MEMO

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Nançay/Abell2440/23.11.11

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Subject: Data analysis status for Abell 2440 (2011)

1 Introduction

This note covers the study of the galaxy cluster Abell 2440 from observations performed with the Nançay Radio Telescope (NRT) between April and June 2011. The source observation (mode ON) points to the galactic coordinates J2000: AR=22.40925/$22^h24^m33.3^s$, DEC=-0.88850/-0°53'18.6". The mode OFF (without source) is pointed ~60^s before the ON (we do not have the exact coordinates yet).

The redshift for this cluster is[1] z~0.0906 (1302.4 MHz), but the identification of the galaxies inside the NRT lobe[2] and their redshift is to be done. This is essential information to look for the cosmological HI line from these objects in our data.

The data have been acquired with the BAO electronics for 2 polarizations in the frequency band [1250,1500] MHz. The results presented in this note are based on the analysis of 210 cycles, i.e. the period ranging from the 15th April to 13th June 2011. This corresponds to an effective observation of the source (mode ON) of ~2100 sec.

After FFT treatment, two spectra (one per polarization or channel) are obtained for both the observation modes ON and OFF. These spectra are normalized by a GAIN, which is a mean OFF spectrum around the DAB-OFF calibration measurement taken in the middle of a run. The difference ON-OFF gives the source signal in arbitrary units. The data reduction is extensively detailed in the internal note ref. Nançay/Abell85/21.11.11. A deeper analysis of the data calibration is treated in the internal note ref. Nançay/Calibration/24.11.11.

In this note, we focus on the following topics:

- The effect of the calibration in the (ON-OFF)/OFF signal in the whole frequency range.
- The stability of the DAQ through the evolution of the integrated ON-OFF signal from the HI galactic line at 1420.4 MHz, and from its side-bands at [1418,1419]∪[1422,1423] MHz, for non-calibrated and calibrated data.
- The evolution of the sensitivity with the integration time in the HI galactic line and in the protected band [1400,1420] MHz (with non-calibrated data).

[1] Taken from the NASA/IPAC Extragalactic Database.
[2] NRT lobe: RA 4' × DEC 12' (FWHM at λ=21 cm).

2 Effect of the calibration in [1250,1500] MHz

We compare in Figure 1 the (ON-OFF)/OFF spectra for both channels (Ch0 in blue, Ch1 in red) without calibration and calibrated using the coefficients obtained per run and per cycle.

We observe that the calibration mainly increases the fluctuations in the two spectra. We find approximately the same effect for calibration per run or per cycle (no plot of calibration per cycle is included).

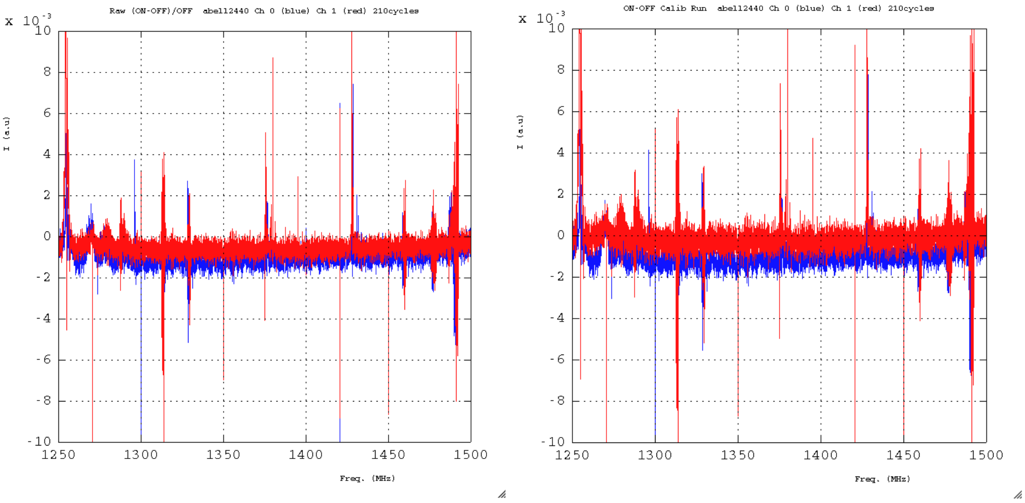

Figure 1. (ON-OFF)/OFF without calibration (left) and ON-OFF calibrated with calibration coefficients obtained per run (right).

3 DAQ stability and calibration

3.1 Residual HI galactic line at 1420.4 MHz

In this section we show the evolution in time of the ON-OFF mean intensity from the galactic HI line integrated in the frequency band [1420.4,1420.7] MHz. This mean intensity includes the subtraction of the mean baseline around the line, calculated in the frequency intervals [1418,1419] ∪ [1422,1423] MHz.

In Figure 2 (left) this signal is plotted versus data cycle. The result obtained is remarkably stable for both channels. In Figure 2 (right) we show the values of the mean and standard deviation of the previous plot.

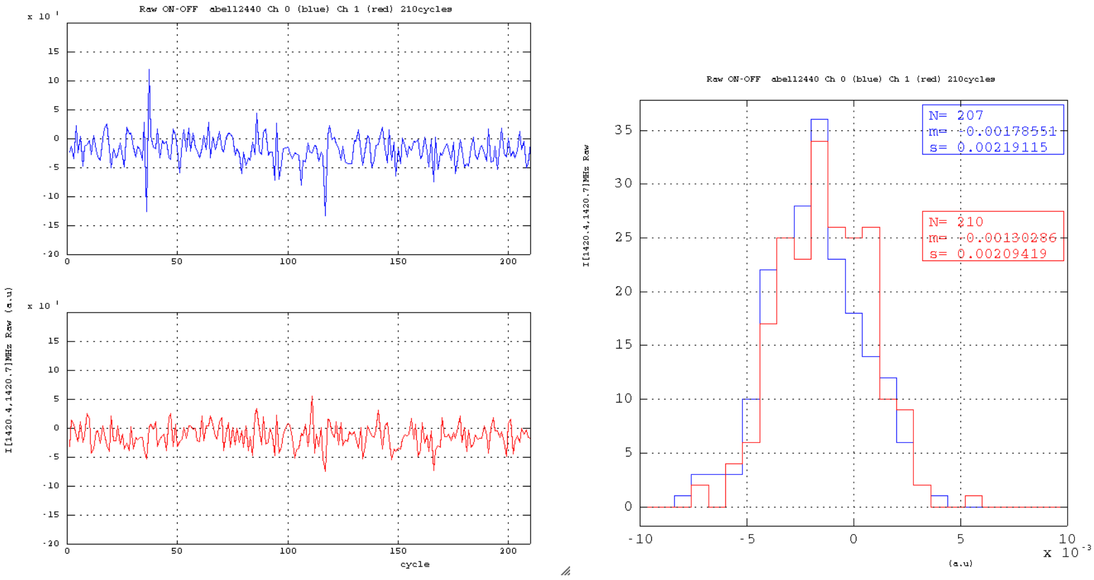

Figure 2. Integrated ON-OFF mean intensity from the galactic HI line without calibration. Signal evolution (left) and mean and sigma of the previous plot (right).

In Figure 3 and Figure 4 we show the result of applying to the previous plot a calibration with coefficients obtained “per run” and coefficients obtained “per cycle”.

In the calibration “per run” some run structure shows up due to the variation of the calibration coefficients from run to run, but it is not as clear as in the case of Abell 1205 (internal note ref. Nançay/Abell1205/23.11.11). Nevertheless, for the channel 0 one can distinguish very well the first (last) run, where the signal is lower (higher) than the bulk of cycles. The resulting sigma of the distribution is greater than the non-calibrated one.

In the calibration “per cycle” the distribution is even more spread and it shows peaks of instability due to calibration coefficients that differ significantly from the typical value within a run. The origin of these anomalous coefficients is under investigation. Note the change in Y-axis scale with respect to the previous plots.

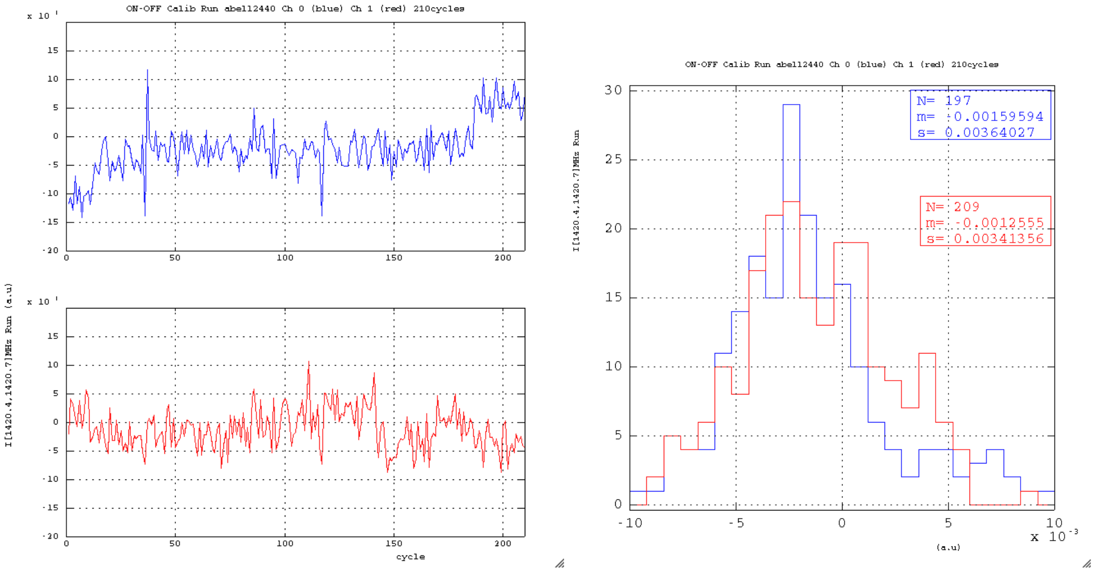

Figure 3. Integrated ON-OFF intensity from the galactic HI line calibrated with coefficients "per run". Signal evolution (left) and mean and sigma of the previous plot (right).

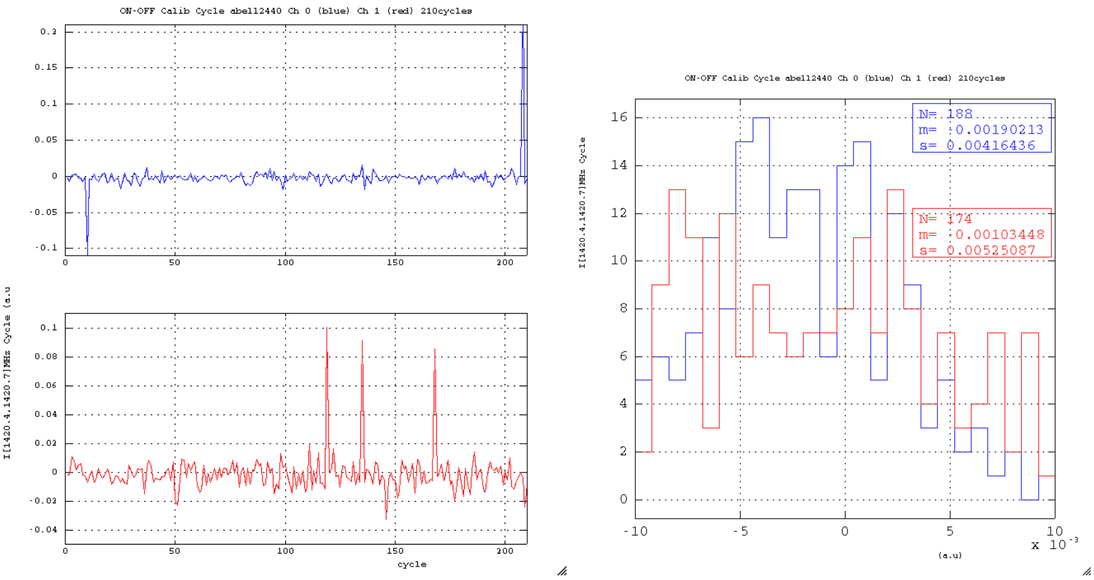

Figure 4. Integrated ON-OFF intensity from the galactic HI line calibrated with coefficients "per cycle". Signal evolution (left) and mean and sigma of the previous plot (right).

3.2 HI galactic line side-bands

We do the same analysis in the region just surrounding the HI line, i.e. the band [1418,1419] ∪ [1422,1423] MHz. We obtain the same results as above. We stress again the stability of non-calibrated data in Figure 5 (analogous to Figure 2).

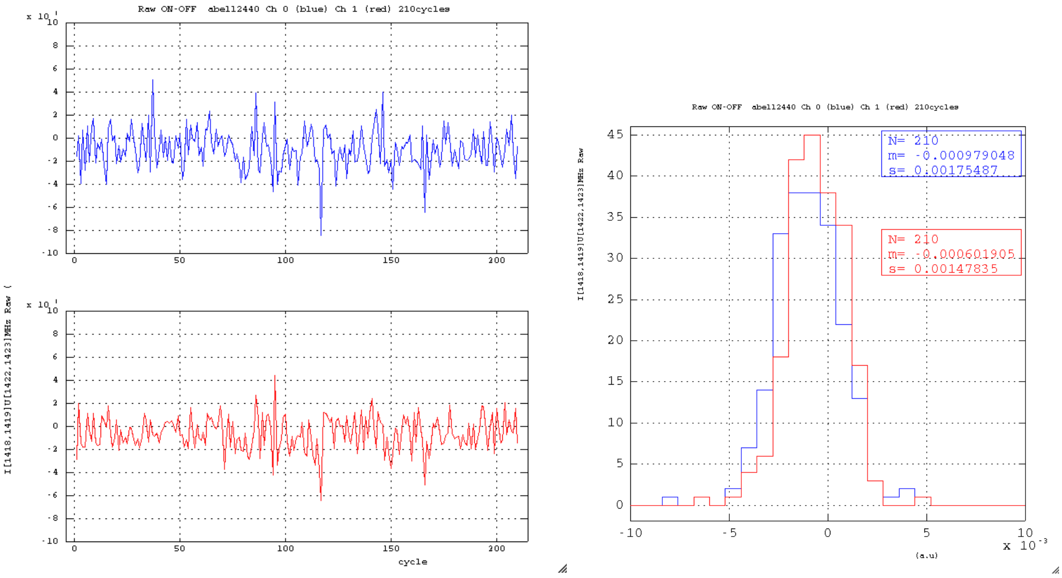

Figure 5. Integrated ON-OFF intensity from the galactic HI-line side-bands without calibration. Signal evolution (left) and mean and sigma of the previous plot (right).

3.3 RFI-protected band [1400,1415] MHz

We also study the stability in the RFI-protected band [1400,1415] MHz. In Figure 6 we show the non-calibrated ON and OFF integrated mean intensity vs. cycle number, with the following color code: Ch0/OFF in blue, Ch0/ON in cyan, Ch1/OFF in red and Ch1/ON in orange.

We observe the same "U" pattern as seen for Abell 85 (internal note ref. Nançay/Abell85/21.11.11), i.e. the mean intensity changes within each run, and these changes can significantly differ from run to run. The variation observed is about ~2-3% and it is due to the evolution of the NRT T_{sys} during the observations.

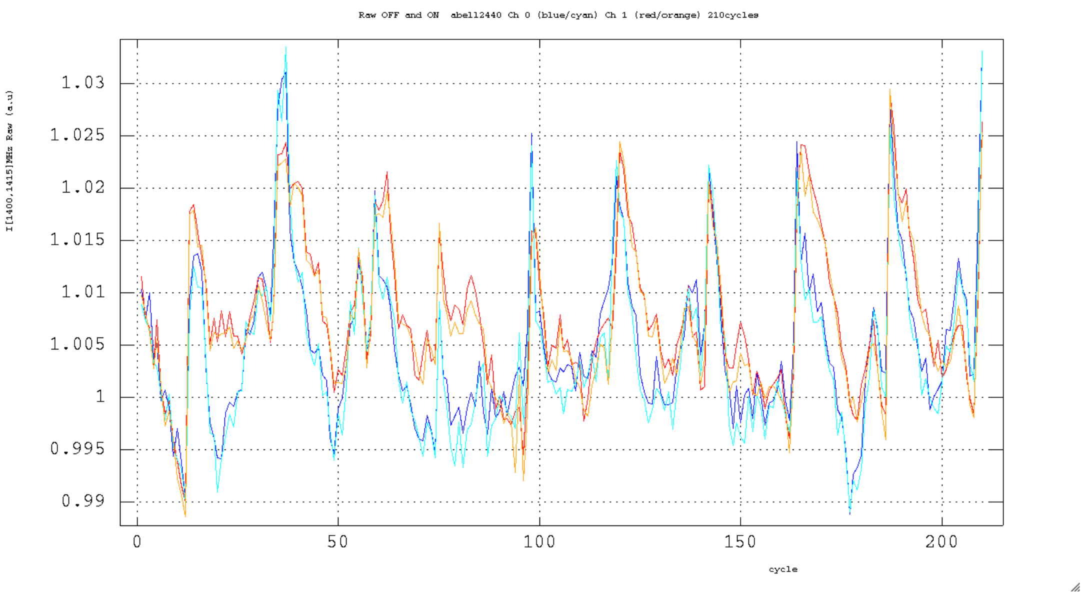

Figure 6. Non-calibrated ON, OFF mean intensity integrated in the RFI-protected band [1400,1415] MHz as a function of cycle number (see text for the color code).

If we normalize both ON and OFF signals by the OFF signal where a median filter is applied over a sliding 2.1-MHz window, we obtain the plot shown in Figure 7 (with the same color code as the previous one). We see that this operation removes the pattern seen in Figure 6. It is remarkable the stability of the OFF/OFF in contrast to the fluctuating ON/OFF signal for both channels, whose fluctuations are of the order of 0.2-0.3 %. This difference between OFF/OFF and ON/OFF are probably due to the different sky regions pointed in the two observation modes.

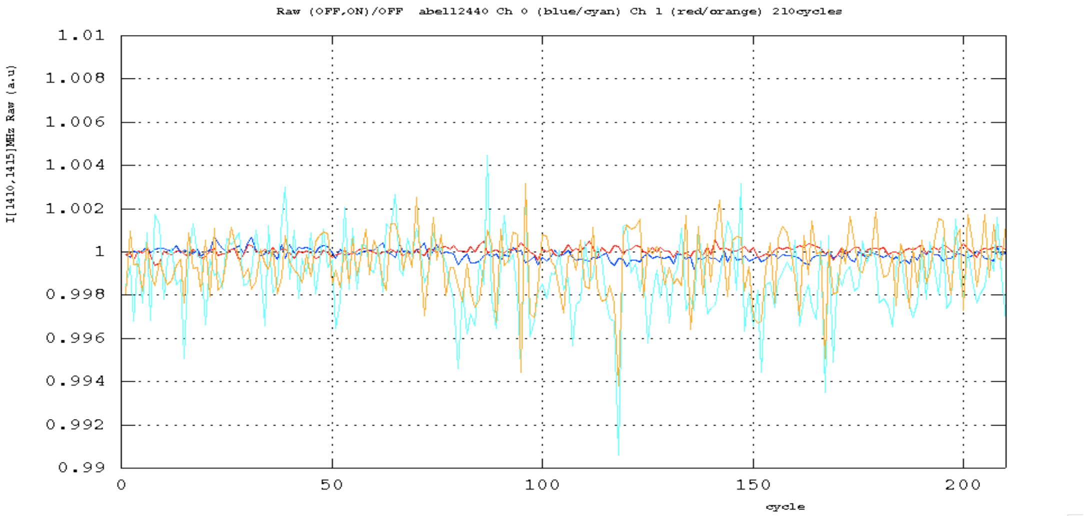

Figure 7. Non-calibrated ON, OFF over median-filtered OFF mean intensity integrated in the RFI-protected band [1400,1415] MHz as a function of cycle number (see text for the color code).

4 Sensitivity vs. integration time

We check if the evolution of sensitivity with integration time follows the expected law $\sigma \propto 1/\sqrt{t_{int}}$, where σ is the baseline standard deviation.

We compute the ON-OFF non-calibrated mean intensity integrated in the HI-line side-bands and in the RFI-protected band [1400,1420] MHz using 210 cycles of data. Gathering these cycles in groups of 1, 10, 25 and 42 cycles, we compute for each group the mean and standard deviation. In Figure 8 we plot the latter as a function of number of cycles per mean value for both channels. To guide the eye, we superimpose in the plots the curve 1/√ cycle # which passes through the first point of channel 0 (≡1 mean per cycle).

The points obtained are in good agreement with the expected behaviour.

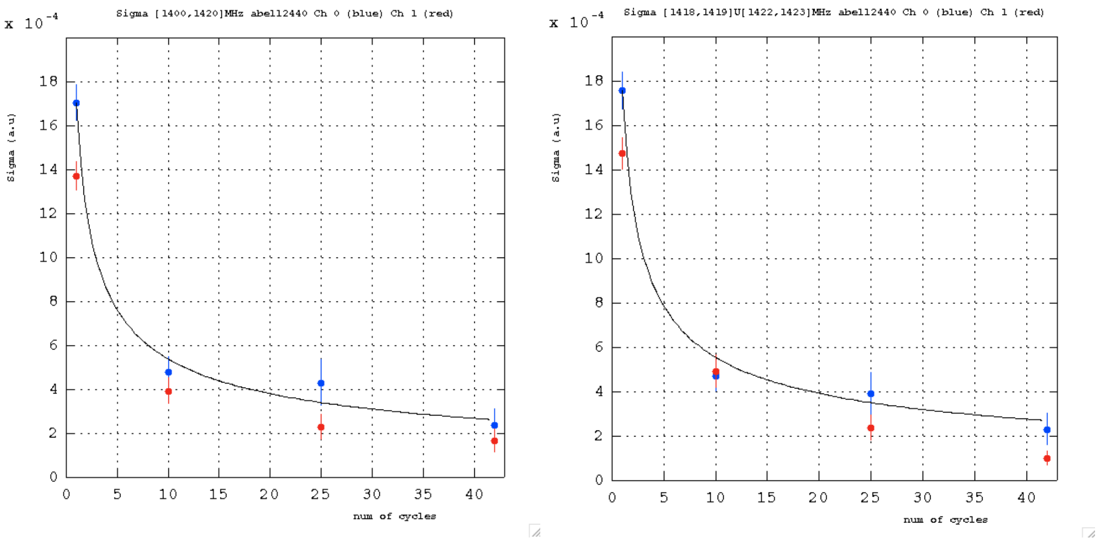

Figure 8. Baseline standard deviation as a function of number of cycles per mean value (see text), for the ON-OFF signal integrated in the HI-line side-bands ([1418,1419] ∪ [1422,1423] MHz) (left) and the RFI-protected band [1400,1420] MHz.

5 Cosmological HI signal

We look at the frequency band where we expect to find the cosmological HI signal from this cluster. As we have not identified the objects falling into the NRT lobe yet, we plot in Figure 9 (left) the (ON-OFF)/OFF signal around the NED redshift, i.e. 1302±10 MHz. We observe two lines at ~1297 MHz and 1300 MHz which are both RFIs. The first one is only seen in one polarization, whereas the HI emission is non-polarised. The second one is seen in both ON/OFF and OFF/OFF signals, as shown in Figure 9 (right), whereas a signal from the cluster could only come from the ON data. Thus, no potential HI cosmological signal is found for this cluster yet (if we are looking at the right frequency band).

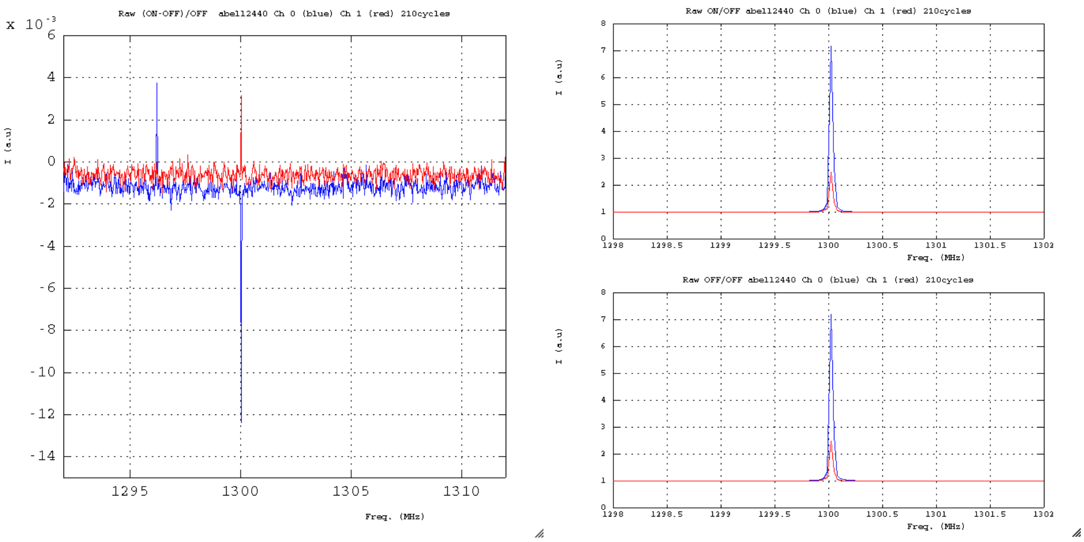

Figure 9. Left: (ON-OFF)/OFF signal around the NED redshift, i.e. 1302±10 MHz. Right: ON/OFF and OFF/OFF signals at 1300 MHz to show that this line is a RFI.

6 Summary

In this note we present the analysis of ~3 months of NRT observations of the galaxy cluster Abell 2440, which correspond to ~2100 s of effective observation time of the source.

We remark the stability of non-calibrated data in different frequency bands: the HI galactic line at 1420.4 MHz and its side-bands at [1418,1419] ∪ [1422,1423] MHz. A calibration procedure is applied to these data using calibration coefficients obtained "per run" and "per cycle". In both cases, this procedure introduces noise in the data, so it should be revised and improved.

We also check the stability of the data in the RFI-protected band [1410,1415] MHz. The evolution of the ON and OFF signals shows a pattern due to the variation of the NRT T_{sys} during observations. The pattern is removed normalizing by an OFF spectrum median-filtered with a sliding window of 2.1 MHz. Thus, this operation must be performed in all data to get rid of systematic effects. The remaining differences between the ON/OFF and OFF/OFF signals are probably due to real differences in flux received when pointing to different regions of the sky.

We have checked that the evolution of sensitivity, defined here as the standard deviation of the mean baseline in the RFI-protected band [1410,1420] MHz, depends on the integration time as $\sigma \propto 1/\sqrt{t_{int}}$, as expected.

We look for the expected cosmological HI signal from this cluster in a 20-MHz band centered on the NED redshift, not finding any evidence.

The results presented here are in agreement with those obtained for the galaxy clusters Abell 85 and Abell 1205, summarized in the internal notes ref. Nançay/Abell85/21.11.11 and Nançay/Abell1205/23.11.11.