The Arecibo Ultra Deep Survey (AUDS)

Bi-Qing For
(On behalf of the AUDS team)

ICRAR/University of Western Australia

International Centre for Radio Astronomy Research

Curtin University

The University of Western Australia

Survey Team Members

Laura Hoppmann

Lister Stevaley-Smith

Bi-Qing For

Martin Zwaan

Wolfram Freudling

Mark Calabretta

Science Goals

Galaxy formation and evolution

- Star formation rate measured (increases by an order of magnitude) over redshift interval $0 < z < 2.5$
- Significant uncertainties in co-evolution with HI and H_2 over same redshift range
- HI observations at cosmological distances ($z > 0.1$) are scarce
- Evolution already very important at other wavelengths over this look-back time (1.3 Gyr)

Motivation

Previous large blind HI surveys

Survey	Reference	Telescope	$\#_{\rm Det}$	Area ($\deg^2$)	Redshift
AHISS[a]	Zwaan et al. (1997)	Arecibo	66	65	0 - 0.025
ADBS[a]	Rosenberg & Schneider (2002)	Arecibo	265	430	0 - 0.027
HIPASS[a]	Meyer et al. (2004)	Parkes	4315	21341	$0 - 0.042$
North. HIPASS[a]	Wong et al. (2006)	Parkes	1002	7997	$0 - 0.042$
40% ALFALFA[a]	Haynes et al. (2011)	Arecibo	$10,119$	2799	$0 - 0.06$
ALFALFA[b]	Giovanelli et al. (2005)	Arecibo	~ 25000	7000	$0 - 0.06$
AGES[b] WAPP	Auld et al. (2006)	Arecibo	~ 1300	105	$0 - 0.06$
Mock			~ 1300	95	$0 - 0.16$
CHILES[b] precursor	Fernández et al. (2013)	VLA	33	0.3	$0 - 0.193$
ALFA ZOA[b] shallow	Henning et al. (2010)	Arecibo	~ 500	1000	$0 - 0.06$
deep			~ 1500	280	$0 - 0.16$
AUDS[a] precursor	Freudling et al. (2011)	Arecibo	18	0.069	$0.07 - 0.16$

[a] Observations completed and survey completely published.

[b] Observations ongoing or data not completely published - survey results not finalised.

- Increase redshift limit for direct detections
- Long integration time, small field
- Unbiased survey

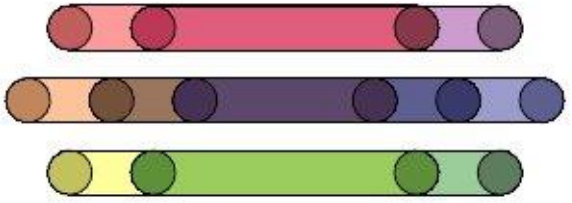
AUDS Precursor

"ALFA Ultra Deep Survey"

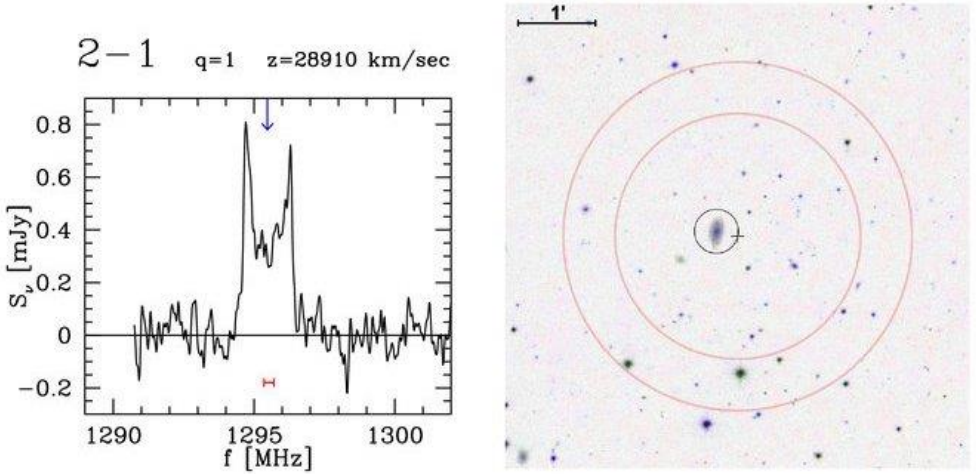
Telescope: 305m Arecibo

Integration time: 53 hr

Detection: 18 21cm emission lines (z=0.07—0.15)



"Drift-and-chase" mode



235948.4+154243
a=34"
z= 0.0964

SDSS 235948.4+154243 was one of the sources used to select the target region. Its SDSS redshift is marked in the spectrum.

Freudling et al. (2011)

AUDS

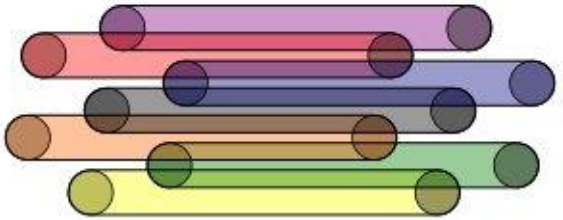
Bandwidth: 1222—1422 MHz (z=0 – 0.16)
Coverage: 0.7 sq.degree (65’ x 44’) x 2 fields

Field selection criteria:

- One field observable all year round during night time
- Overlap with SDSS and Arecibo Environment Survey (AGES)
- Avoid strong continuum sources in the field

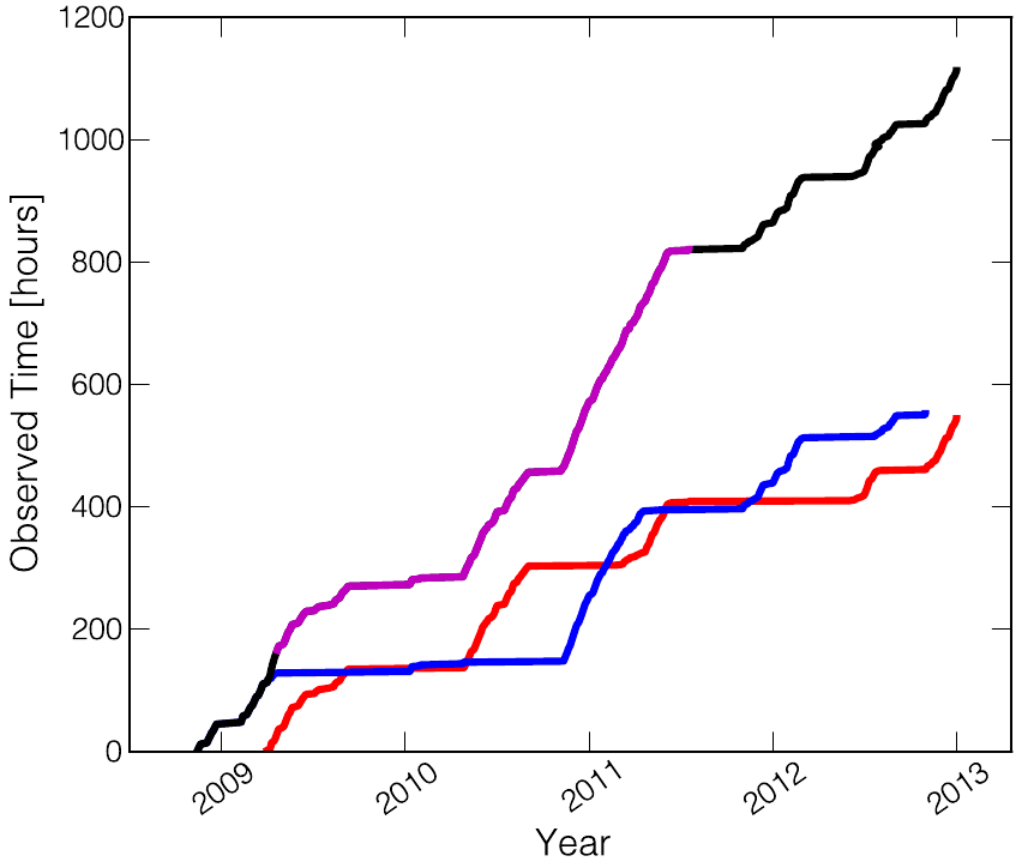
Field 1: α=08:20:00 δ=22:12:00
Field 2: α=17:00:00 δ=19:14:00

Total: 1100hr
40 hr integration time per pointing



“Drift-scan-mode”
Rotated 15°—23°

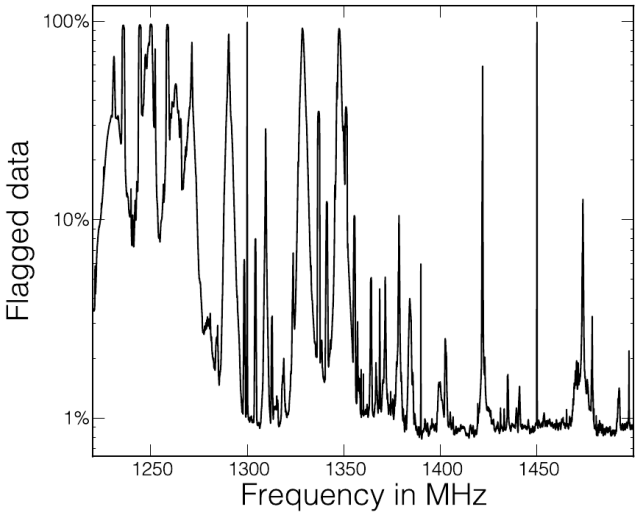
AUDS observation log

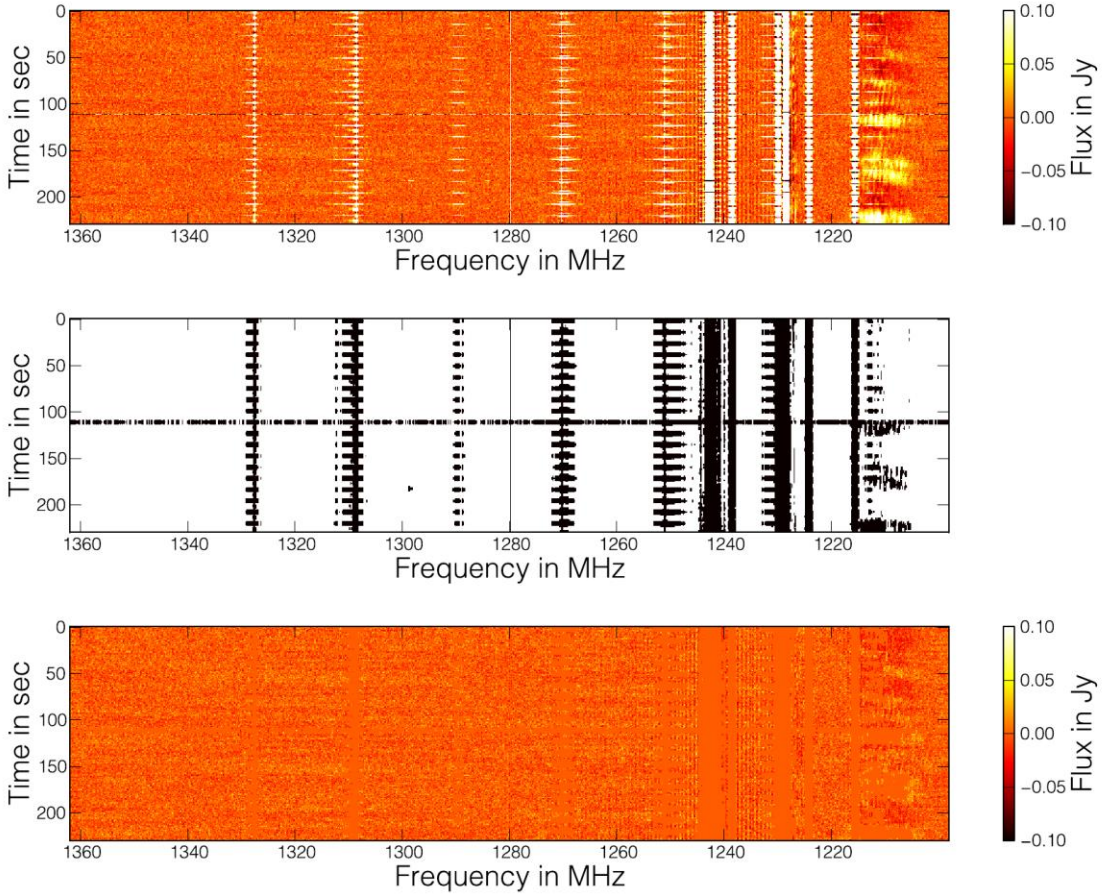


Hoppmann et al. (2015)

Red: field 1, blue: field 2. Purple: data used in this study (~50%)

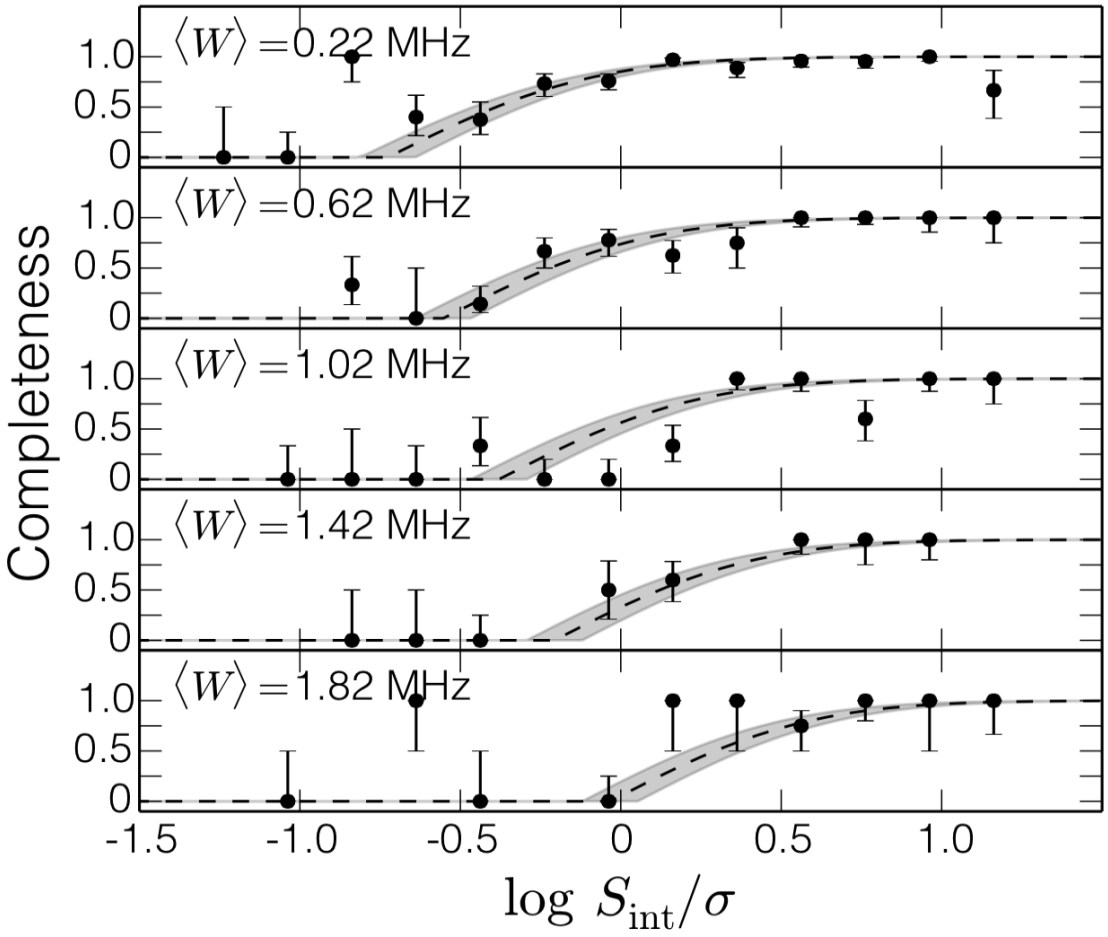
RFI flagging





Top: stacked data from one beam after bandpass removal and calibration
Middle: 3σ mask created in the flagging process
Bottom: end result

Completeness



Completeness as a function of integrated flux, rms noise and velocity width. Curves obtained using false injection of convolved Busy functions.

Reliability & Cosmic Variance

Reliability:

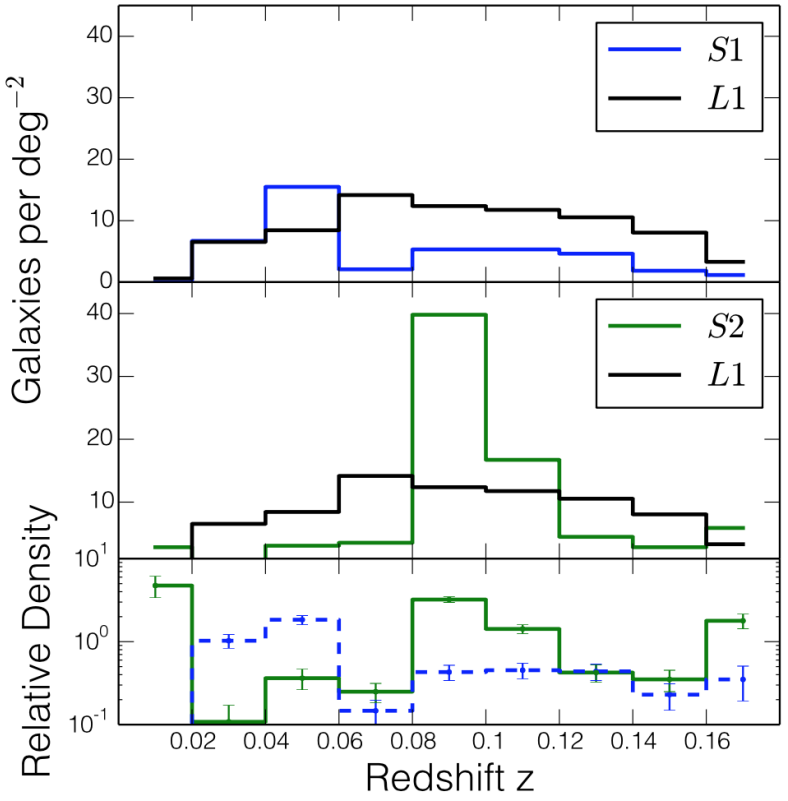
- Comparing overlap regions between high and low frequency bands, and by injecting synthetic objects:
  - ~4% false detection rate, 96% reliability (first pass catalog)

Cosmic Variance:

- One field: 43±5%
- Two fields: 29±4%
- SDSS: 7% (Driver & Robotham 2010)

Cosmic Variance corrected:

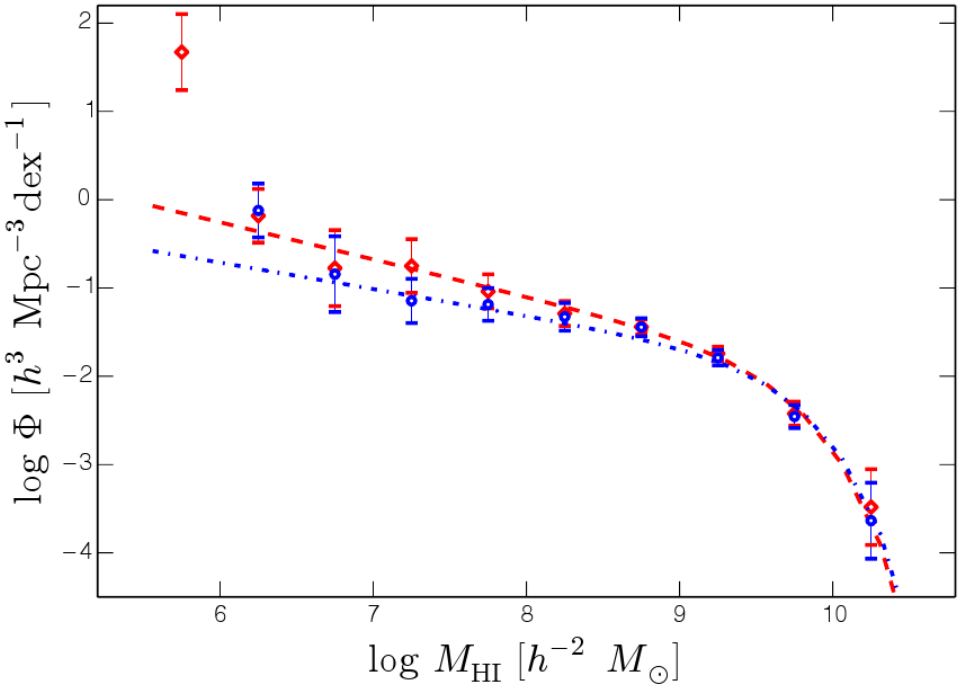
- One field: 16%
- Two fields: 11%



HI Mass Function Φ_{HI}

Methods:

- Σ 1/V_{max} (Schmidt, 1968)
- 2D stepwise maximum likelihood (SWML; Zwaan et al. 2003) – independent of density variation



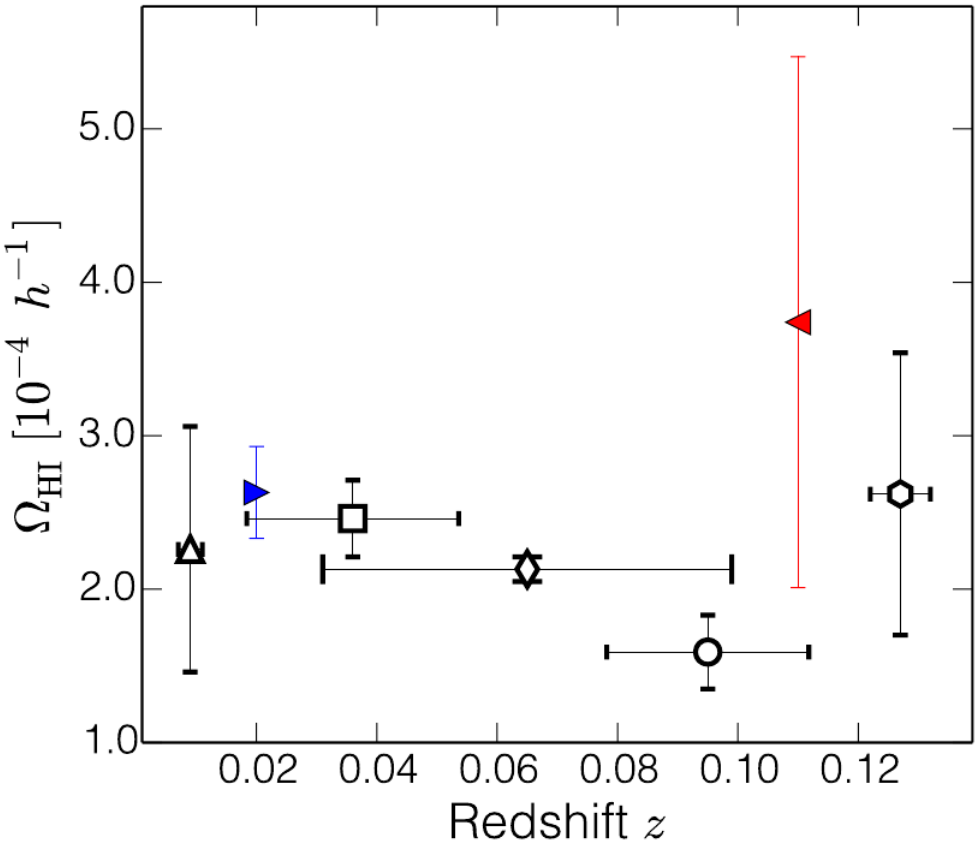
Schechter fit

α= -1.42 ± 0.02
log($M^*_{HI}/M_\odot$)=9.68 ± 0.05 +2 log h
$\Phi^* = 6.85 \pm 1.6 \times 10^3\ h^3 Mpc^{-3}$

α= -1.30 ± 0.10
log($M^*_{HI}/M_\odot$)=9.70 ± 0.06 +2 log h
$\Phi^* = 6.60 \pm 2.0 \times 10^3\ h^3 Mpc^{-3}$

Comparison between the 2 methods.
Red: Σ 1/V_{max} (cosmic variance corrected) ; blue: SWML

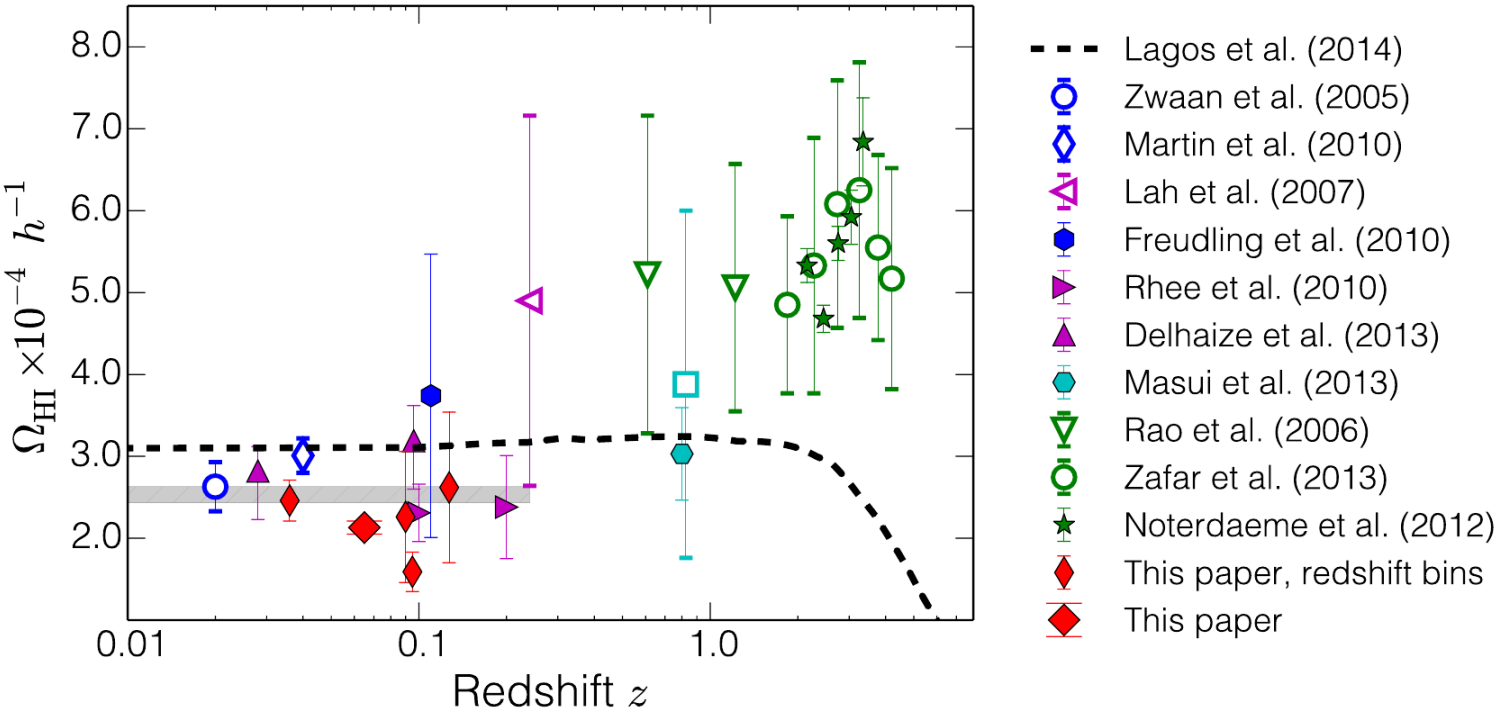
Cosmic HI Density Ω_{HI}



Black: AUDS ; blue: HIPASS ; red: AUDS precursor

** No evolution in the cosmic HI density out to z=0.2

Cosmic HI Density Ω_{HI}



AUDS (direct detection)

Mean redshift: z = 0.065

$\Omega_{HI} = (2.13 \pm 0.08) \times 10^{-4}\ h^{-1}$

Future Work

- Complete reducing and analyzing the last 50% of AUDS data
  → sensitivity limit down to 50—60 μJy, detect more galaxies
  → low mass end at the high redshift range

- Improve RFI flagging

- Better handling of continuum sources

Summary and Conclusions

- Data were collected from 2008—2013, only 50% data are presented here
- Completeness decreases for smaller fluxes for all bin
- 96% reliability, cosmic variance has been corrected (11%)
- α= -1.42 ± 0.02, log(M*HI/M⊙)=9.68 ± 0.05 +2 log h, Φ* = 6.85 ± 1.6 x 103 h3Mpc-3
- No evolution in the cosmic HI density out to z=0.2

Stay tuned! More to come!