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Observation of Neutral Hydrogen using FFT Spectrometer Argos on a 5m telescope

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Abstract. The aim of this work was to use the new FFT spectrometer Argos in high resolution mode (12.2kHz) to observe neutral hydrogen at 21cm wavelength in our galaxy. The measured line profile is rather strong at this frequency so the 5m telescope at Bleien observatory has sufficient receiving area for the observation. The target position is already known for a long time as a reference source or as a test bed for spectrometer testing.

Key words. Neutral hydrogen, FFT spectrometer

1. Introduction

Testing of the FFT-spectrometer without having our own antenna system is very time consuming. For every test we had to go to a foreign institute somewhere in Switzerland or Germany. So we decided to build our own test bed by misusing our solar telescopes for molecular respective atomic line observation. Many attempts to measure atomic lines failed due to strong electromagnetic interference from mobile phone and pager transmitters near our site. We then decided to let manufactured a dedicated band pass filter by a specialized German company. Recently we got the filter with excellent characteristics concerning band pass ripple, loss and selectivity. The filter was inserted between antenna and preamplifier and the signal was feed to our spectrometer. Most of our measurements were successful showing the expected line profile already after a few seconds of observation. There are still a couple of parameters and components which may be improved but, as a first result we are quite happy with the

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Keyword	Meaning
AC240	2Gs/sec sampler board of Acqiris company
Antos	Antenna control system
AR5000	Commercial communication receiver
Argos	FFT spectrometer
Bleien	Observation place
FFT	Fast Fourier Transformation
FPGA	Field Programmable Gate Array
FPU	Focal plane unit
IF	Intermediate frequency 10.7MHz
rf	radio frequency
SNR	Signal to noise ration

Table 1. Abbreviations in text and labels.

Fig. 1. 5m radio telescope in twilight at Bleien observatory. A logarithmic periodic dipole array is mounted in front of the FPU.

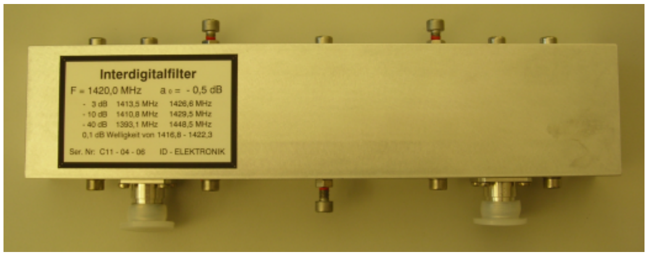

Fig. 2. Interdigital filter 1413.5MHz ... 1426.6MHz, low loss -0.5dB as well as low cost.

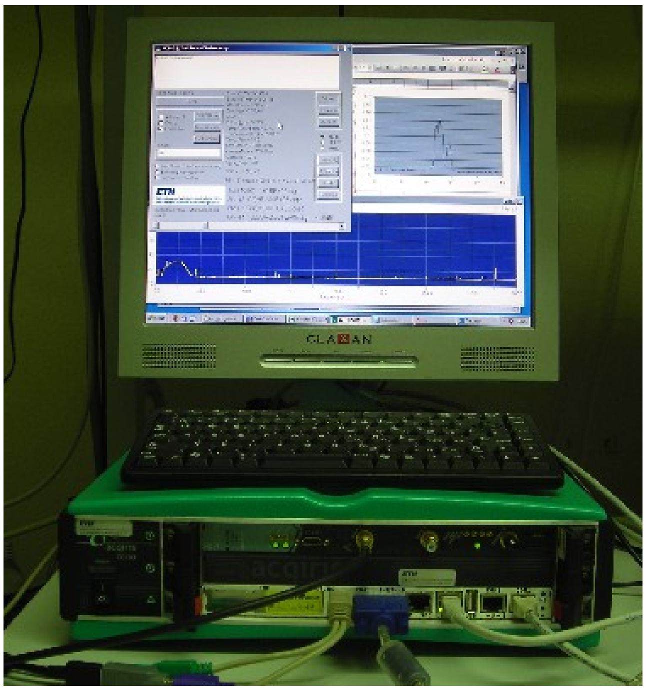

Fig. 3. Argos FFT spectrometer, 1GHz bandwidth and 16384channels. In this configuration in high resolution mode at 12.2KHz.

outcome, see figures 7 and 8. For abbreviations within text and labels, see table 1.

2. System configuration

The feed, a logarithmic periodic antenna, was exactly the same as it is used for solar observations. Between this feed and the high gain low noise preamplifier the interdigital band pass filter was switched in. All calibration components were bypassed to not loose sensitivity. The output of the preamplifier was fed via a low loss coaxial cable to the communication receiver AR5000 which was set to 1420.406MHz. The broad band IF output of the AR5000 was amplified by 20dB and feed through a low pass filter to the analog input of the AC240 board of the FFT spectrometer. Although we had the interdigital filter in front of the preamplifier, there were still some unwanted signals within the reception band thus, the AR5000 was sometimes saturated. To prevent the AR5000 from being saturated, we switched in a fixed attenuator of 7dB. With that configuration we got acceptable spectra which were

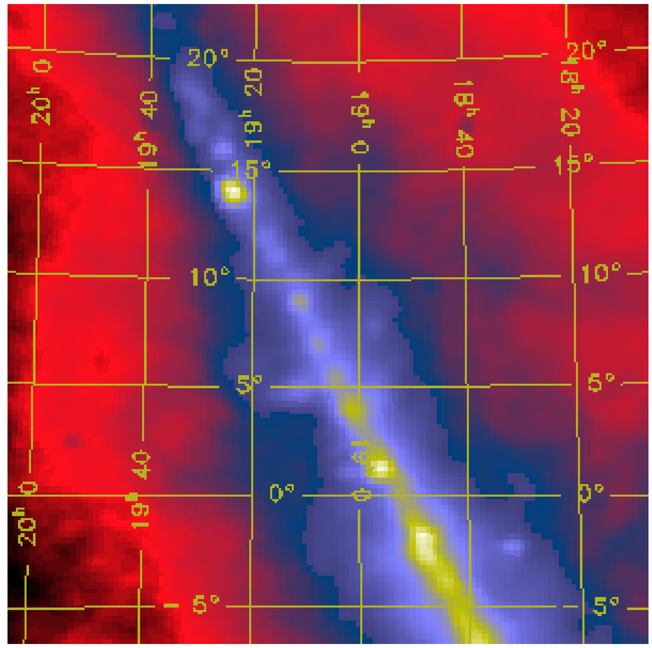

Fig. 4. View of the HI region (on source) at 21cm measured with the 100m telescope at Effelsberg.

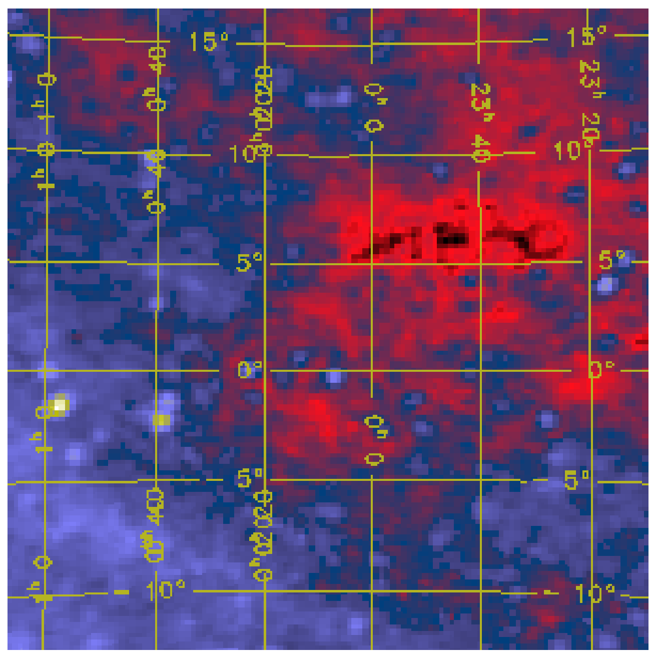

Fig. 5. View of the reference region (off source) at 21cm measured with the 100m telescope at Effelsberg.

stored on harddisc. All spectra were sequentially stored in FITS-files and were later analyzed using standard software tools.

3. Measurement method

All measurements were done in beam switching method. The source position, see figure 4 at $l = 41.9°$, $b = 0°$ in galactic coordinates or $\alpha = 286.42°$, $\delta = 7.98°$ in equatorial coordinates was observed by a certain time, e.g. 1sec-

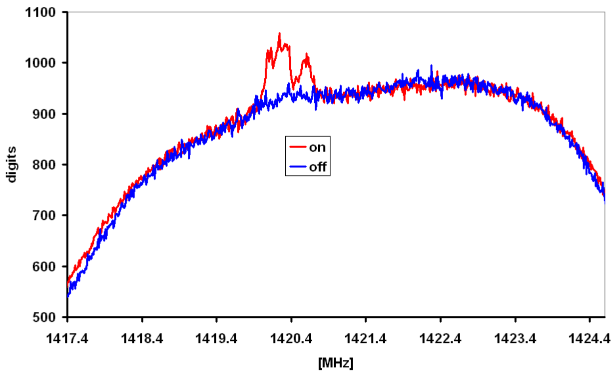

Fig. 6. On-/off-source measurement to remove the standing waves and band pass ripples within the receiver system. On source signal is shown in red while the reference signal is shown in blue solid line.

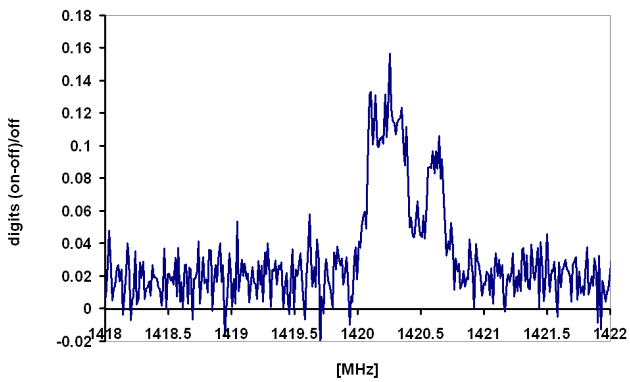

Fig. 7. Neutral hydrogen measured with the 5m telescope at Bleien observatory. Integration time on source 1 second. Depicted is the standardized signal (on source-off source)/off source.

ond. After that the telescope was moved to the reference position, see figure 5 at $\alpha = 2.10°$, $\delta = 3.12°$, a position with low hydrogen density. Unfortunately this was quite far away from the measured hydrogen region thus, it took quite a long time to reach the reference position. The final measurement was done with integration time of 900seconds. After analysis of the stored data we again found artifacts which we originally called "3/4 Takt". The reason lies in the finite number of digits within the FPGA. For future observations we have to switch the beam more often and do the final integration off-line with full precision arithmetics of the PC. During the measurements of the source the position was tracked by our standard antenna control system Antos.

4. Results

The final results came off surprisingly and unexpected well, see figure 8. If we take into account a reported line temperature of about 170 Kelvin we may derive a temperature resolution of a few milli Kelvins. Already after an integration time of 1 sec, see figure 7, the line profile

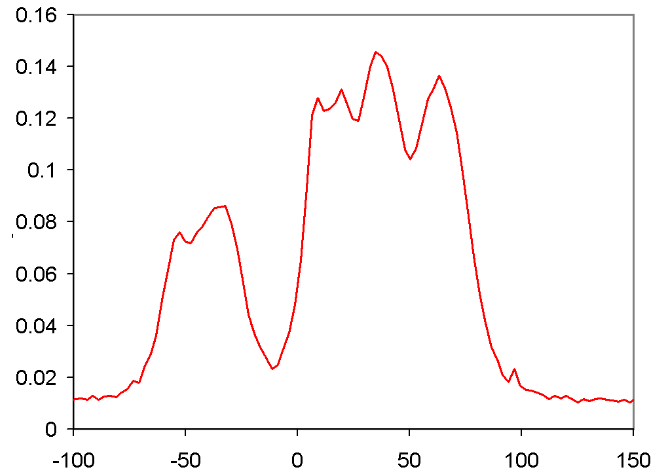

Fig. 8. Neutral hydrogen measured with the 5m telescope at Bleien observatory. Integration time on source 900 seconds. Depicted is the standardized signal (on source-off source)/off source. X-axis in km/sec, y-axis in SNR units.

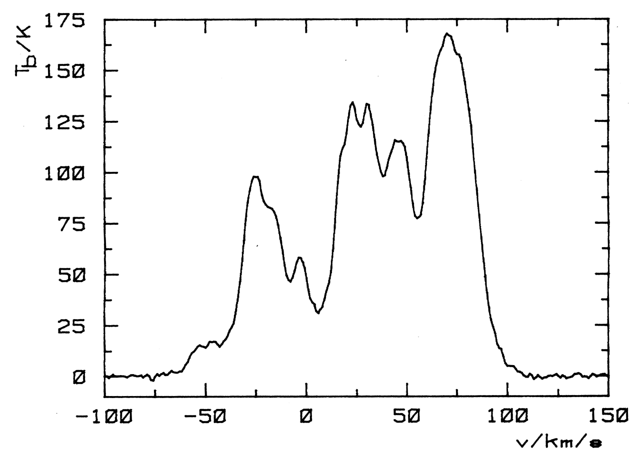

Fig. 9. For comparison only the 21 cm-line profile for $l = 41.9°$, $b = 0°$ measured with the Effelsberg 100 m-telescope. Picture was taken from (Rohlfs, 1986).

gets out of the noise very clearly. In figure 6 we see both line profiles, at the source position (figure 4) as well as at the reference position (figure 5). Luckily both showed the same basic profile which allows to cancel out standing waves and ripple of all band pass characteristics of the individual rf components. Due to non existing calibration unit the result in figure 8 doesn't show temperature but the flux ratio SNR expressed as a number where

$$SNR = \frac{on - off}{off} \tag{1}$$

In this context on means antenna on source and off stands for antenna at reference position. For qualitative line profile comparison, see figure 9 taken at Effelsberg telescope.

5. Conclusion

It is definitely possible to observe atomic or molecular lines with our existing instrumentation although it's optimized for solar radio observation. Just a few adaptations have to be made to get full sensitivity for spectroscopy. It's very convenient and also cheap to have our own instrumentation for testing of new hardware and software components. Whether the system shall be improved to observe other lines than hydrogen has to be discussed internally but it's possible at least technically. From the actual point of hardware and knowledge it might be possible to offer that kind of observation also for students exercises or even advanced lab courses.

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