Deep Studies of the Universe at 21cm

The Arecibo Ultra-Deep Survey (AUDS)

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Arecibo Ultra Deep Survey (AUDS)

→ Deep 21cm blind survey

Aim: Increasing limit of direct detections of extra-galactic HI

Idea: Long integration on a small field

→ Telescope: 305m Arecibo Observatory
→ Instrument: ALFA (Arecibo L-Band Feed Array)
→ Bandwidth: 1222-1422 MHz
→ z = 0 - 0.16
→ 7 beams
→ 1200h Observation time on two fields
→ 2577: α = 08:20:00 δ = 22:11:00
→ 17H: α = 17:00:00 δ = 19:45:00
→ 40h per pointing
→ Drift-and-scan mode
→ Area: 0.36 deg^2

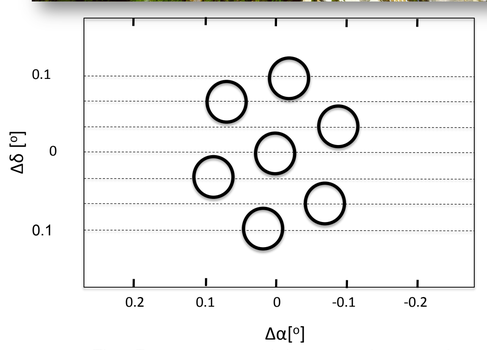

Fig.: Beam pattern of the seven beams of the ALFA instrument

Science Goal: Gaseous Evolution in Galaxies

→ HI is a key ingredient for star and galaxy formation
→ Star formation increases by a factor of five between z≈0 and z≈1 (e.g. Hopkins 2004)
→ **Goal:** Correlate cosmic neutral hydrogen density ($\Omega_{\rm HI}$) to star formation rate
→ **Problem:** Observations at cosmological distances (z < 0. 1) are scarce
→ **But:** Intermediate redshifts are crucial to improve our understanding of galaxy formation

Galaxy formation remains a fundamental question in modern astrophysics.

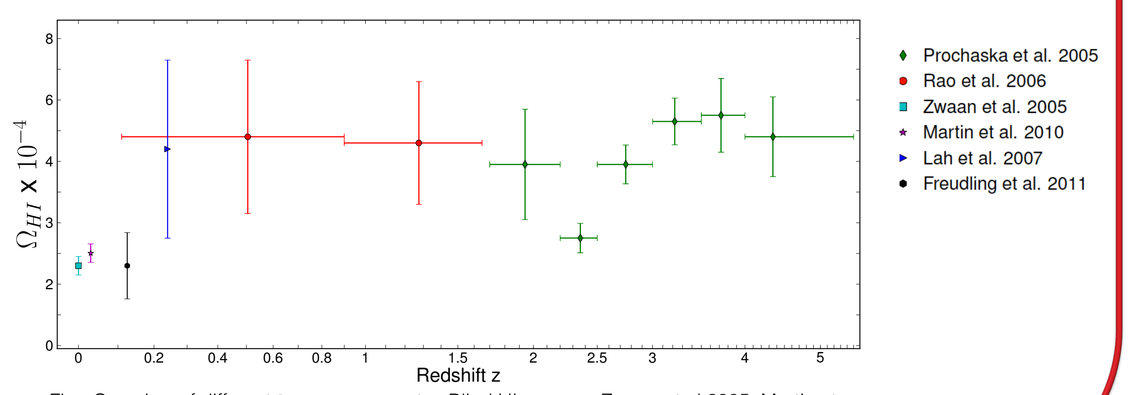

Fig.: Overview of different $\Omega_{\rm HI}$ measurements: Blind HI surveys: Zwaan et al 2005, Martin et al. 2010, Freudling et al. 2011; Stacking: Lah et al. 2007, DLA measurements : Rao et al. 2006, Prochaska et al. 2005

AUDS Precursor Observations

(Freudling et al. 2011)

→ Precursor observations proof feasibility of AUDS
→ 53 hours of integration time
→ sensitivity level of 80μJy
→ 18 detected HI sources in redshift range: z=0.07-0.15

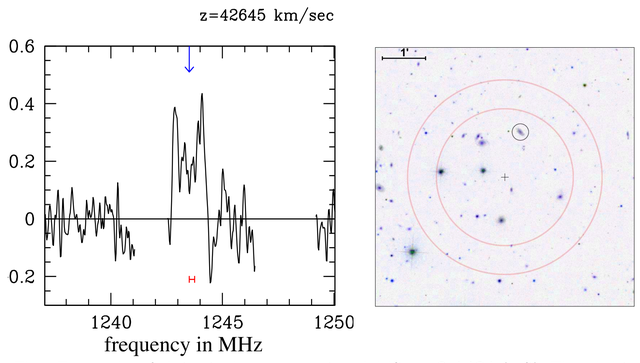

Fig.: Example of detected sources at redshift z= 0.1421 (left). The right figure presents the optical counterpart (from SDSS). Its redshift is marked in red in the spectrum.

→ HI Mass function (HIMF)
→ HIMF computed from sample using the standard 1/v_{max} method (Schmidt 1968)
→ Comparison of AUDS HIMF to HIPASS local HIMF (Zwaan et al. 2005)
→ shape of the derived HIMF consistent with the local HIMF
→ normalisation of HIMF is by a factor of 3.2±1.0 higher than the local HIMF
→ Reason: AUDS samples a smaller volume which was not chosen randomly (relative HI overdensity in region: $\delta_{\rm HI} = 2.5 \pm 0.8$)
→ Derived mean HI density:

$$\rho_{\rm HI}(z = 0.125) = (1.0 \pm 0.3)\ \rho_0$$

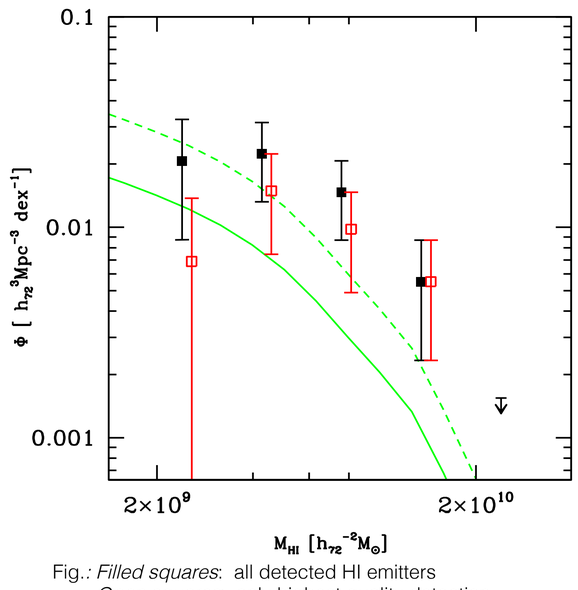

Fig.: *Filled squares*: all detected HI emitters
Open squares: only highest quality detection
Solid line: local HIMF by Zwaan et al. (2005)
Dashed line: local HIMF multiplied by the relative overdensity of survey region

RFI & Flagging

→ All data are impacted by radio frequency interference (RFI) in certain channels
→ Robust identification and flagging of RFI necessary
→ Automatic routine using 3-sigma clipping and smoothing in the time-frequency domain

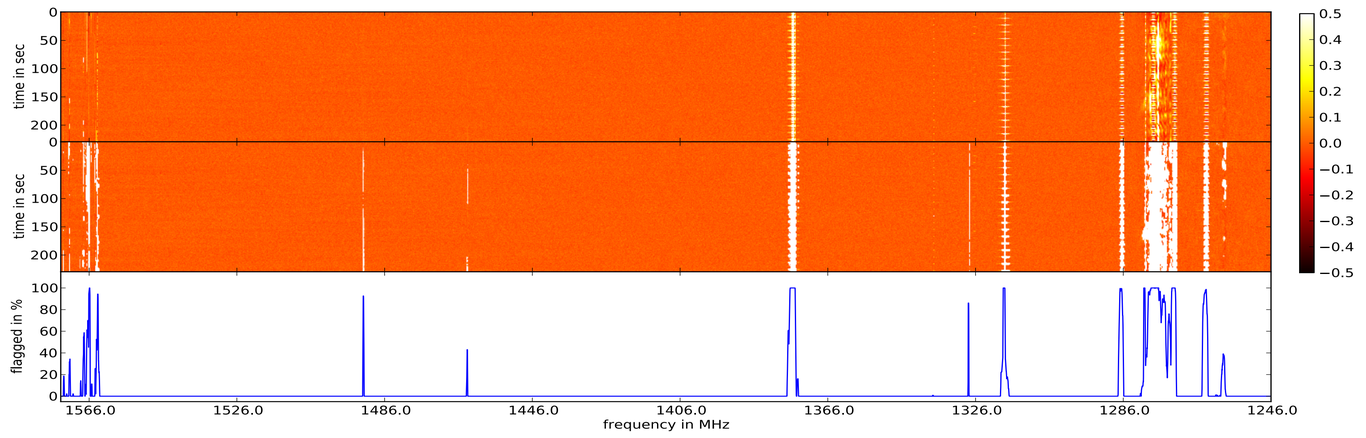

Fig.: Example of data of beam 0, observed at 01/06/2010; Observations are done in drift-and-scan mode, 230 spectra with 1s integration time each
First figure: After band pass estimation and removal, Doppler correction and calibration (done with *livedata* (written by Mark Calabretta))
Second figure: Data after 3-sigma flagging
Third figure: Precents of data flagged per channel in the second figure

Data & Observation

→ Observations started in Nov 2008
→ 800hours allocated until June 2011
→ First sources already detectable
→ e.g. source at z ≈ 0.157

First step for pushing the limit of direct 21cm detections!

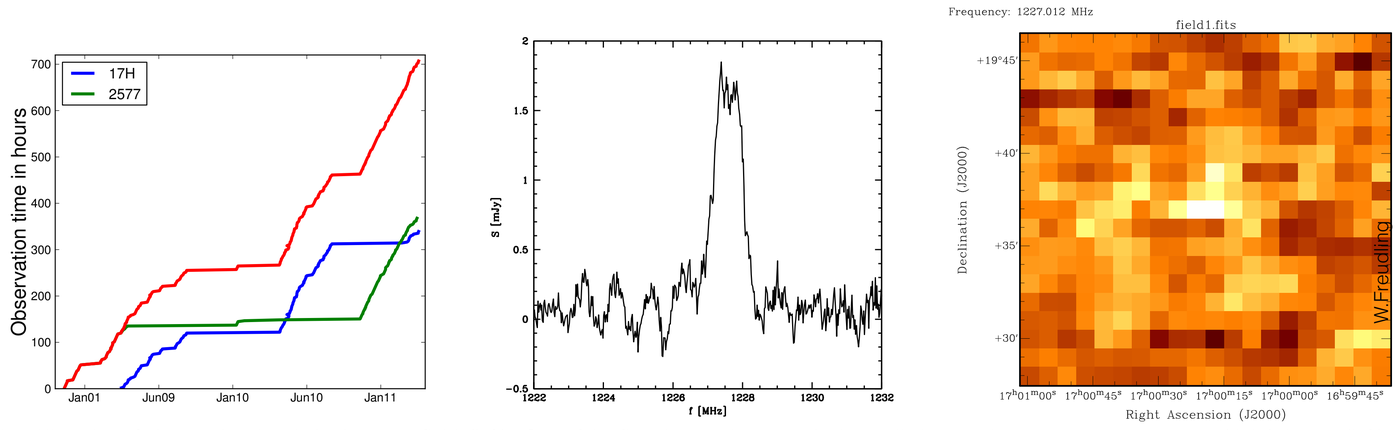

Fig.: Allocation of observation time in both survey fields(left); One of the first detected sources in the preliminary cubes at z≈0.157, spectrum (right), image (left)

The AUDS team

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