal spirals of this shallow phase of the survey. As the deep survey continues, spirals at higher velocities will be recovered. The effective depth of the shallow survey is not quite sufficient to recover large numbers of galaxies which might be associated with the Great Attractor (but see Juraszek et al. this volume.) However, a striking feature becomes apparent with the addition of the ZOA galaxies. An enormous filament, which crosses the ZOA twice, is clearly evident when these ZOA data are displayed along with optically-known galaxies above and below the plane within 3500 $\mathrm{km\,s^{-1}}$ (Fig. 2.) This structure snakes over $\sim 180\,\mathrm{deg}$ through the southern sky.

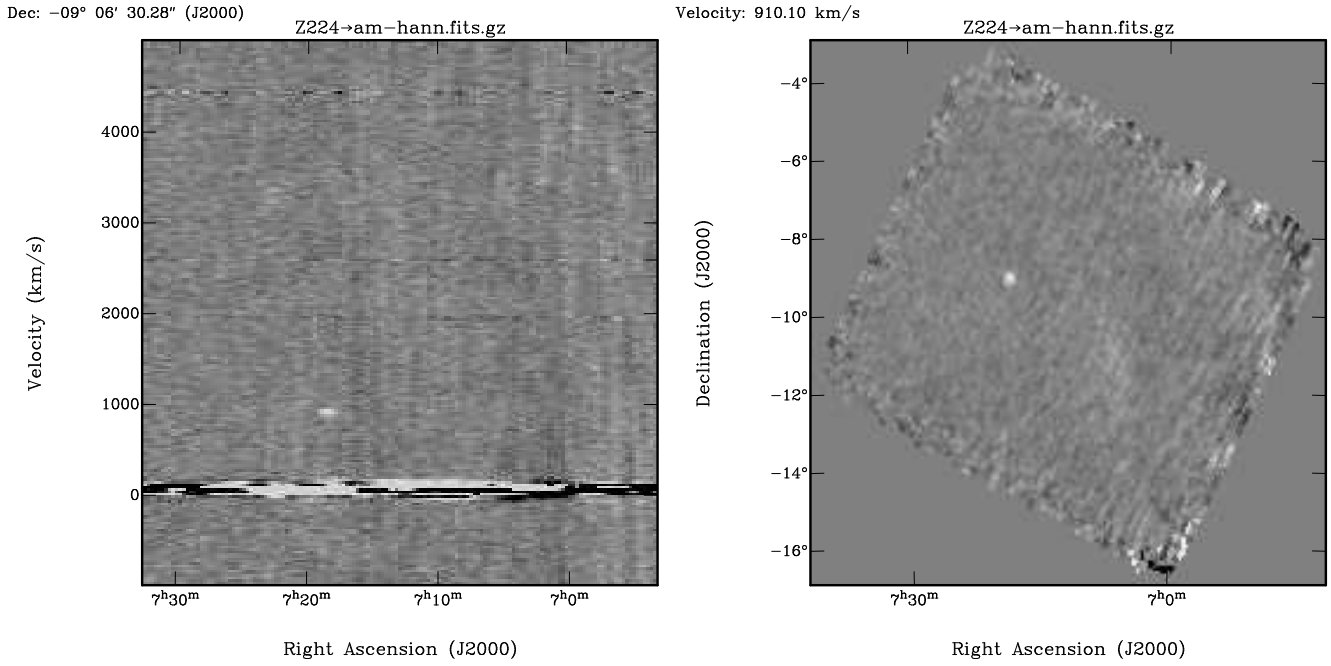


Figure 1: Left panel shows a right ascension – velocity slice to 5000 $\mathrm{km\,s^{-1}}$ which includes a galaxy discovered by the survey. Galactic HI appears as the strong horizontal feature at zero velocity. Note the extragalactic HI signal at $7^{\mathrm{h}}18^{\mathrm{m}}$, 900 $\mathrm{km\,s^{-1}}$. Right panel shows a right ascension – declination plane at the velocity of the suspected signal. The galaxy is evident at $7^{\mathrm{h}}18^{\mathrm{m}}$, −9 deg.

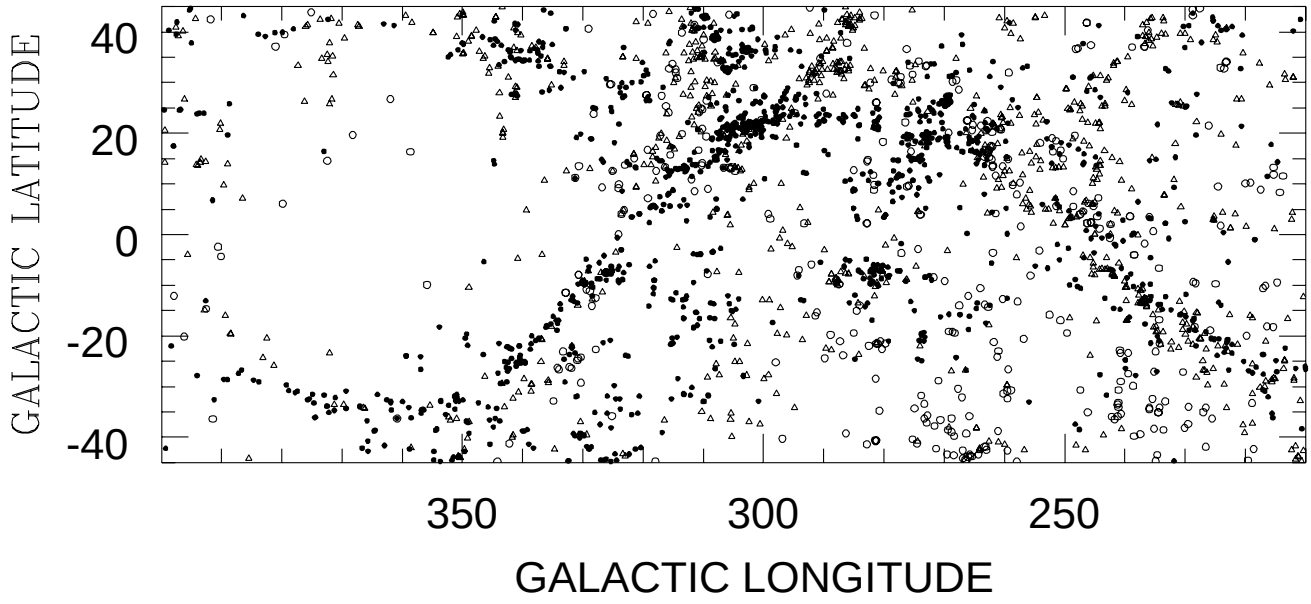


Figure 2: Galaxies within v $\leq$ 3500 km s$^{-1}$. The open circles mark galaxies between 500 – 1500 km s$^{-1}$, triangles for 1500 – 2500 km s$^{-1}$, and dots for those with 2500 – 3500 km s$^{-1}$. High latitude data are taken from the literature (LEDA). Also plotted are galaxies from deep optical ZOA surveys (Kraan-Korteweg et al. this volume.) The galaxies discovered by the multibeam shallow ZOA survey fill in the lowest galactic latitudes, where optical surveys fail.

Taking a mean distance of $30h^{-1}$ Mpc, this implies a linear size of $\sim 100h^{-1}$ Mpc, with thickness of $\sim 5h^{-1}$ Mpc or less.

Also, note the relative emptiness of the Local Void. Three hidden galaxies found on a boundary of the Void ($l \sim 30$ deg) lie at $\sim$ 1500 km s$^{-1}$. Two of these objects were also recovered by the Dwingeloo Obscured Galaxies Survey (Rivers et al. this volume.) The positions and redshifts of these objects are consistent with their being members of the cluster at this location proposed by Roman et al. (1998).

Of the 107 objects found, 28 have counterparts in the NASA/IPAC Extragalactic Database (NED) with matching positions and redshifts. Optical absorption, estimated from the Galactic dust data of Schlegel et al. (1998), ranges from $A_B = 1$ to more than 60 mag at the positions of the 107 galaxies, and is patchy over the survey area. No objects lying behind more than about 6 mag of obscuration have confirmed counterparts in NED, as expected.

The shallow multibeam HI survey connects structures all the way across the ZOA within 3500 km s$^{-1}$ for the first time. The ongoing, deep ZOA survey will have sufficient sensitivity to connect structures at higher redshifts.

While 14 of the 107 galaxies lie within 1000 km s$^{-1}$ and are therefore fairly nearby, all of the newly-discovered objects have peak HI flux densities an order of magnitude or more lower than the Circinus galaxy. Thus, it seems our census of the most dynamically important, HI-rich nearby galaxies is now complete, at least for those objects with velocities offset from Galactic HI. Simulations are currently being devised to investigate our sensitivity to HI galaxies whose signals lie within the frequency range of the Milky Way's HI. This will be done by embedding artificial HI signals of varying strength, width, position, and frequency, into real data cubes. Then, an

experienced HI galaxy finder (PH) will examine the cubes without previous knowledge of the locations of the fake galaxies. In this way, we hope to quantify better this remaining blind spot of the HI search method.

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