The H I column density distribution function in faint dwarf galaxies

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ABSTRACT

We present the H I column density distribution function, $f(N_{\text{HI}})$, as measured from dwarf galaxies observed as part of the Faint Irregular Galaxy Giant Metrewave Radio Telescope (GMRT) Survey (FIGGS). We find that the shape of the dwarf galaxy $f(N_{\text{HI}})$ is significantly different from the $f(N_{\text{HI}})$ for high-redshift damped Lyman $\alpha$ absorbers (DLAs) or the $f(N_{\text{HI}})$ for a representative sample of $z = 0$ gas-rich galaxies. The dwarf $f(N_{\text{HI}})$ falls much more steeply at high H I column densities as compared to the other determinations. While $\sim 10$ per cent of the cross-section above $N_{\text{HI}} = 10^{20.3}$ atoms cm$^{-2}$ at $z = 0$ is provided by dwarf galaxies, the fraction falls to $\lesssim 1$ per cent by $N_{\text{HI}} = 10^{21.5}$ atoms cm$^{-2}$. In the local universe, the contribution to the high $N_{\text{HI}}$ end of the $f(N_{\text{HI}})$ distribution comes predominantly from the inclined discs of large galaxies. Dwarf galaxies, both because of their smaller scalelengths and their larger intrinsic axial ratios, do not produce large H I column densities even when viewed edge-on. If high-column-density DLAs/Gamma Ray Burst (GRB) hosts correspond to galaxies like the local dwarfs, this would require that either (i) the absorption arises from merging and not isolated systems or (ii) the observed lines of sight are strongly biased towards high-column-density regions.

Key words: galaxies: dwarf – galaxies: evolution – galaxies: ISM.

1 INTRODUCTION

Neutral atomic gas at high redshifts can only be studied via the absorption lines that are produced when a gas cloud happens to lie in front of a more distant quasar. Much of what we know about the H I content of the early universe comes from the study of these absorption line systems. The absorption systems with the highest column densities ($N_{\text{HI}} \gtrsim 10^{20.3}$ atoms cm$^{-2}$), the so-called damped Lyman $\alpha$ absorbers (DLAs), are known to contain the bulk of the neutral gas at high redshifts. DLAs are of particular interest because at these column densities self-shielding results in the ionized fraction of the gas being small (Wolfe, Gawiser & Prochaska 2005). As such, DLAs represent the most likely progenitors of the gas-rich galaxies seen at the current epoch.

Systematic surveys (e.g. Wolfe et al. 1986; Noterdaeme et al. 2009; Prochaska & Wolfe 2009) have resulted in the discovery of a large number of DLAs. Noterdaeme et al. (2009) report the discovery of 937 DLAs using data from the SDSS DR7 (Abazajian et al. 2009). However, despite decades of study, the nature of DLAs remains unclear; in particular, the size and morphology of the systems remain very poorly constrained by observations. Two extremes of the models that have been proposed are (i) that DLAs arise from large rotating discs, much like the discs of modern-day spirals (e.g. Wolfe et al. 1986; Prochaska & Wolfe 1997) at the one end and (ii) that DLAs arise from small systems analogous to the current-day dwarf galaxies at the other (e.g. Haehnelt, Steinmetz & Rauch 1998). Recent numerical simulations suggest a more nuanced picture where a wide range of hosts gives rise to the observed DLAs (see e.g. Pontzen et al. 2008; Cen 2012).

Because the observable information available for DLAs is limited to the narrow pencil beam illuminated by the background quasar, there is limited scope for quantitative comparisons of the properties of DLAs and gas-rich local galaxies. For DLAs with a compact background radio source, the spin temperature of the H I 21 cm line can be measured (Wolfe & Davis 1979). The spin temperature is typically higher than that observed in the discs of nearby spiral galaxies (see e.g. Wolfe & Davis 1979; Carilli et al. 1996; Kanekar & Chengalur 2003), but similar to what might be expected in dwarf galaxies with low metallicity and low central pressures (Chengalur & Kanekar 2000; Kanekar et al. 2009). Another direct observable from the absorption studies is the column density distribution function $f(N_{\text{HI}})$, which gives the expected number of absorbers with H I column density between $N_{\text{HI}}$ and $N_{\text{HI}} + dN_{\text{HI}}$ per unit distance. For the local galaxy population also $f(N_{\text{HI}})$ can be computed; this makes it one of the few statistics which can be computed for both the high-redshift and local populations. Further interest in studying $f(N_{\text{HI}})$ comes from the idea that various physical processes, e.g. the onset of self-shielding, the threshold at which the gas goes from becoming dominantly atomic to dominantly molecular, would affect its shape (Altay et al. 2011). Studies of the evolution of $f(N_{\text{HI}})$
could hence also lead to an understanding of the evolution with redshift of the physical conditions in neutral gas.

In this paper we present \( f(N_{\text{HI}}) \) computed from the Faint Irregular Galaxy GMRT Survey (FIGGS; Begum et al. 2008). The FIGGS sample consists of extremely faint gas-rich dwarfs; the median \( \text{H} \) mass of the galaxies that we use here is only \( \sim 1.4 \times 10^7 \, M_\odot \). Our data set is complementary to the one used by Zwaan et al. (2005) to study \( f(N_{\text{HI}}) \) at \( z \sim 0 \). Those authors used \( \text{H} \) maps of 355 nearby galaxies from the WSRT-based WHISP survey to determine \( f(N_{\text{HI}}) \). Their sample contains a representative mix of galaxy types, albeit being somewhat biased towards early types S0–Sb, which they correct for using a type-specific \( \text{H} \) mass function. The Zwaan et al. (2005) study demonstrated that the cross-section for producing DLAs at \( z \sim 0 \) is dominated by large spiral galaxies. The \( f(N_{\text{HI}}) \) that they compute is hence essentially that corresponding to large galaxies. Our current sample excludes large spirals, and the \( f(N_{\text{HI}}) \) that is computed here corresponds to that in the smallest star-forming galaxies.

There are a number of reasons why it is interesting to study the \( f(N_{\text{HI}}) \) in such small galaxies. First, since the gas in dwarf galaxies is dust poor, one would expect the transition from atomic to molecular gas to happen at a higher column density than in spirals (McKee & Krumholz 2010; Welty, Xue & Wong 2012). Further, unlike in spiral galaxies the gas in dwarfs is not in a thin, dynamically cold disc (Roychowdhury et al. 2010). For these reasons, it is not a priori obvious that the \( f(N_{\text{HI}}) \) in dwarf galaxies would be similar to that in large spirals. Finally, in hierarchical models of galaxy formation, small objects form first, and one would expect that the properties of the gas-rich objects in the early universe would more closely resemble dwarfs than large spirals. These are the themes that we explore in the rest of this paper.

## 2 Description of the Sample and Primary Data

The data that we use were gathered as part of FIGGS (Begum et al. 2008). The survey used a sample of 65 dwarf galaxies, selected from the Karachentsev et al. (2004) catalogue, that satisfied the following selection criteria: (i) absolute blue magnitude \( M_B \geq -14.5 \, \text{mag} \), (ii) \( \text{H} \) integrated flux \( > 1.0 \, \text{Jy km s}^{-1} \) and (iii) optical B-band major axis \( \geq 1.0 \, \text{arcmin} \). Three of the galaxies in the FIGGS sample were not detected in \( \text{H} \). One galaxy had a companion that was detected in \( \text{H} \), which we also use for our analysis. This leaves us with a total of 63 galaxies from FIGGS. A further 16 fainter local galaxies which satisfy the following selection criteria (i) absolute blue magnitude, \( M_B \geq -12.0 \, \text{mag} \), and (ii) integrated \( \text{H} \) flux \( \geq 0.5 \, \text{Jy km s}^{-1} \) were later added to the sample (Patra et al., in preparation).

The GMRT has a hybrid configuration (Swarup et al. 1991), i.e. with a mix of short and long baselines. Consequently, images at a range of resolutions can be made from a single GMRT observation. For the FIGGS galaxies we have data cubes and moment maps at resolutions ranging from \( \sim 40 \) to \( \sim 4 \) arcsec, corresponding to linear resolutions of 850–85 pc at the median distance to the galaxies in the sample. For this study we use only those galaxies for which good quality images were available at all resolutions. This leaves us with a total of 62 galaxies. Fig. 1 shows the distribution of absolute blue magnitude and \( \text{H} \) mass for our sample galaxies. For this subsample, the median \( \text{H} \) mass is \( \sim 1.4 \times 10^7 \, M_\odot \), the median blue magnitude is \( M_B \sim -12.3 \, \text{mag} \) and the median distance is \( \sim 4.4 \, \text{Mpc} \).

In Fig. 2 we show the integrated \( \text{H} \) image for a representative sample galaxy, UGC 8833, which has an \( \text{H} \) mass of \( 10^{12} \, M_\odot \) and an inclination of \( \sim 28^\circ \). Maps at three different resolutions, namely \( \sim 40, 12 \) and 4 arcsec, are shown. As can be clearly seen, the low-resolution images smooth over the high-column-density clumps that are seen at higher resolutions. Conversely, the smooth diffuse emission that is seen in the low-resolution images is largely resolved out in the high-resolution images. Clearly, for any individual galaxy one would need to use data from a range of resolutions to get an accurate estimate of the \( \text{H} \) column density distribution. We return to this issue in the next section where we compute the \( \text{H} \) column density distribution for our sample of galaxies.

![Figure 1](https://example.com/figure1.png)

**Figure 1.** Distribution of absolute blue magnitude \( M_B \) (left-hand panel) and \( M_{\text{HI}} \) (right-hand panel). Because of problems with the high-resolution images of some galaxies, we use only a subset of the total sample for the analysis in this paper (see the text for more details). The dotted lines represent the entire FIGGS sample, whereas the solid lines are for the galaxies whose data are used in this paper.
3 THE COLUMN DENSITY DISTRIBUTION FUNCTION

The \( \text{H} \) column density distribution \( f(N_{\text{HI}}) \) was first used in the context of gas seen in absorption against distant quasars. It is defined such that \( f(N_{\text{HI}})dN_{\text{HI}}dX \) gives the number of systems with gas column density between \( N_{\text{HI}} \) and \( N_{\text{HI}} + dN_{\text{HI}} \) that would be encountered within an absorption distance \( dX \) (Bahcall & Peebles 1969). The quantity \( f(N_{\text{HI}}) \) is directly computable from absorption spectra (see e.g. Wolfe et al. 1986; Noterdaeme et al. 2009; Prochaska & Wolfe 2009) and is hence fairly well known at redshifts \( \geq 2 \). At redshifts below \( \sim 2 \) the Lyman \( \alpha \) line cannot be observed from ground-based telescopes; \( f(N_{\text{HI}}) \) is consequently not well measured at these redshifts. At the lowest redshifts (i.e. \( z \sim 0 \) however, \( f(N_{\text{HI}}) \) can be computed from resolved images of the \( \text{H} \) discs of galaxies and knowledge of the \( \text{H} \) mass function (see e.g. Rao & Briggs 1993; Zwaan et al. 2005). Specifically, from the integrated \( \text{H} \) map of a galaxy one can compute the total area in the map that is covered by gas with column densities between \( N_{\text{HI}} \) and \( N_{\text{HI}} + dN_{\text{HI}} \). This area is clearly dependent on the inclination of the galaxy to the line of sight; however, if one has a large sample of galaxies with random inclinations to the line of sight, the average area \( A(N_{\text{HI}}, M_{\text{HI}}) \), provided by galaxies in some \( \text{H} \) mass bin would automatically represent the average over different inclinations. In order to compute the average area along a random line of sight through the universe, this average area has to be further normalized by the number density of galaxies with \( \text{H} \) mass in the given mass bin, i.e. the \( \text{H} \) mass function. Putting this all together, and also using the fact that at \( z = 0, dX/dz = 1 \) \( f(N_{\text{HI}}) \) can be computed as (see e.g. Zwaan et al. 2005)

\[
f(N_{\text{HI}})dN_{\text{HI}} = \frac{c}{H_0} \int \psi(M_{\text{HI}})A(N_{\text{HI}}, M_{\text{HI}})dM_{\text{HI}},
\]

where

\[
\psi(M_{\text{HI}}) = \frac{\phi(M_{\text{HI}})}{\ln(10)M_{\text{HI}}}
\]

and \( \phi(M_{\text{HI}}) \) is the usual \( \text{H} \) mass function [per unit interval of \( \log 10(M_{\text{HI}}) \)] which is generally parametrized as a Schechter function. Here we use the Schechter function parametrization provided by Martin et al. (2010) with \( \alpha = -1.33, \phi_* = 4.8 \times 10^{-3} \text{Mpc}^{-3}\text{dex}^{-1}, M_{\text{HI}} = 10^{9.96} \text{M}_\odot \). The integral in equation (1) was computed by summing the integrand computed over logarithmic bins in \( M_{\text{HI}} \), the bin width was taken to be 0.3. We have confirmed that the result is not very sensitive to the chosen bin width, results obtained using bin widths of 0.2 and 0.4 overlap within the error bars. The slope of the faint end of the \( \text{H} \) mass function remains somewhat uncertain. In the tabulation in Martin et al. (2010) of various determinations of the \( \text{H} \) mass function, the values reported for the faint end slope in different studies vary from \(-1.20 \) to \(-1.41 \). We conservatively take the error bars to be the quadrature sum of the variation in \( f(N_{\text{HI}}) \) that one gets using these extreme values of the faint end slope and the errors obtained from bootstrap resampling over 100 runs.

Fig. 3 (left-hand panel) shows \( f(N_{\text{HI}}) \) computed from images at different resolutions. As discussed above, the \( f(N_{\text{HI}}) \) computed from the low-resolution images will underestimate the true \( f(N_{\text{HI}}) \) at high column densities, while the \( f(N_{\text{HI}}) \) computed from the high-resolution images will underestimate \( f(N_{\text{HI}}) \) at low column densities. This is clearly seen in Fig. 3 (left-hand panel). We hence also use a ‘hybrid’ \( f(N_{\text{HI}}) \). For the hybrid \( f(N_{\text{HI}}) \), the value at any \( N_{\text{HI}} \) is set to the maximum value obtained for the different resolutions. We note that the hybrid curve differs from the curve made using the low-resolution 40 arcsec data only at the highest column densities, namely \( N_{\text{HI}} \geq 10^{19} \text{atoms cm}^{-2} \). Zwaan et al. (2005) point out that a hybrid \( f(N_{\text{HI}}) \) computed in this way will be an overestimate, since the gas that is seen at high column densities in the high-resolution images will also, after the smoothing that happens in the low-resolution image, contribute to gas at lower column densities. In plots below we hence show results computed from both the hybrid \( f(N_{\text{HI}}) \) and the \( f(N_{\text{HI}}) \) computed from the 40 arcsec resolution images.

3.1 Results and discussion

Fig. 3 (right-hand panel) shows the hybrid \( f(N_{\text{HI}}) \), as well as the \( f(N_{\text{HI}}) \) derived from the 40 arcsec resolution data. To allow easy comparison with previous works, we also show two different fits, i.e. a broken power law and a gamma function defined as

\[
f(N_{\text{HI}}) = \alpha \left( \frac{N_{\text{HI}}}{N_\alpha} \right)^{-\beta} e^{-(N_{\text{HI}}/N_\alpha)}.
\]

Below (see also Table 1) we compare the \( f(N_{\text{HI}}) \) computed here with those determined by Zwaan et al. (2005) and Noterdaeme et al. (2009). In the piece-wise power-law fit to the dwarf galaxy \( f(N_{\text{HI}}) \), the break point which gives the best fit is at \( \log(N_{\text{HI}}) \approx 21.0 \) for the hybrid \( f(N_{\text{HI}}) \) and 20.9 for the \( f(N_{\text{HI}}) \) derived from the 40 arcsec resolution data. As can be seen from Fig. 3 (right-hand panel) \( f(N_{\text{HI}}) \) is curved at high column densities and the gamma
function provides a much better fit to the data than a broken power law. This curvature of the $f(N_{\text{HI}})$ curve is very similar to what Zwaan et al. (2005) found for their WHISP sample.

A particularly interesting result to come out of the earlier data sets is that the shape of the $f(N_{\text{HI}})$ derived for the local galaxy population agrees well with that derived from DLAs (Zwaan et al. 2005; Prochaska & Wolfe 2009). This is a surprising result for a number of reasons, namely (i) the total neutral gas density evolves, changing by about a factor of 2 between high redshifts and $z \sim 0$ (Zwaan et al. 2003; Noterdaeme et al. 2009), (ii) the morphological mix of galaxies is significantly different at high redshifts (Conselice, Blackburne & Papovich 2005), and (iii) DLAs have significantly lower metallicity than low-redshift spiral galaxies that dominate the $\text{H}_{\text{i}}$ cross-section at $z = 0$. The non-evolution of $f(N_{\text{HI}})$ has led to suggestions that it is set by some universal process that shapes the gas distribution (Erkal, Gnedin & Kravtsov 2012). A possible explanation is geometric – for gas in a thin disc, averaging over different orientations would lead to an $f(N_{\text{HI}})$ that falls as $N_{\text{HI}}^{-3}$ at column densities larger than the maximum face-on column density of the disc (Milgrom 1988; Erkal et al. 2012).

In Fig. 4 we show the $f(N_{\text{HI}})$ computed by Zwaan et al. (2005), Noterdaeme et al. (2009) and for the FIGGS sample. All the $f(N_{\text{HI}})$ curves have been normalized to have the same value at $N_{\text{HI}} = 10^{20}$ atoms cm$^{-2}$ so that one is comparing only the difference in shapes.

As can be seen, the dwarf galaxy $f(N_{\text{HI}})$ differs markedly from the other two in that it falls much more steeply at the high-column-density end ($N_{\text{HI}} \gtrsim 10^{21}$ atoms cm$^{-2}$). The $\text{H}_{\text{i}}$ cross-section at $z \sim 0$ is dominated by large galaxies (Zwaan et al. 2005), so the difference between the FIGGS $f(N_{\text{HI}})$ and that determined by Zwaan et al. (2005) is essentially the difference between large galaxies and dwarfs. It is interesting that the $f(N_{\text{HI}})$ for dwarf galaxies begins to fall below the other two curves for column densities larger than $\log(N_{\text{HI}}) \sim 21.0$ atoms cm$^{-2}$. For the $f(N_{\text{HI}})$ derived from the THINGS sample, Erkal et al. (2012) also find a turnover at $N_{\text{HI}} \sim 10^{21}$ atoms cm$^{-2}$. They attribute this feature to the $\text{H}_{\text{i}}$ cross-section above this column density being dominated by highly inclined thin discs. The high column densities come from the long path lengths that the line of sight traverses through these discs. The sharp decline of the dwarf galaxy $f(N_{\text{HI}})$ at high $N_{\text{HI}}$ is presumably because in dwarfs the $\text{H}_{\text{i}}$ gas is not in a thin disc. Roychowdhury et al. (2010) show that for the FIGGS sample, the median intrinsic axial ratio is $\sim 0.6$. In this context it is worth noting that the falloff at high $N_{\text{HI}}$ is found in the dwarf data despite the relatively high linear resolution of $\sim 100$ pc of our data. (In contrast, the Zwaan et al. (2005) sample was observed with a resolution of $\sim 1.3$ kpc.) In DLAs the drop in $f(N_{\text{HI}})$ at $N_{\text{HI}} \sim 10^{22}$ atoms cm$^{-2}$ is attributed to the onset of $\text{H}_2$ formation; above this column density, the gas transitions to being mostly molecular (see e.g. Altay et al. 2011).

Table 1. Parameters of the gamma function fit to $f(N_{\text{HI}})$.

| Parameter | Zwaan et al. (2005) | Noterdaeme et al. (2009) | FIGGS (Hybrid) | FIGGS 40 arcsec |
|-----------|-------------------|--------------------------|----------------|-----------------|
| $\log (\alpha)$ | $-22.91$ | $-22.75$ | $-23.29 \pm 0.04$ | $-22.79 \pm 0.06$ |
| $\beta$ | $1.24$ | $1.27$ | $0.88 \pm 0.04$ | $0.57 \pm 0.07$ |
| $\log N_\alpha$ | $21.2$ | $21.26$ | $20.82 \pm 0.01$ | $20.55 \pm 0.03$ |
Since this transition happens at still higher column densities in low-metallicity dwarfs (McKee & Krumholz 2010; Welty et al. 2012), it cannot be the cause of the drop-off that we see in the dwarf \( f(N_{\text{H}_1}) \).

We note that the \( f(N_{\text{H}_1}) \) computed here as well as in Zwaan et al. (2005) assumes that the emission is optically thin. Braun (2012) models the \( \text{H}_1 \) emission as arising from an isothermal gas distribution and finds that in this model optical depth corrections could lead to \( \text{H}_1 \) column densities as high as a few times \( 10^2 \) atoms cm\(^{-2} \). This is in contrast to the current understanding that the gas becomes predominantly molecular at these column densities (e.g. Schaye 2001). If optical depth corrections are indeed important, the comparison of the \( f(N_{\text{H}_1}) \) of dwarfs with DLAs may need some revision at the high-column-density end. However, the comparison of \( f(N_{\text{H}_1}) \) between the dwarf \( f(N_{\text{H}_1}) \) and the Zwaan et al. (2005) result should remain largely unaffected, since both will have similar corrections.

Fig. 5 shows the ratio \( dn/dz(N_{\text{H}_1}) \) as computed from the FIGGS data and from the Zwaan et al. (2005) sample. \( dn/dz(N_{\text{H}_1}) \) is the integral over \( dN_{\text{H}_1} \) of \( f(N_{\text{H}_1}) \) and gives the average number of absorbers with column density greater than \( N_{\text{H}_1} \) per unit redshift. As can be seen, above the DLAs column density limit \( (N_{\text{H}_1} = 10^{20.3} \) atoms cm\(^{-2} \)\)) dwarfs (with \( M_{\text{HI}} \lesssim 10^8 \) M\(_\odot \)) contribute about 10 per cent to the cross-section. However, the fraction drops rapidly with increasing \( N_{\text{H}_1} \), and by \( N_{\text{H}_1} \sim 10^{21.3} \) atoms cm\(^{-2} \), dwarfs contribute less than 1 per cent to the cross-section. In a model in which the host galaxies of DLAs were similar to the \( z = 0 \) dwarfs, one could match the DLAs number count [i.e. \( dn/dz(N_{\text{H}_1} = 10^{20.3}) \)] by scaling up the number density of dwarfs at high redshift. However, such a model would predict \( \lesssim 3 \) DLAs with \( N_{\text{H}_1} > 10^{21.3} \) atoms cm\(^{-2} \) in the SDSS volume, instead of the \( \gtrsim 30 \) found by Noterdaeme et al. (2009). Further, DLAs with \( N_{\text{H}_1} \sim 10^{22} \) atoms cm\(^{-2} \) have been found in the SDSS (Noterdaeme et al. 2009; Kulkarni et al. 2012). From the \( f(N_{\text{H}_1}) \) for DLAs, Noterdaeme et al. (2009) estimate that only approximately one such high-column-density DLA should be detected in the SDSS volume. Since the \( f(N_{\text{H}_1}) \) for dwarfs falls sharply at high column densities, the probability of finding two such high-column-density absorbers in the SDSS volume is vanishingly small for a host population dominated by dwarfs. Similarly, high column densities are also seen in the DLAs arising from the host galaxies of high-redshift GRBs (GRB-DLAs). Photometry of GRB hosts suggests that they are small galaxies (Chen et al. 2009), albeit somewhat brighter than the dwarfs considered here. Nonetheless, the sharp falloff in \( f(N_{\text{H}_1}) \) at high column densities for dwarfs strongly supports the suggestions (see e.g. Prochaska et al. 2007) that GRBs probe biased regions of the interstellar medium, i.e. those with the highest column density. In the case of ordinary DLAs, as argued above, models where the host galaxies are all similar to \( z = 0 \) dwarfs appear to be ruled out. However, models with a larger fraction of dwarfs but either (i) a sufficient number of disc galaxies to provide the observed cross-section at high column densities and/or (ii) where a significant fraction of the high-column-density gas arises from merging dwarfs may still be consistent with both the observed DLA \( f(N_{\text{H}_1}) \) and the large velocity spreads observed in the DLAs’ low-ionization metal lines (see e.g. Prochaska & Wolfe 1997).

To summarize, we determine the \( f(N_{\text{H}_1}) \) in faint local dwarfs and find that it falls off significantly faster at high column densities than the \( f(N_{\text{H}_1}) \) in DLAs or in the \( f(N_{\text{H}_1}) \) determined from a representative sample of the local galaxy population. For the local galaxy population, at the high \( N_{\text{HI}} \) end, the dominant contribution to \( f(N_{\text{H}_1}) \) comes from the discs of large spiral galaxies viewed edge-on. Isolated galaxies like the \( z = 0 \) dwarfs hence cannot form the dominant host population of high-redshift DLAs and GRB-DLAs unless there is significant biasing of the observed lines of sight and/or corrections for the opacity of the \( \text{H}_1 \) line are important even for dwarf galaxies. The FIGGS sample is one of the largest existing samples of faint dwarf galaxies with high-resolution \( \text{H}_1 \) images. We hence expect that further significant progress on the shape of \( f(N_{\text{H}_1}) \) in dwarfs will require data from \( \text{H}_1 \) surveys using the next generation telescopes, i.e. the Australian SKA Pathfinder (ASKAP;
Deboer et al. (2009), MeerKAT (Jonas J. L. 2009) in South Africa and APERTIF (Verheijen et al. 2008) in the Netherlands.

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