MEMO

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Nançay/Abell1205/23.11.11

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Subject: Data analysis status for Abell 1205 (2011)

1 Introduction

This note covers the study of the galaxy cluster Abell 1205 from observations performed with the Nançay Radio Telescope (NRT) between April and September 2011. The source observation (mode ON) points to the galactic coordinates J2000: AR=11.25233/$11^h15^m8.4^s$, DEC=2.55039/$2^\circ33'1.4''$. 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~0.0754 (1321 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 600 cycles, i.e. the period ranging from the 15th April to 18th August 2011. This corresponds to an effective observation of the source (mode ON) of ~6000 s. The data from September are not reliable, as we will show below.

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 changes the mean differently in both channels and 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).

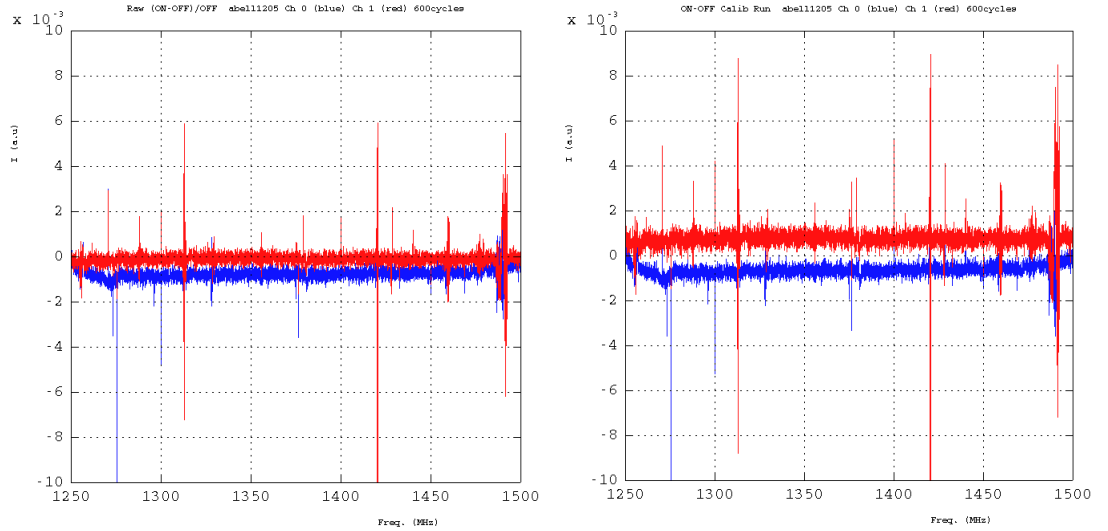

Figure 1. (ON-OFF)/OFF without calibration (left) and ON-OFF calibrated with calibration coefficients obtained per run (right).

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 [1420.1,1420.6] MHz This mean intensity includes the subtraction of the mean baseline around the line, calculated in the frequency intervals [1418,1419] $\cup$ [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.

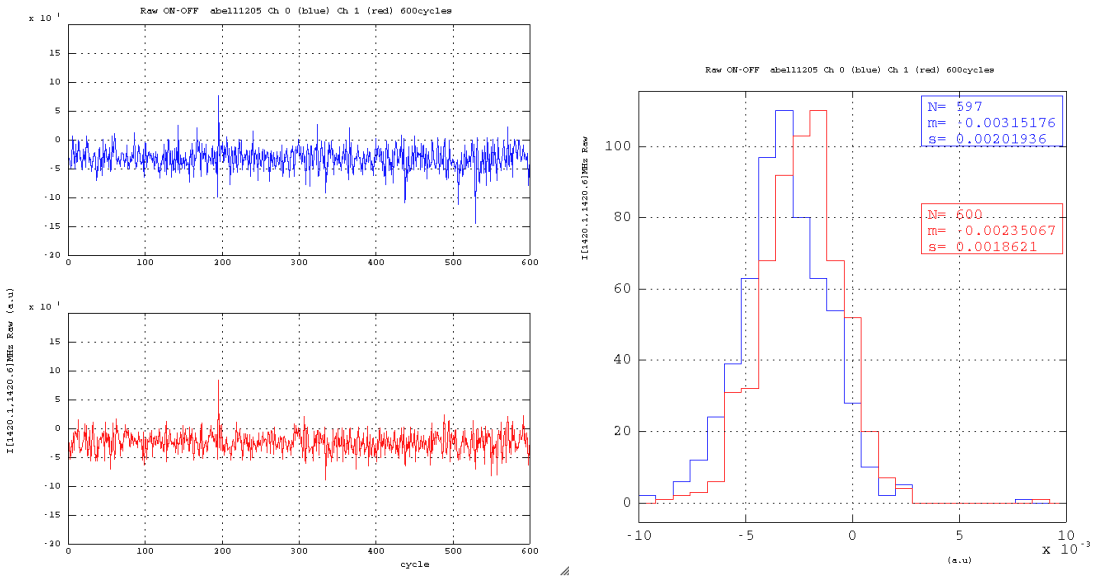

Figure 2. Integrated ON-OFF mean intensity from the galactic HI line without calibration. Signal evolution (left) and mean and sigma of the previous plot (right).

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” the run structure shows up due to the variation of the calibration coefficients from run to run. 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.

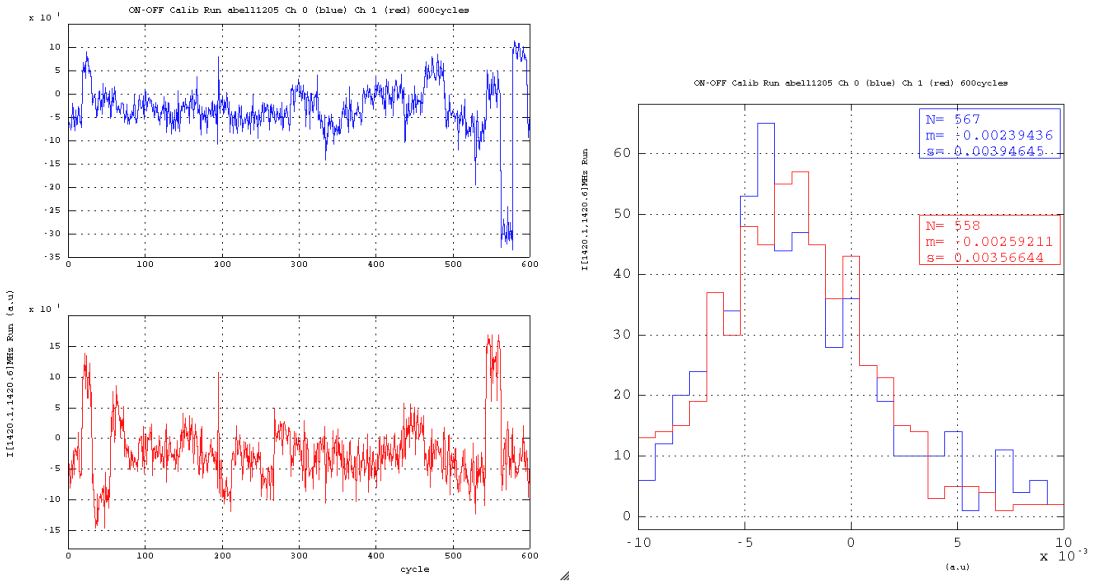

Figure 3. Integrated ON-OFF intensity from the galactic HI line calibrated with coefficients “per run”. Signal evolution (left) and mean and sigma of the previous plot (right).

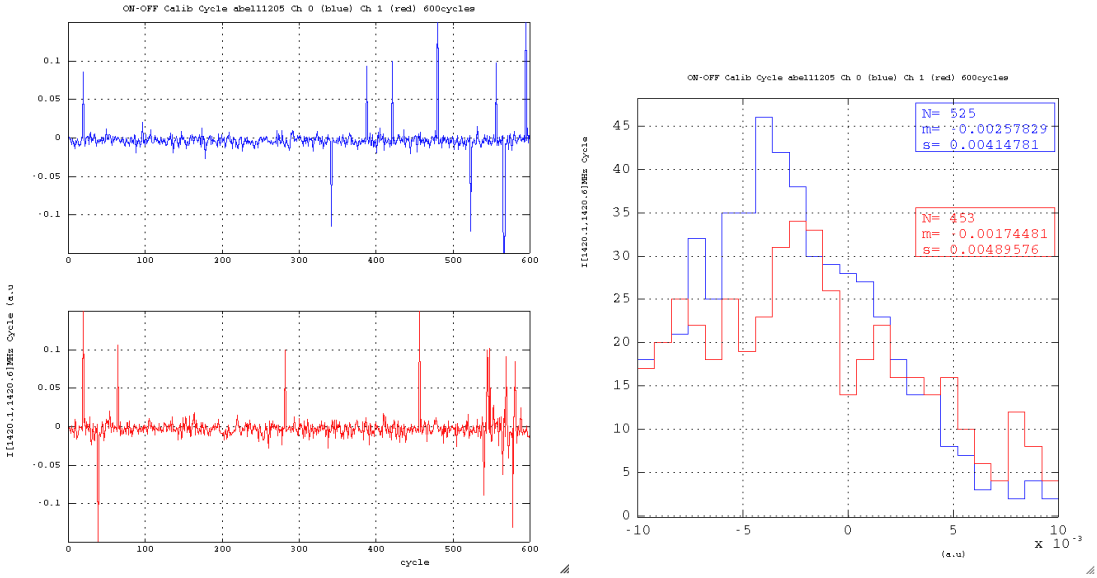

Figure 4. Integrated ON-OFF intensity from the galactic HI line calibrated with coefficients "per cycle". Signal evolution (left) and mean and sigma of the previous plot (right).

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).

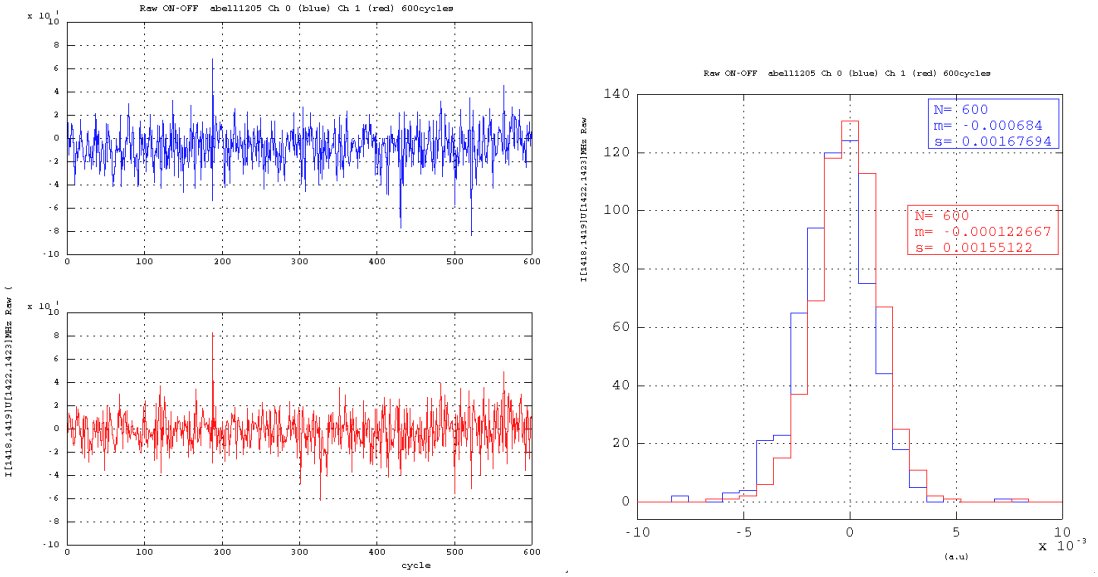

Figure 5. Integrated ON-OFF intensity from the galactic HI-line side-bands without calibration. Signal evolution (left) and mean and sigma of the previous plot (right).

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. Most of times this variation is about ~2-4%, but in some cases it can reach up to ~10%, and it is due to the evolution of the NRT T_{sys} during the observations.

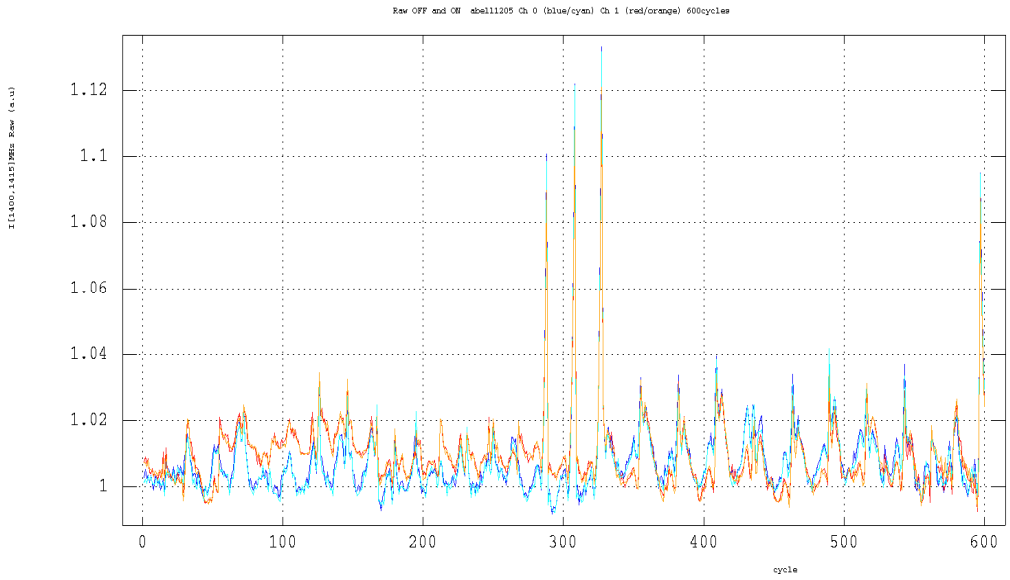

Figure 6. Non-calibrated ON, OFF mean intensity integrated in the RFI-protected band [1400,1415] MHz as a function of cycle number (see text for the color code).

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, although some anomalies remain, for instance the step around 550 cycles (which might be due to unexpected RFI, as shown in the Abell 85 data for an RFI at ~1407 MHz). 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 0.1 % except for some cases where they reach ~1%. This difference between OFF/OFF and ON/OFF are probably due to the different sky regions pointed in the two observation modes.

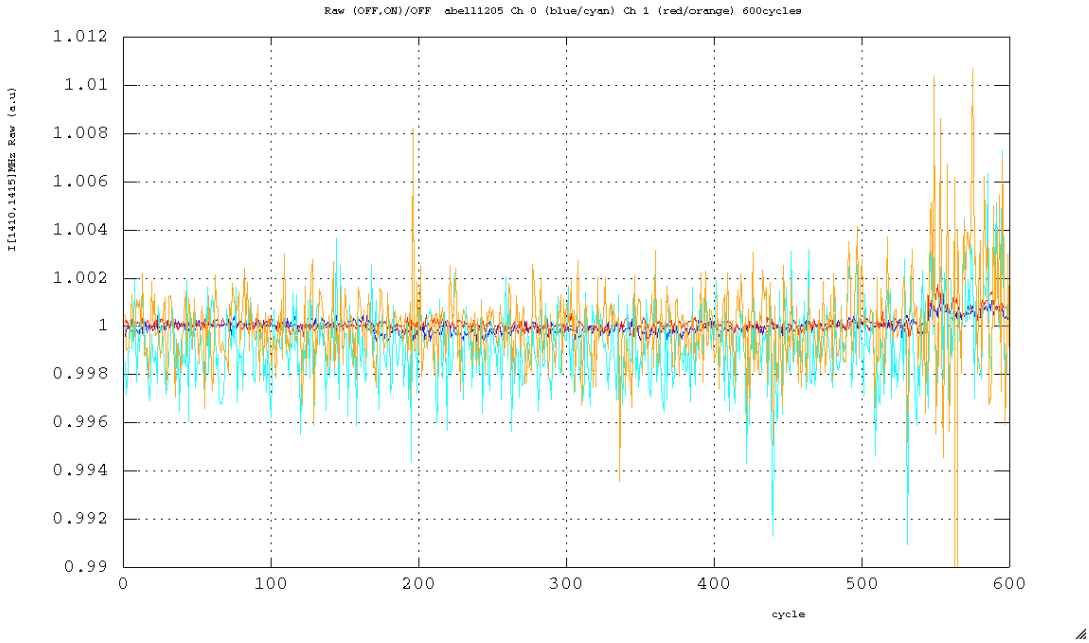

Figure 7. Non-calibrated ON, OFF over median-filtered OFF mean intensity integrated in the RFI-protected band [1400,1415] MHz as a function of cycle number (see text for the color code).

3.4 Data quality

We remark a worsening in the data quality at the end of August 2011. It is clearly seen, for example, in the non-calibrated ON-OFF signal from the galactic HI line plotted as a function of cycle shown in Figure 8. The 600 cycles used in this analysis correspond approximately to the period 15th April – 18th August 2011, where data are stable. Anomalies appear from 22nd August to 15th September. We find in the logbook comments on RAZ problems in September, in addition to the change in SCA file structure noticed on 31st August 2011. Normal functioning seems to be recovered at the end of September (22nd and 24th September data).

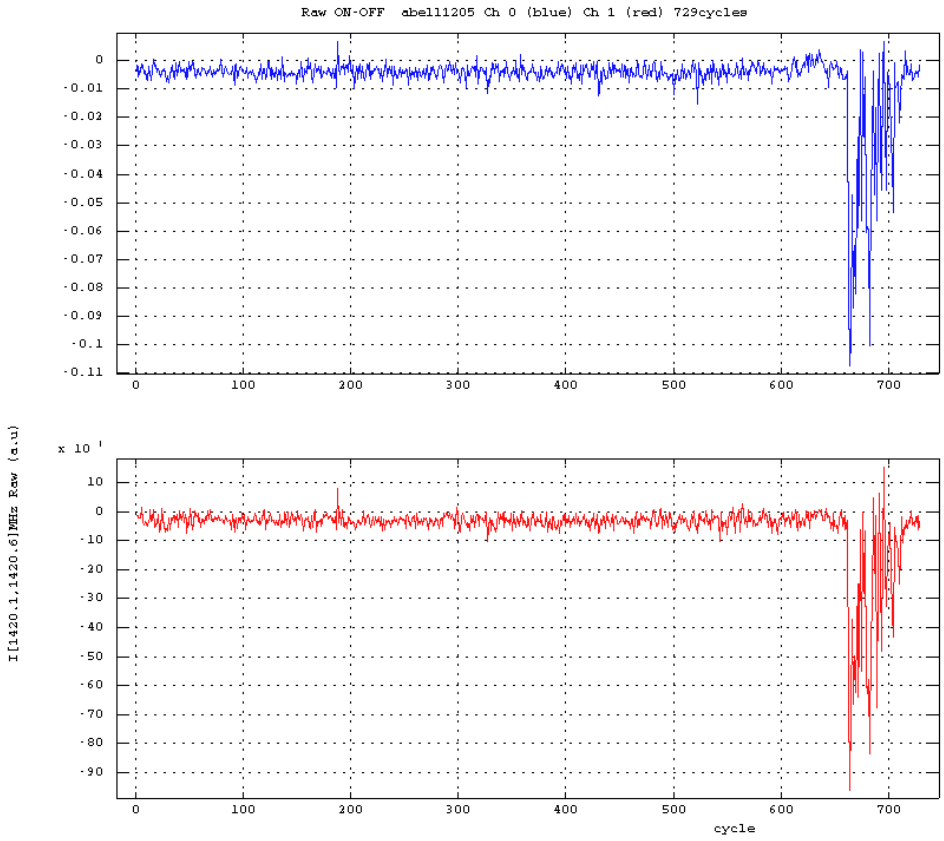

Figure 8. Integrated ON-OFF intensity from the galactic HI line ([1420.2,1420.6] MHz) without calibration as a function of cycle number.

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 600 cycles of data. Gathering these cycles in groups of 1, 10, 25, 50, 100 and 120 cycles, we compute for each group the mean and standard deviation. In Figure 9 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 $1/\sqrt{}$ 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. In the protected band, a signal increase observed at frequencies close to 1420 MHz might account for the upgoing trend shown by the last point.

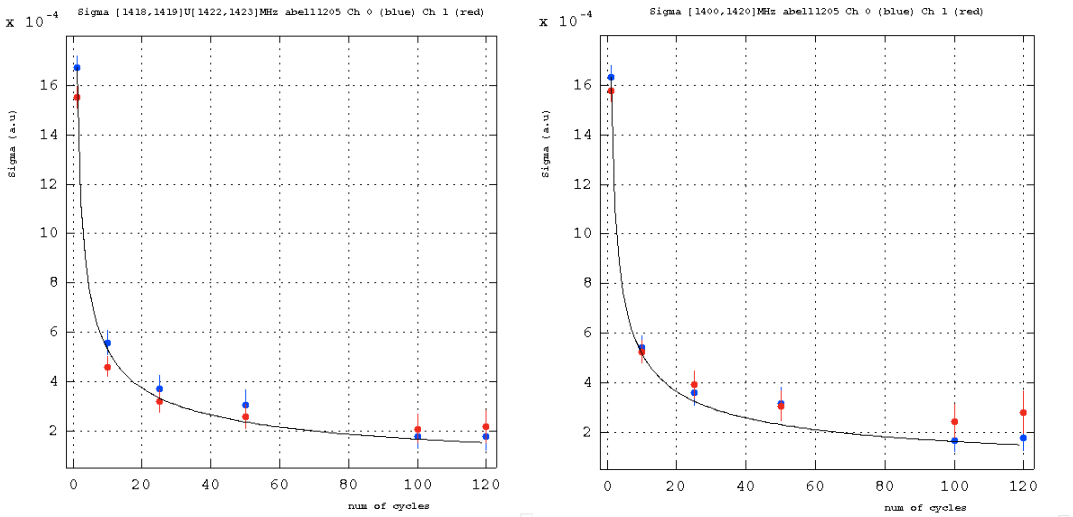

Figure 9. Baseline standard deviation as a function of number of cycles per mean value (see text), for the ON-OFF signal integrated in the HI-line side-bands ([1418,1419] ∪ [1422,1423] MHz) (left) and the RFI-protected band [1400,1420] MHz.

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 10 the (ON-OFF)/OFF signal around the NED redshift, i.e. 1321±10 MHz. We observe RFI pollution at ~1312 MHz and ~1327 MHz, but not a potential cosmological HI signal (if we are looking at the right frequency band).

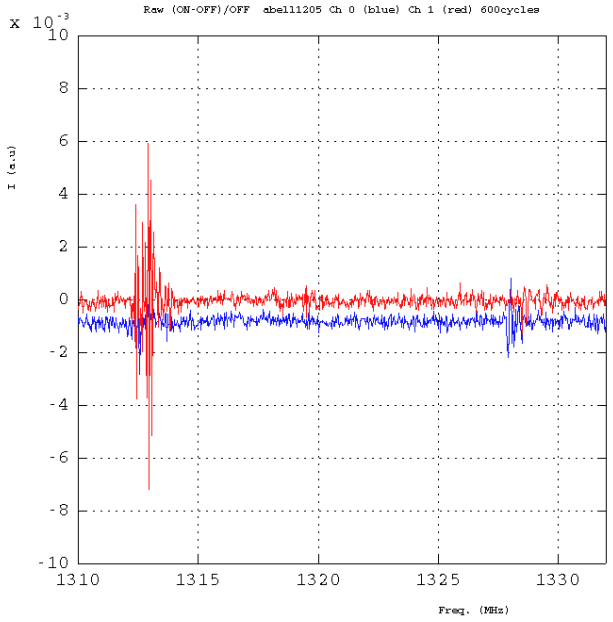

Figure 10. (ON-OFF)/OFF signal around the NED redshift, i.e. 1321±10 MHz.

6 Summary

In this note we present the analysis of ~5 months of NRT observations of the galaxy cluster Abell 1205, which correspond to ~6000 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] $\cup$ [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 2440, summarized in the internal notes ref. Nançay/Abell85/21.11.11 and Nançay/Abell2440/23.11.11.