HI absorption blind survey in CRAFTS at 1300– 1450MHz

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Introduction

The HI 21-cm absorption lines, arising from foreground gas absorbing the flux of background bright radio source, is a good tool to measure the HI content and constrain the redshift evolution of Ω_{HI}, probe the physical conditions in the ISM, reveal the evolution history of the SFR density and place stringent constraints on the variation of fundamental constants of physics. Known that the compact sources have the higher rate of HI absorption detection and the majority of DLAs show strong MgII absorption, most of HI absorption searches have been pointed at selected targets with these features. However, these pre-selection methods could introduce biases in studying the intrinsic physics of HI absorptions, which has not been well-understood. An unbiased radio survey would help overcome these limitations. Thanks to the high sensitivity and large sky coverage, the Five-hundred-meter Aperture Spherical radio Telescope (FAST) can play an important role in the blind survey for the HI absorption. In this poster, we report the early science results from a purely blind search for HI absorption lines at z<0.09 in 643.8 hours data which spans 3155 deg^2 sky in the CRAFTS.

Data

CRAFTS is a multi-purpose drift-scan survey using the FAST L-band Array of 19 feed-horns , which aims to observe the galactic and extragalactic HI emission, and to search for pulsars and radio transients. The survey region will be observed by two passes, with the feed rotated by 23.4°to achieve a super-Nyquist sampling. The full survey will cover over 20000 deg^2 within a declination (DEC) between -14°and 66°, and reach a redshift of 0.35. Limited by the allocated time, there is only one survey pass at present.

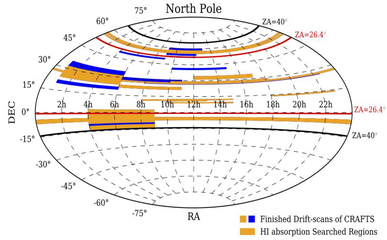

Figure 1. The CRAFTS sky coverage in Equatorial coordinates, as up to July 7th, 2022. We have carried out our search in the orange regions, the orange and blue regions have been surveyed with CRAFTS. The zenith angle of 40° (maximum zenith angle for FAST) and 26.4° (zenith angle within which FAST has full gain) are shown as black circles and red circles, respectively.

For CRAFTS data, the Radio Frequency Interference (RFI) dominates the frequency range from 1.15 GHz to 1.3 GHz. In the range of 1.05 GHz to 1.15 GHz, there are also many smaller peaks due to chronically present RFI. Considering the data quality, the data in the frequency range of 1.3 GHz to 1.45 GHz which is relatively clean is used in the present study. We are also searching the HI absorption in the range of 1.05 GHz to 1.15 GHz, this will be presented in the future.

Methodology

The raw CRAFTS data set has a time resolution of 0.2 s, and a frequency resolution of 7.63 kHz. Considering our scientific objectives and computing capacity, we further re-bin the data into a time resolution of ~12s (~ the transit time in drift scan).

Spectra at each time point were extracted from the data cubes. After the removal of the baseline of the bandpass, the matched-filtering approach was applied to find the absorption profiles. The final candidates are selected by use of the transit information recorded by the 19-beams of FAST.

The band baseline is estimated by smoothing the spectrum with a low-pass filter. The HI absorption signal is searched in both the XX and YY polarizations of each beam. Only those candidates with a total S/N > 5.5 and can be found at nearly the same frequency ($\Delta f < 0.1$ MHz) with S/N > 3.5 in both XX and YY polarizations are selected.

In CRAFTS, the feed array is rotated by 23.4 degrees. During the drift-scan, the true HI absorber will be scanned by more than one beams which are distributed along the direction of the scanning path. The false signals caused by RFI, on the other hand, can appear in data from many beams, but not necessarily corresponding to the same sky direction. In this way we select the final candidates.

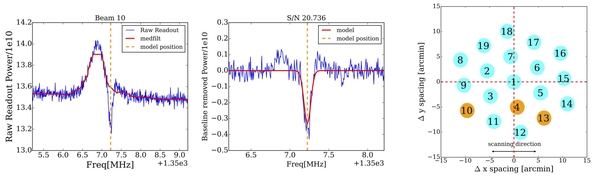

Figure 2. The spectra of the HI absorption system UGC 00613. The left and middel panel shows the raw data and the right column shows the baseline removed data. The absorption of UGC 00613 is detedted by and only by beam 10, beam 4 and beam 13 in turn along the drift scanning direction, this is shown in the right panel.

Results

After processing the data by applying the matched filter and the multi-beam candidate selection pipeline, we find 10 candidates, including 3 previously known (UGC 00613, 3C 293 and 4C +27.14) ones. We have made follow-up observations for these candidates in the ON-OFF tracking observation mode, with 990 s integration on each. Besides the three previously known ones, two are confirmed to be bona fide absorbers, while the other 5 candidates are either produced by features in the bandpass, or the combined features from the HI emission and bandpass ripples. We fit the profiles of the true HI absorptions with multi-components Gaussian functions, and presented the basic physical information for each source. The absolute photometric flux is calibrated with 3C\,48 and the FAST built-in noise diode.

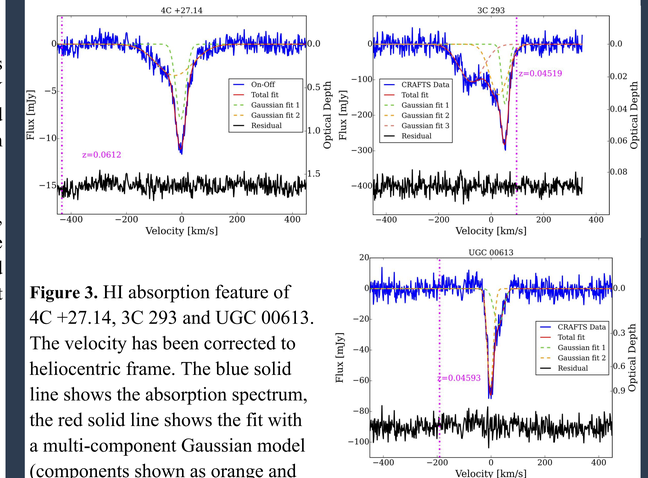

Figure 3. HI absorption feature of 4C +27.14, 3C 293 and UGC 00613. The velocity has been corrected to heliocentric frame. The blue solid line shows the absorption spectrum, the red solid line shows the fit with a multi-component Gaussian model (components shown as orange and green dashed lines). The magenta dot-dashed vertical line mark the redshift of 4C +27.14, 3C 293 and UGC 00613. as given in the NASA/IPAC Extragalactic Database. The fitting residual is shown as black solid line in the bottom. Optical depth value for the HI absorption is shown on the right scale.

Figure 4. The spectra of 2 new absorption systems and their infrared map from WISE. New abs1 was detected in beam 10, beam 4 and beam 14, while new abs 2 was only detected in beam12. We verified new abs 2 using followup observation.

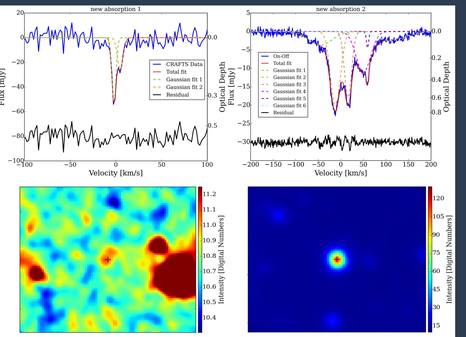

Table 1. Some basic physical parameters for the two new absorptions.

Radio Source	absorption type	Component	σ_{peak} (km s^{-1})	FWHM (km s^{-1})	S_{fit_peak} (mJy)	$\int S_{fit}\,dv$ (mJy km s^{-1})	τ_{peak}	$\int \tau dv$ (km s^{-1})	N_{HI} (10^{20}cm^{-2}K^{-1})
New Abs 1	unknown	1	18790.52	5.20	-53.17	-294.82	0.33	1.82	$0.03T_s$
		2	18797.77	7.15	-26.10	-198.50	0.15	1.15	$0.02T_s$
		Total	18797.77	9.12	-54.04	-493.32	0.34	3.01	$0.05T_s$
New Abs 2	associated	1	19899.88	60.81	-3.70	-239.20	0.097	6.19	$0.113T_s$
		2	19933.06	26.08	-20.17	-559.72	0.702	17.53	$0.319T_s$
		3	19960.99	18.78	-17.84	-356.73	0.591	10.81	$0.197T_s$
		4	19994.99	38.18	-11.08	-450.01	0.324	12.55	$0.229T_s$
		5	20004.30	5.94	-4.47	-28.25	0.118	0.74	$0.013T_s$
		6	20055.36	75.00	-2.46	-196.30	0.063	5.02	$0.091T_s$
		Total	19944.95	89.53	-21.85	-1830.21	0.790	55.81	$1.016T_s$

Disscussion & Conclusion

- 3 know and 2 new HI absorbers are detected in the purely blind HI absorption survey.
- 1.3-1.45 GHz data of 3155 deg^2 CRAFTS were searched.
- The power of FAST in HI absorption blind searching is demonstrated.
- The forecast for the FAST HI absorption blind searching indicates high sensitivity to N_{HI} frequency distribution function could be obtained with CRAFTS.

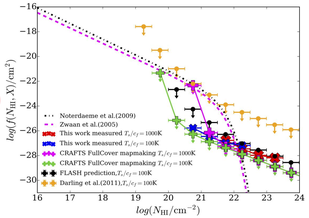

Figure 5. The measured HI column density frequency distribution for analysed data in this work and the 95% upper limits for full cover CRAFTS map-making data and previous works.

Acknowledgements

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