MEMO

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Objet: Analysis of calibrator sources

1 Introduction

In a previous MEMO (ref. Nançay/Amas/12.12.11) we have investigated the possibility to use the DAB signal to calibrate the BAO data. Unfortunately, we have concluded that the calibration coefficients extracted from DAB are dramatically instable and we have shown that this is due to intrinsic variations of the DAB itself and not to changes in the BAO electronic chain. Moreover the DAB signal has been confirmed by BAO electronic chain to be extremely chromatic. So, to analyze the Abell clusters, we have decided to use raw data only waiting for an overall calibration thanks to stable sources. This MEMO is the first analysis of such sources as 3C161, and 3C273. An analysis of NGC4383 is also presented.

2 3C161

This strong source is regularly followed by the NRT calibration task and it is supposed to be stable at a few percent levels. The 9th Dec. 2011, two drift scans (ref 158451.171 & 158452.171) have been performed with the BAO chain. We have used mainly the second and longest one composed of 7 cycles. A drift cycle is composed of a DAB sub-cycle with the same structure as in case of ON-OFF data taking (see Nançay/Abell85/21.11.11), followed by 180s with the RT carriage at a fixed position in such a way that the source maximum occurs in the middle of the cycle. The BAO analysis pipeline has been adapted accordingly:

1. A global gain is adjusted using the data around the DAB signal of the cycle at the middle of the run; it is used to normalize all the spectra before further treatment although it is used as simple arbitrary interim computation especially considering point n°4;
2. 170s over the 180s of the ON-like data are used to compute spectra using the median per frequency channel among 5120 BAO-frames[1] which correspond to about 1 spectra per 0.6s;
3. for each cycle a OFF-like spectra is computed with the first 30s (mean of the frames) and then it is subtracted to the totality of cycle frames,
4. And finally the result is divided by this OFF-like spectra to produce time-frequency images with [I(ν,t)-OFF(ν)]/OFF(ν) values.
5. Integrating in frequency bands allows one to follow in time the signal along a run, a cycle…

[1] In case of ON data in ON-OFF run, we produce spectra resulting of the mean of 5 median computed as mentioned in the text (see Nançay/Abell85/21.11.11).

Figure 1 is an example of a cumulative time-frequency image.

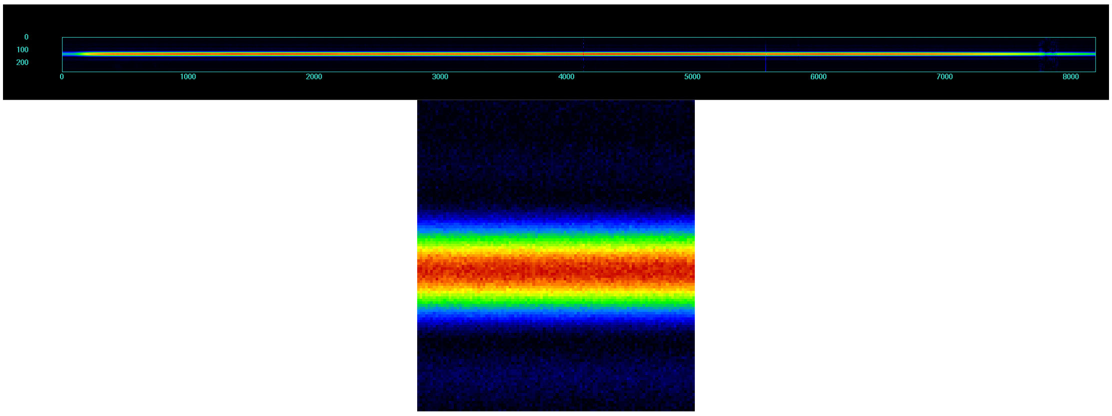


Figure 1 Time vs Freq. (170s x 250MHz) image and a zoom as the result of the mean among the 7 cycles of the drift.

By taking the mean intensity in the frequency (protected) band [1405, 1415]MHz, the signal along the run is shown to not be a constant (Figure 2). It turns out that this is due to the T_{sys} (characterized by the OFF-like spectrum) dramatic increase at the end of the run as a probable consequence of the RT mirror orientation. A selection on the T_{sys} stability has been performed to decrease the source strength measurement uncertainty.

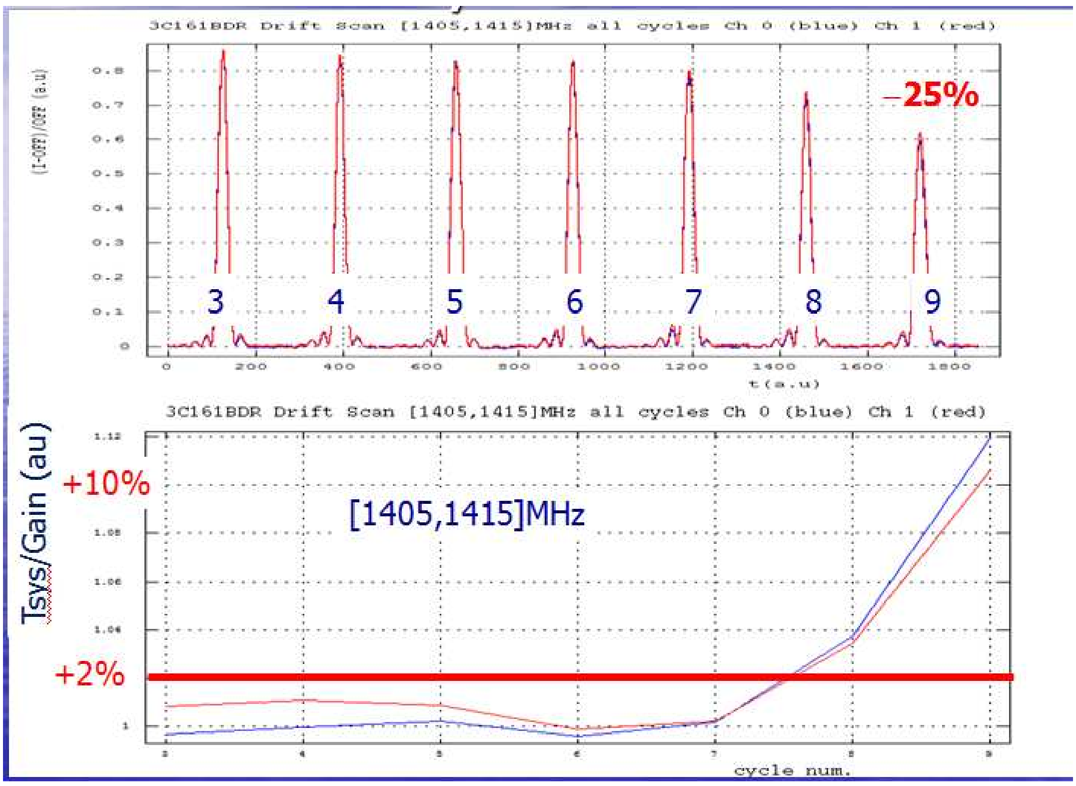


Figure 2 Top: Evolution of the signal (I-OFF)/OFF in the [1405, 1415]MHz band along the 7 cycles used in the run. Bottom: the cycle by cycle evolution of the OFF(=Tsys) divided by the gain in the same frequency band. In blue BAO Channel 0 and in red BAO Channel 1.

Taking into account cycles 3 to 7, the addition of all the excitation curves gives the result presented on Figure 3. The mean value of both channels at the peak is:

$$< (I - OFF)/OFF >_{peak} \approx 0.819 \text{ a.u.}$$

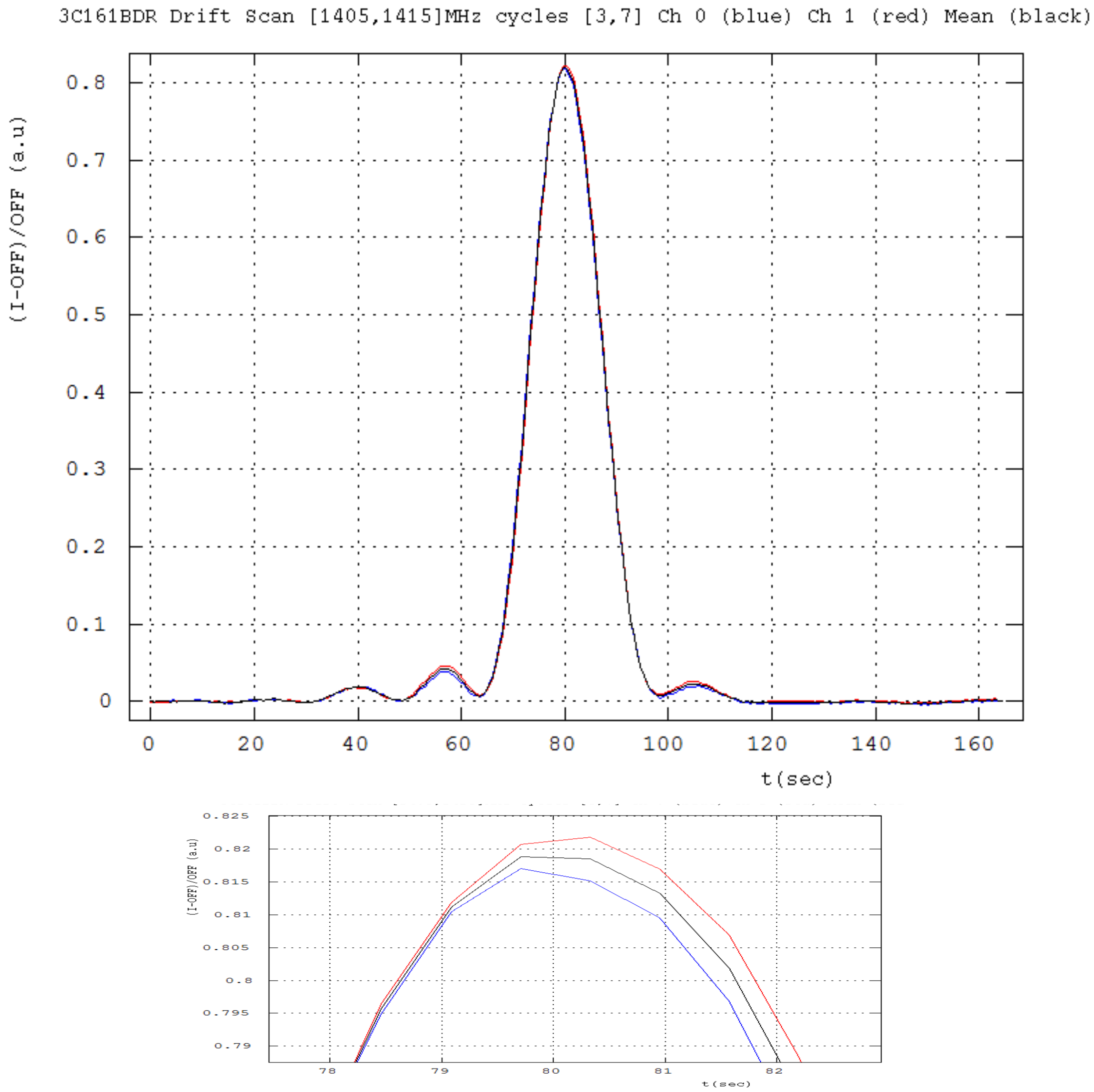


Figure 3 The mean of excitation curves taken during cycles 3 to 7 where the Tsys is stable. The time is estimated with a trigger of 8.2kHz. The bottom plot shows a zoom at the peak: the red curve for channel 0, the blue curve for channel 1 and the black curve for the mean of the two channels.

To use this value for calibration, first we have found in the literature (P. Colom private communication) the following total intensity measurements in Jansky (Jy):

Freq.	Flux	Ref.
1410 MHz	18.937 Jy	Baars et al 1977
1408 MHz	18.58 (0.09) Jy	Ott et al. 1994 (meas. 1990)

We decided to take the latest measurement with a systematic of 3%. Secondly, we define the calibration coefficient taking both channels/polarizations in consideration as followed:

$$\left(I_{\max}^{Ch0}+I_{\max}^{Ch1}\right)(a.u)\times C_{mean\ polar}=2\times I_{\max}^{Mean}\times C_{mean\ polar}\equiv I_{tot}(Jy)$$

With our measurement given previously, this yields a coefficient value of:

$$\boxed{C_{mean\ polar}^{3C161}(1410Mhz)=(11.3\pm 0.3)\ (Jy/au)}$$

The frequency spectrum from the integration during the FWHM of the peak is shown on Figure 4. We note a certain chromaticity and difference between the two polarization responses.

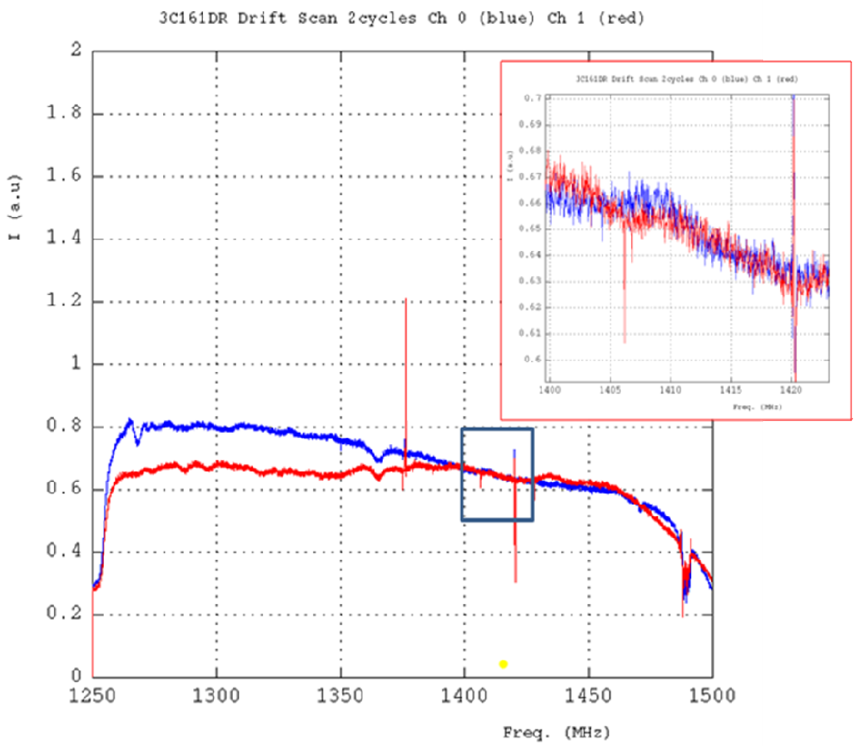
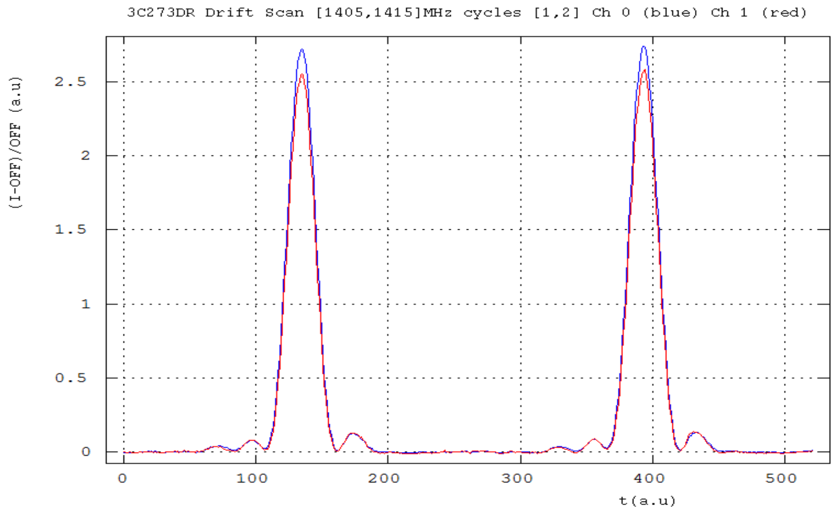


Figure 4 Mean value of (I-OFF)/OFF summed up in the FWHM part of the peak of Figure 3.

3 3C273

The 3C273 strong source although less stable than 3C161, has been investigated using both ON-OFF data and Drift Scan data. These runs correspond to the scans 158461.171 and 158462.171, respectively. The mean intensity evolution computed during the Drift Scan as previously defined in the band [1405, 1415]MHz is shown in Figure 5.



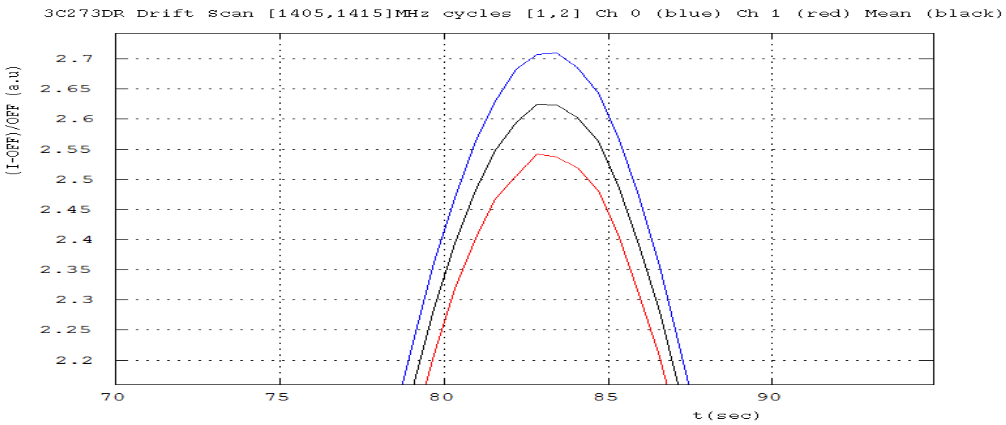


Figure 5 Time evolution of the intensity during the 2 cycles of the run (top) and the mean (bottom). The red, blue and black curves stand for channel 0, 1 and their mean respectively.

If we take for granted the calibration coefficient determined thanks to 3C161 Drift Scan then the intensity measured in the same frequency band for 3C273 is given by:

$$I_{tot}^{3C373} \approx 2\times 2.62\times 11.3 \approx 59.2\pm 1.6\,(Jy)$$

with the error computed from the uncertainty on the calibration coefficient only.

In the literature there are several measurements, here are those relevant for 1410MHz (P. Colom's private communication):

Flux	Ref.
41.28 (1.23) Jy	Witzel et al. 1971
38.84 (0.70) Jy	Bridle et al., 1972
45.17 (1.07) Jy	Wills 1975
50.10 (…) Jy	White et al., 1992, 300ft, -> Condon et al. 1985,1986
42.00 (…) Jy	Wright et al. 1990, Parkes
54.992 (1.900) Jy	Condon et al. 1998, NVSS
35.82 (…) Jy	Tingay et al., 2003, PASJ

It is clear that there is not a consensus on the flux of this source, but our measurement is higher than all the others and compatible with the NVSS (1998) result.

With the ON-OFF run, the result on the (ON-OFF)/OFF_filtered spectra (see Nançay/Abell85/21.11.11) are shown on Figure 6 for both channels and their mean value. It is noticeable that the intensity measured in the band [1405, 1415]MHz is a little bit lower (~2.51 a.u) than the peak value in the drift scan (~2.62 a.u), but this is a ±2.5% effect. We can also see that the spectra present some “accidents” and “oscillations” that seem reveal some imperfection of the electronic chains. This will be investigated in a later MEMO.

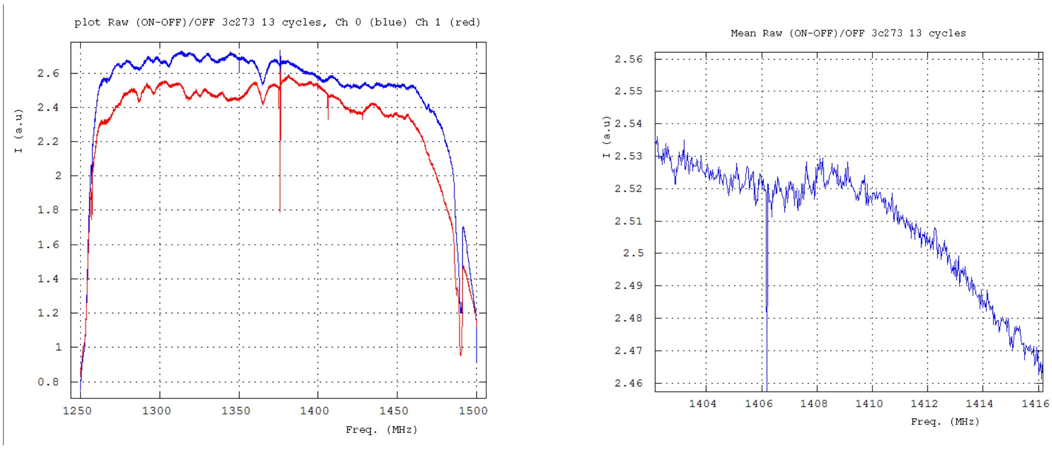


Figure 6 Intensity on both channels measured during the ON-OFF run. The right plot gives the mean intensity on a zoom. Note that same accidents are common to Figure 4 which may indicates features of the RT/BAO response.

4 NGC4383

4.1 Drift

This source is not really considered to be a calibrator, as in the literature[2] we have found the following measurements concerning both the continuum and the HI line [1412, 1413]MHz which indicate a low brightness compared to 3C161 and 3C273.

HI line intensity	48.4 ± 5.1 Jy km/s ~ 227 ± 24 mJy
HI line width	213 km/s ~1MHz
Continuum	44.3 ± 4.1 mJy

The purpose of studying this source is to use 3C161 calibration coefficient and see how our measurements is comparable to the previous ones.

The source has been followed both in ON-OFF (scan 156855.171 with 3 cycles only available due to delay of the DAQ warm up) and in Drift Scan (scan 157756.171 with 14 cycles).

[2] A. Chung et al, VLA IMAGING OF VIRGO SPIRALS IN ATOMIC GAS (VIVA). I. THE ATLAS AND THE HI PROPERTIES. The Astronomical Journal, 138:1741–1816, 2009 December.

For the Drift Scan, as there is a contribution from the continuum, to extract the HI line we proceed to the image production in two frequency bands: [1412, 1413]MHz which contains both the HI line and the continuum, and [1414, 1418]MHz only affected by the continuum. We suppose a flat continuum which is a good approximation as it will be shown hereafter. Figure 7 presents the continuum evolution during a cycle, and we see that there are at least 2 main contributions.

Figure 7 Evolution of the continuum in the band [1414, 1418]MHz averaged on the 3 cycles (I on the vertical axis means (I-OFF)/OFF)). The double peaks shape reveals the presence of at least two galaxies in the field.

The HI line evolution as the result of the subtraction of the two frequency bands is shown on Figure 8.

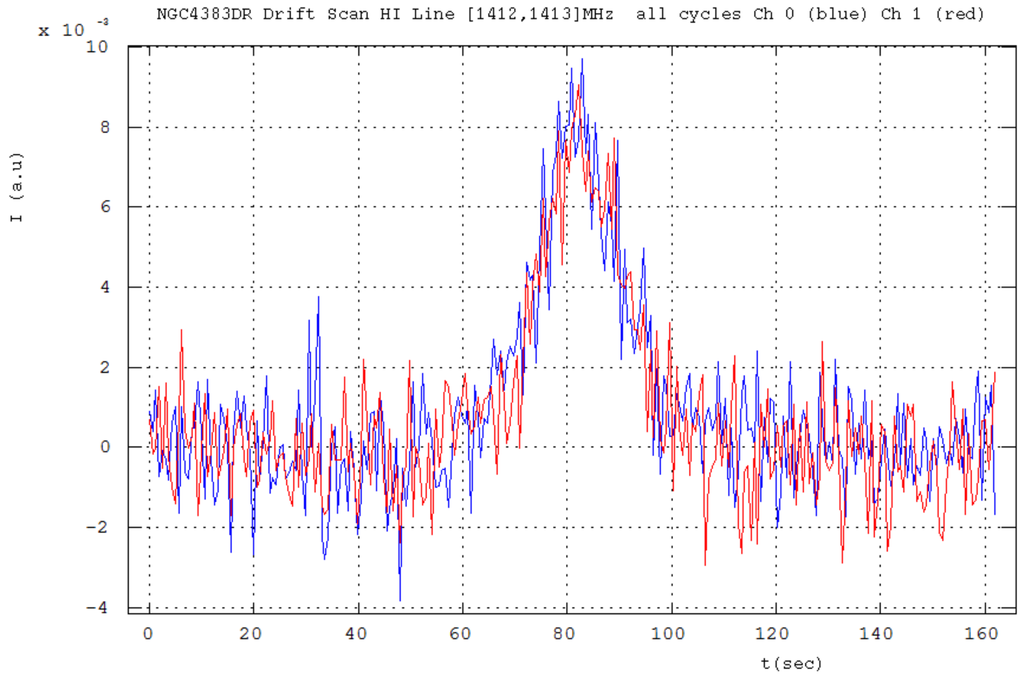


Figure 8 Evolution of the HI line where the continuum has been estimated and subtracted from Figure 7.

Taking into account the calibration coefficient obtained with 3C161 (at 1410MHz), it yields that the total line intensity (the width = 1MHz) estimation is:

$$I_{tot}^{NGC\,4383} \approx 2 \times \left(8 \times 10^{-3}\right) \times 11.3 \approx (181 \pm 5)\,(mJy)$$

This value is to be compared to the literature measurement (227 ± 24) mJy, that is to say there is a reasonable agreement. Notice that the error quoted for our measurement takes only into account an uncertainty on the 3C161 calibration coefficient.

It is not easy to estimate the continuum contribution: if the maximum amplitude of the HI line indicates in Figure 8 that the "zenith" time of the source is right after 80s, then on Figure 7 we see that the time evolution of the continuum at that time is a quite rapid function decreasing from 6 to 3 (in 10^{-3} au). Applying the 3C161 calibration coefficient would yield a value between 68mJy and 136mJy. Clearly these values are too high although a multi-source contribution may be advocated.

4.2 ON-OFF

The ON-OFF run offers another possibility to look at both the HI line intensity and the continuum contribution. Figure 9 presents the spectra of the usual quantity (ON-OFF)/OFF_filtered estimated over 4 cycles. The flatness of the continuum validates the hypothesis used to extract Figure 8.

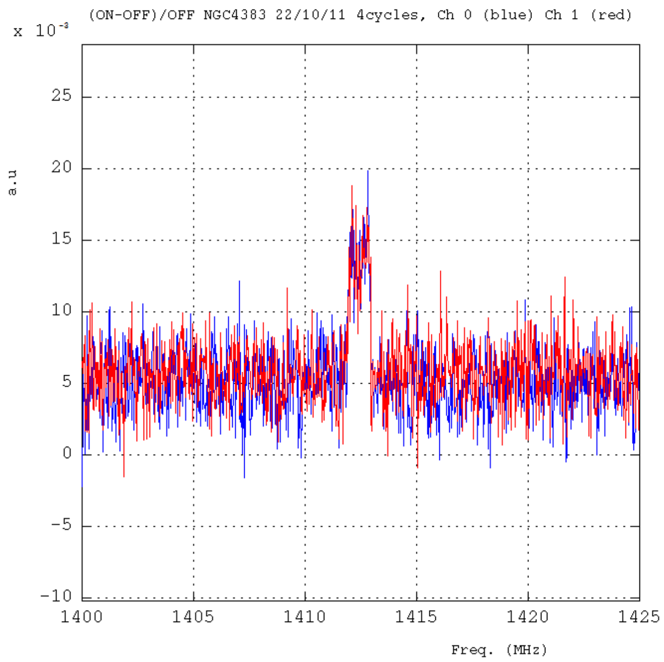


Figure 9 The mean value of ON-OFF divided by the OFF filtered as usual, for both channels during 4 cycles (30s each ON or OFF w/o efficiency taken into account). The HI line is clearly visible as well as a non-zero value of the continuum.

The HI line strength can be extracted as followed:

$$\begin{aligned}\int HI(\nu)d\nu &= 2_{polar} \times \left(\sum_i (S_i - Conti_i)\right)\Delta\nu \\ &= 2 \times (447 - 175)\ 10^{-3}[a.u] \times 30\ 10^{-3}[MHz] \times 213[km/s/MHz] \times C_{mean\ polar} \\ &= 3.48[a.u.km/s] \times C_{mean\ polar} \\ &= 48.4 \pm 5.1\ [\mathrm{Jy.km/s}]\end{aligned}$$

This leads to a value of a calibration coefficient $C^{NGC4383}_{mean\ polar}(1410Mhz) = 13.9 \pm 1.5\ \ Jy/au$ which is to be compared to the 3C161-based coefficient 11.3 ± 0.3 Jy/au. Another way is to use the latter value to get an estimate of the HI line strength. This leads to approximately (39 ± 2) Jy.km/s which is compatible with the measurement quoted in the literature.

It is noticeable that if one uses the above calibration coefficient $C^{NGC4383}_{mean\ polar}$, then we would have estimated a value of 222mJy for the intensity of the HI line during the Drift Scan, which would be in perfect agreement with the literature. This implies that both NGC4383 runs are in perfect agreement to each other, and that the continuum subtraction procedure for the Drift Scan analysis is correct. In contrast if we had used this NGC4383-based calibration coefficient, this would have produced an estimate of the 3C273 strength even higher than the one we have found with the 3C161-based coefficient.

Concerning the continuum level, from Figure 9, one deduces a value equal to:

$$I_{continuum}^{NGC\,4283} \approx 2\times\left(5\times10^{-3}\right)\times11.3\approx\left(113\pm9\right)mJy$$

where the error quoted comes from the continuum fluctuations which dominates the error from the calibration coefficient. This continuum determination is compatible with the estimate using the Drift Scan, but it is also affected by an unknown systematic which comes from the "0" definition and by the r.m.s. confusion limit at the RT which is known to be about 20mJy at 1420MHz and is to be considered in a ON-OFF analysis. So, the continuum level we measure is higher than that from the literature by at least a factor 2.

5 Summary

In this MEMO, we have investigated the use of the 3C161 source to extract a calibration coefficient at 1410MHz although the stability of this source can be questioned and the chromaticity too (cf. Figure 4). If we take for granted the stability of this source, the determination of the calibration coefficient yields:

$$C_{mean\ polar}^{3C161}(1410Mhz) = (11.3\pm0.3)\ (Jy/au)$$

This value has the consequence to overestimate a bit the strength of 3C273 continuum compared to literature measurements, although this source is suspected to be less stable than 3C161. The same reference coefficient in contrast leads to an underestimation of the HI line of NGC4383 even if this source is also known to probably fluctuate. The continuum determination of this last source is tricky and leads to an overestimate by at least a factor 2.

Finally, we notice that the calibration coefficient value quoted just above is close to the one estimated in reference Nançay/Amas/12.12.11using the BAO Ch 1 DAB (Voie E) spectra normalized to the PKS1127-14 spectra by the WIBAR DAQ.

New runs over well known stable calibrator sources may be envisaged to straighten the validity of the calibration coefficient determined in this note, and also address the question of the chromaticity of this coefficient.