

Gaseous Evolution in Galaxies: The Arecibo Ultra-Deep Survey (AUDS)



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Introduction

At redshifts between zero and unity, the global co-moving star-formation rate increases by about a factor of five (e.g. Hopkins 2004). But little is known of the corresponding increase in the density of cool gas, which is the fuel for star formation. Observations of Damped Lyman- α Absorbers (DLA) (e.g. Peroux et al. 2003) suggest only a mild increase in the redshift density of absorbers $\propto (1+z)^{-1}$, consistent with constant co-moving gas density. However, models suggest more substantial evolution with $\Omega_{\text{HI}} \propto (1+z)^{2-3}$. (Pei et al. 1999, Cole et al. 2000, Baugh et al. 2004). Perhaps DLAs do not trace the bulk of the gas available for star formation? Since HI emission observations are easier to interpret, we have obtained a set of deep observations with the Arecibo telescope in attempt to more cleanly measure Ω_{HI} as a function of redshift.

Observations

As part of the commissioning phase of the Arecibo L-Band Feed Array (ALFA), precursor observations were taken around a target field centered at RA 00:00:14.9, Decl. +15:43:42.5 (J2000) between October 2004 and February 2005. The field was chosen to contain four late-type SDSS galaxies with strong H α and to be free of strong continuum sources.

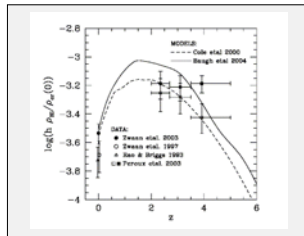
A total of 53 hrs observing was acquired in 'drift-and-chase' mode, resulting in a maximum integration time per beam of 16 hrs. The data was reduced in the AIPS++ *LiveData* and *Gridzilla* packages using specially developed techniques to mitigate the effects of radio-frequency interference.



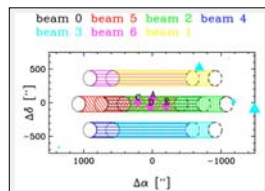
The 7-beam Arecibo L-Band Feed Array (ALFA) used in the Arecibo Ultra Deep Survey (AUDS). The array is situated at the Gregorian focus of the telescope and was installed in May 2004. The frequency range extends down to 1225 MHz, allowing HI observations to a redshift of 0.16.



The 305-m Arecibo telescope in Puerto Rico, the largest and most sensitive instrument of its kind.



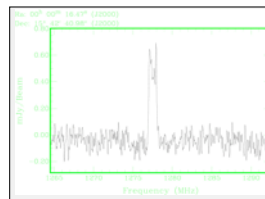
The density evolution of cool gas in the Universe has been modelled by Cole et al. (2000) and Baugh et al. (2004). These, and other, models predict an increase in co-moving gas density between $z=0$ and 1 of a factor of 2-4. Even at $z=0.2$, an increase of 30-70% is predicted. This makes it feasible to use accurate Arecibo HI measurements to assess evolution models at low redshift (from Baugh et al. 2004).



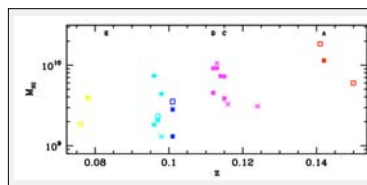
The precursor data was taken in a field (J000014.9+154342.5) containing four SDSS galaxies (A,C,D,E) with strong H α emission lying in the redshift range 0.08 to 0.15. Redundant tracks were used to increase the effective integration time. Radio continuum sources are marked as blue triangles.

Results

The rms of the spectra in the most sensitive part of the precursor data is 80 μJy which was close to theoretical expectation. After manual inspection of the data cube, we found 14 well-detected HI lines and nine candidate detections. Due to the beamwidth of the Arecibo telescope (3 arcmin) and the lack of complete redshift information in the field, it was not possible to unambiguously identify optical counterparts. The redshifts range from 0.07 to 0.15. Above a redshift of 0.1, there are nine well-detected HI lines and six candidates. This is a larger sample than all previously published HI detections at these redshifts.

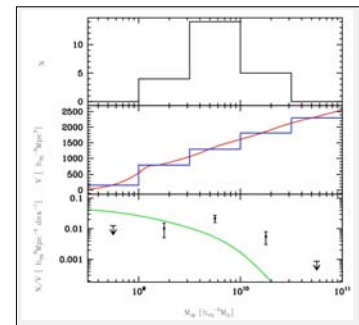


The HI profile of a galaxy convincingly detected at a redshift of 0.11. Peak flux density is 0.7 mJy.



HI mass against redshift for all galaxies detected in the AUDS precursor observations. Solid squares are the best detections, crosses are mid-quality detections, and empty squares are detections that remain to be confirmed.

For each galaxy, the maximum accessible volume was calculated and a binned HI mass function was computed using the $1/V(\text{max})$ method. Preliminary results suggest a galaxy detection rate which is a factor of 2-3 times higher than expected from the local HI mass function derived from HIPASS (Zwaan et al. 2003).



From top to bottom: (a) the number of detections as a function of HI mass; (b) the volume sampled; (c) the HI mass function. The green line is the HIPASS mass function of Zwaan et al. (2003). Galaxies in the two populated HI mass bins above 5×10^8 solar masses (approximately $10^9 M_{\odot}$) at $z=0$ have densities a few times the local density in the volume surveyed.

Conclusion & Future Observations

Precursor observations with ALFA on the Arecibo telescope have demonstrated the feasibility of deep HI observations, even in the presence of substantial radio frequency interference.

At least 14 galaxies were detected (nine with $z > 0.1$), which is larger than the sum of all previously published detections.

Based on the sample volume, the detection rate is a factor of 2-3 times higher than expected from the local (HIPASS) mass function, and higher than expected from models. However, the significance of the results remains low due to the small sample volume, and selection effects.

We plan to extend this precursor study to a larger field of view (0.36 deg^2), longer integration times (40 hrs per pointing), giving lower noise levels (50 μJy) over the full redshift range $0 < z < 0.16$. The rms mass sensitivity will be a few 10^8 solar masses at $z=0.16$.

In the future, detections of HI in emission will be possible at redshifts above 0.5 with the proposed extended New Technology Demonstrator (xNTD) and SKA Molonglo Prototype (SKAMP) telescopes in Australia, and possibly with other SKA pathfinder telescopes.

References

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