INTERNAL REPORT

INSTALLATION, CABLING AND TESTING OF THE XARCOS SPECTROPOLARIMETER ON THE SARDINIA RADIO TELESCOPE

A. Melis[1], C. Migoni[1], R. Concu[1], G. Comoretto[2], P. Castangia[1], P. Marongiu[1], A. Poddighe[1], A. Tarchi[1], G. Valente[1]

Report N. 29, released: 13/09/2013

Reviewer: S. Poppi

Osservatorio Astronomico di Cagliari

(1) INAF Osservatorio Astronomico di Cagliari
(2) INAF Osservatorio Astrofisico di Arcetri

Abstract

XARCOS is a spectropolarimeter developed by the electronic group of the Astrophysical Observatory of Arcetri (Florence). The system is capable of acquiring and processing up to sixteen signals with a bandwidth of 125 MHz each.
In this paper, we provide an overview of the overall system and describe the details of the installation and cabling of XARCOS on the Sardinia Radio Telescope. Last, we briefly report on the first preliminary test observations we performed with XARCOS on very bright spectral line astronomical sources.

1 System overview

XARCOS [1] is a spectropolarimeter developed by the electronic group of the Astrophysical Observatory of Arcetri (Florence). The system is equipped with 4 boards, containing a total of 40 FPGAs, capable of acquiring and processing up to sixteen intermediate frequency signals (IFs) and to provide total power and spectropolarimetric information.

The processing chain starts with the amplification of the signal coming from the front-end system (i.e., the receivers mounted on the radiotelescope) and, after a pass-band filtering operating into the range 125-250 MHz, a conversion of the data from analog to digital form is performed by two ADC boards.

Each ADC board contains eight analog-to-digital converter operating in its second Nyquist window, down-converting the input signal to base-band (between 0 and 125 MHz).

Once data (having a resolution of 8 bits) are in the digital form , four Xilinx FPGAs contained into the ADC boards convert the data into complex-valued samples at a frequency of 125 Msample/s . Then, the signal goes through a backplane toward the FFT boards.

Due to the backplane's limitations, only 96 connections ADC-FFT boards are available, allowing not more than six complex signals with an 8 bit representation for each couple of boards. Thus, by having two ADC-FFT board couples, twelve 8 bit signals can be sent. Since, however, multi-feed receivers (as the K-band receiver available at the SRT) has fourteen IFs, a 6-bit representation is therefore mandatory in this case.

The Altera FPGA's firmware of the FFT boards contains several variable decimating filters, enabling to select different values for the input bandwidth for each IF, starting from a bandwidth of 125 MHz halving until to a bandwidth of 0.488 MHz. After that, a chain composed by an FFT spectrometer followed to a polarimeter provides both spectral auto- and cross-correlation of the left and right polarization of corresponding double-polarization input signal. Finally, the four parallel output signals from the polarimeter are integrated for a programmable time.

A computer control, containing communication software [2] with boards, is controlled by ACS component. Data are sent via an ethernet interface (TCP/IP protocol) to the NURAGHE control station.

2 Installation and cabling

The backend (shown in figure 1) has been placed into the Elevation Equipment Room (EER) of the SRT and installed in the rack adjacent to the Focus Selector boards [3].

Figure 1: *XARCOS spectropolarimeter*

XARCOS is mainly thought to be employed in conjunction with the K-band multi-feed receiver of the SRT. It is, however, exploitable also for the single-feed receiver operating at C-band.
Unfortunately, instead, it cannot be used to process data from the dual-frequency L-P receiver because the frequency range (305-410 MHz; 1300-1800 MHz) of the receiver

is out of the corresponding interval available for XARCOS (see above); both receiver's bands have no down-conversion, because they are already into the IF band (0.1-2.1 GHz) of the SRT.
Connections between the outputs (labeled as “Low”) of the Focus Selector and the ADC inputs were made by using fourteen coaxial cables SMA with a length of about 7 meters each. Inputs 6 and 7 of the second ADC board have no connections.

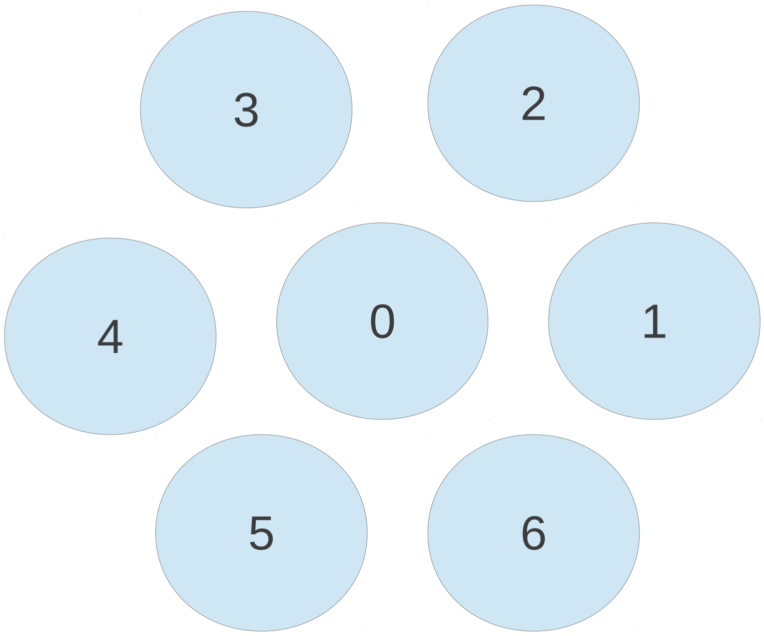

Figure 2*: Geometry of the 7 beam of the multi-feed 22 GHz receiver of the SRT [4].*

Beam	**Labels**	**ADC board**	**XARCOS inputs**	**Receiver**
0	1L, 1R	1	2,3	C, K
1	2L, 2R	1	4,5	K
2	3L, 3R	2	0,1	K
3	4L, 4R	1	0,1	K
4	5L, 5R	1	6,7	K
5	6L, 6R	2	2,3	K
6	7L, 7R	2	4,5	K
-	-	2	6,7	-

Table 1: *Cabling scheme.*

As shown in Table 1, the connections numbering does not follow that of the beams (see figure 2). Indeed, this 'particular' configuration is required by both the control software and some observational modes. In particular, the 8-bit mode forces the system to use not more than twelve inputs, thus a seven-beam configuration would, in this case, be not feasible. Hence, since in the 8-bit mode both ADC board inputs 0 and 1 are disabled, we avoided to connect them to the beams numbered 0,1,4 in particular since these beams, being of the same elevation in the sky during observations, are those to be selected in beam nodding mode [5] measurements. Therefore, in case full polarization information from all the seven beams is required the 6-bit mode is the only usable mode.
Figure 3 shows the backend after installing and cabling:

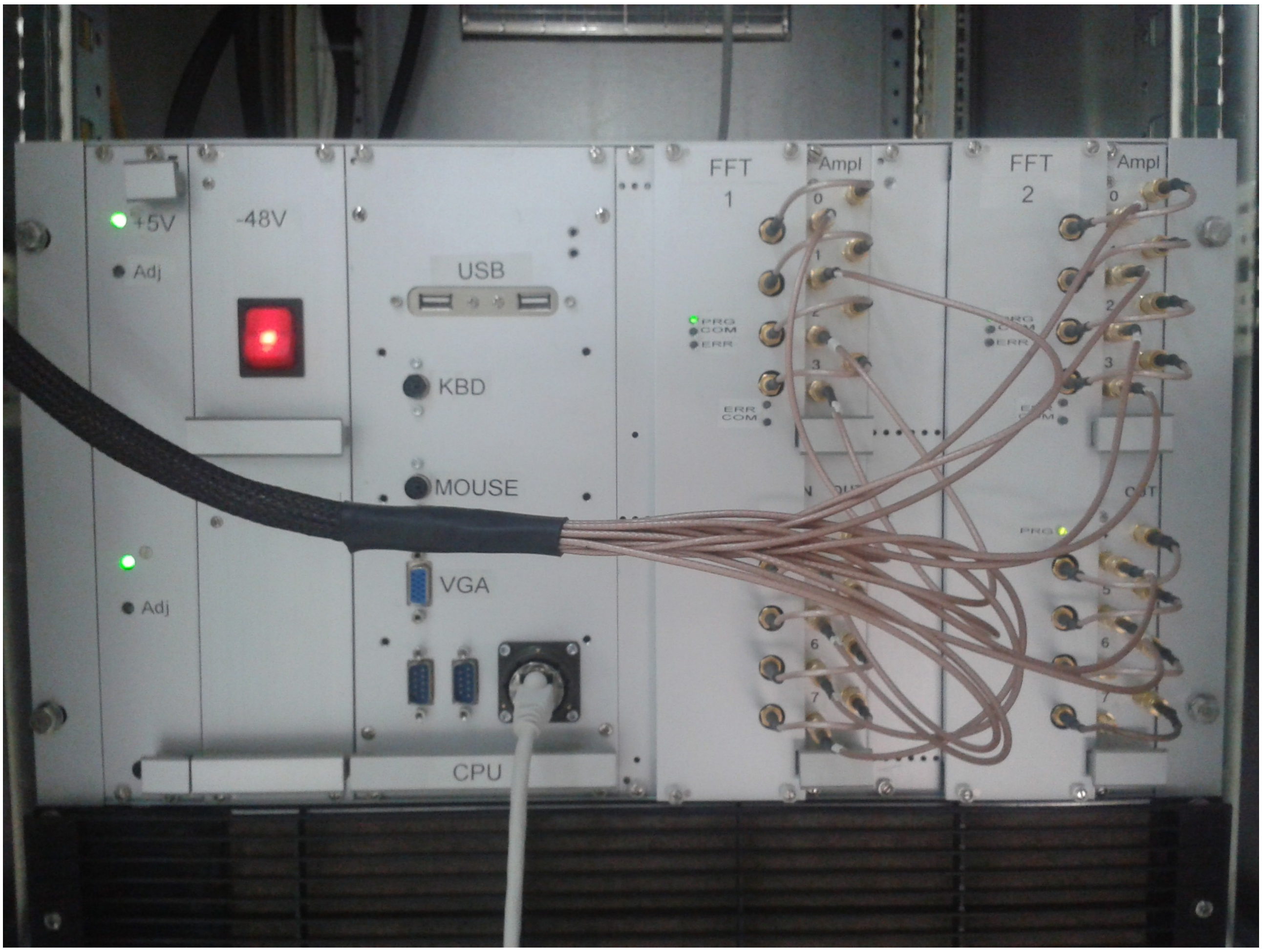

Figure 3*: XARCOS spectropolarimeter after installing and cabling.*

3 Preliminary test observation

In order to test the correct acquisition capabilities of XARCOS from the front-end system, we performed preliminary observations of well-known astronomical sources of intense spectral line emission. In particular, we have observed the bright 22-GHz water maser lines from the ultra-compact HII region W3(OH) and the Orion Kleinmann-Low (Orion KL; see, e.g., [6], [7]) nebula with the central feed (only) of the K-band receiver. In addition, we have also observed, with the C(-high) band receiver, the 6.7-GHz methanol maser line in the massive Young Stellar Object (YSO) IRAS06058+2138 (see, e.g., [8]). Lines were successfully detected in all cases within few seconds of integration (Figs. 4-6).

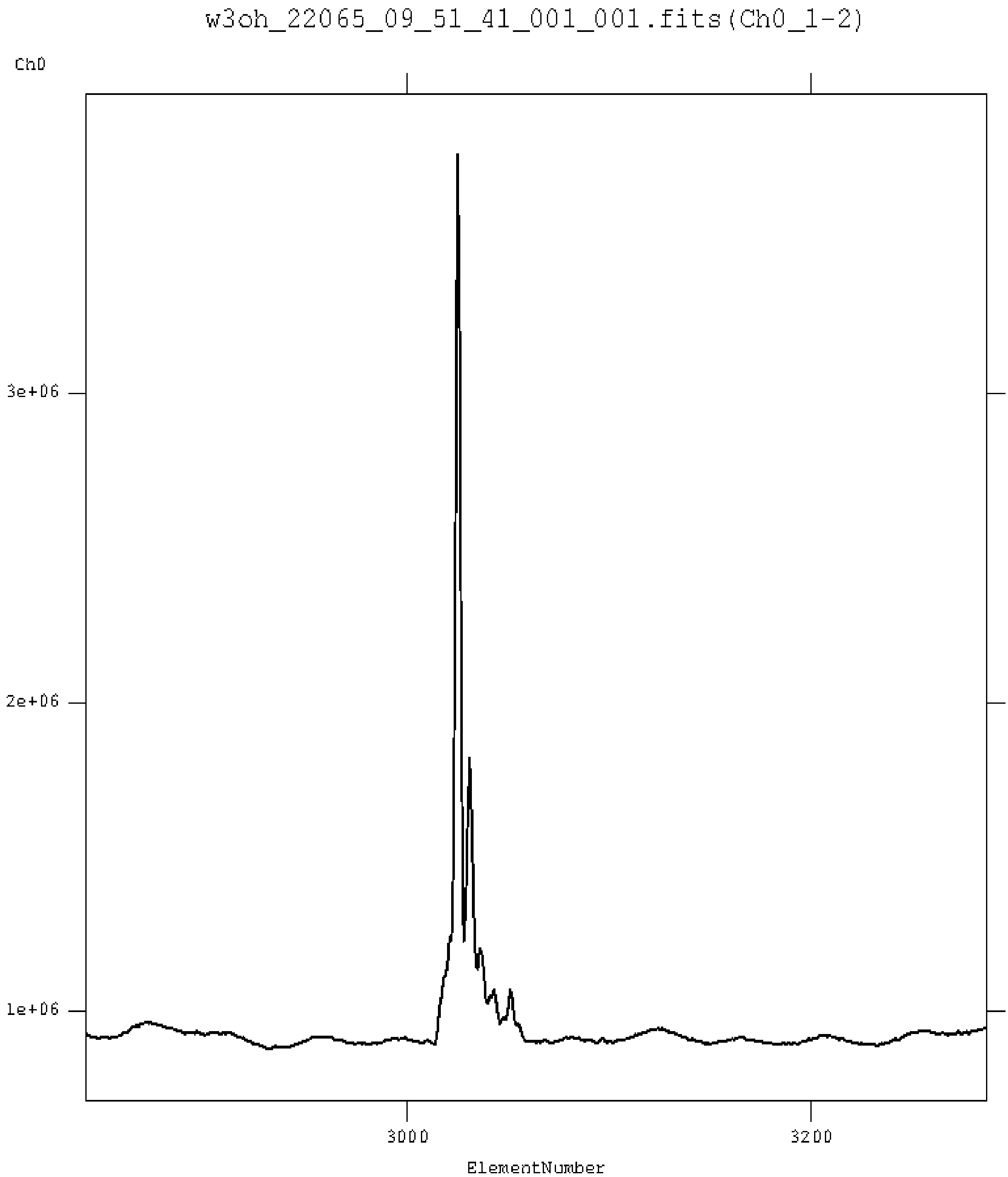

Figure 4: *Uncalibrated on-source spectrum of the 22 GHz water maser emission in W3(OH). The X and Y axis are channels and counts, respectively.*

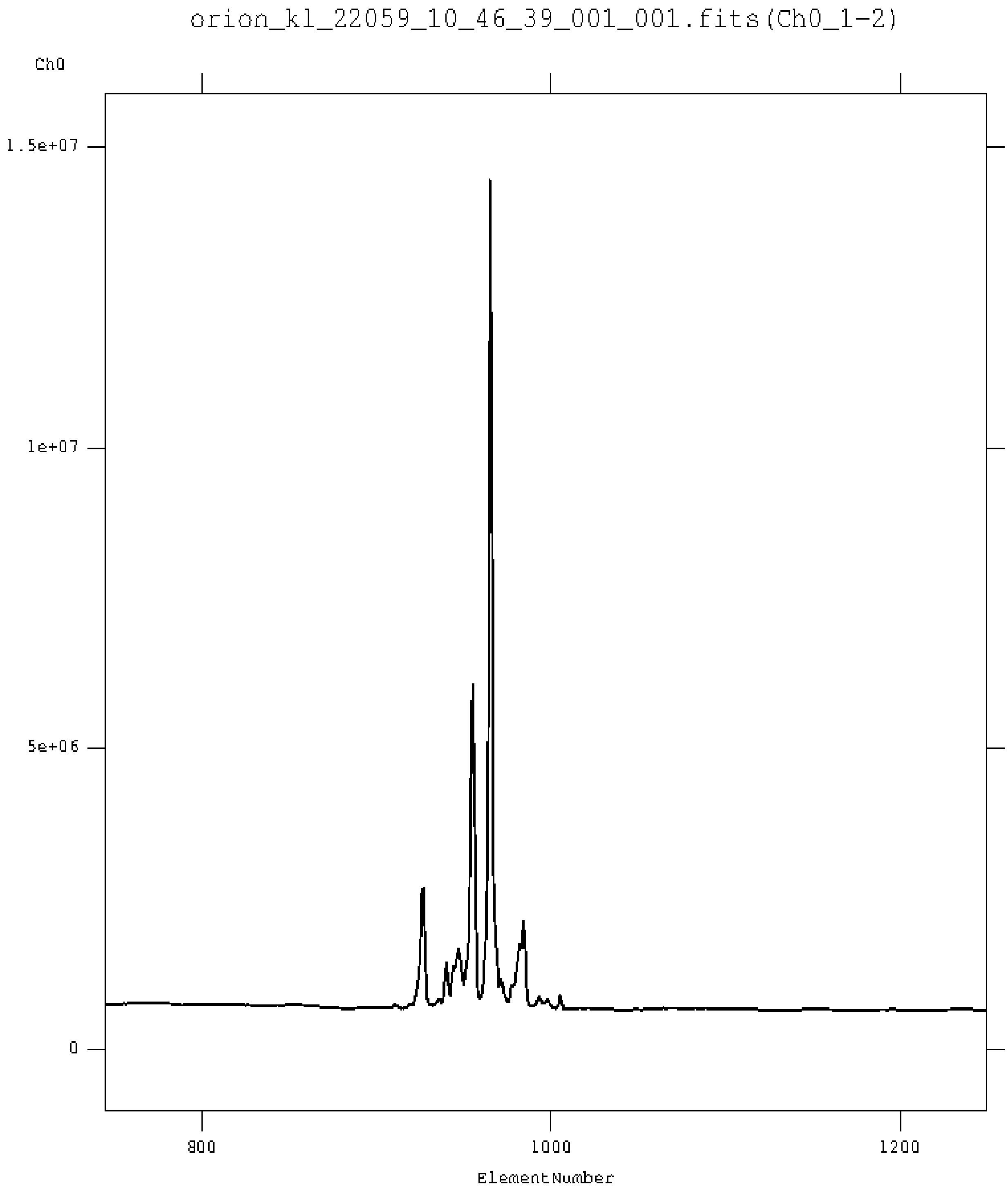

Figure 5: *Uncalibrated on-source spectrum of the 22 GHz water maser emission in Orion KL. The X and Y axis are channels and counts, respectively.*

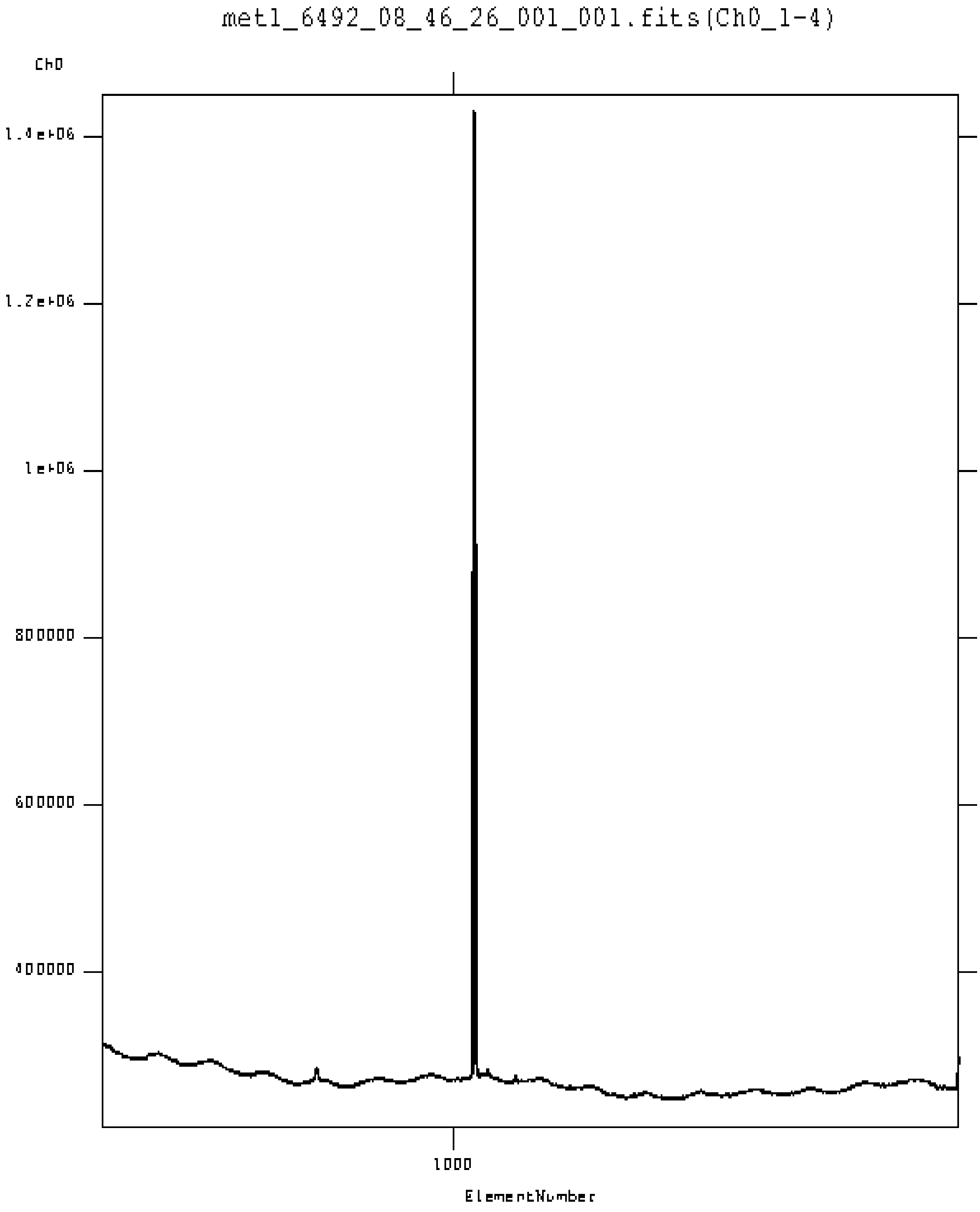

Figure 6: *Uncalibrated on-source spectrum of the 6.7 GHz methanol maser emission in IRAS06058+2138. The X and Y axis are channels and counts, respectively.*

Only on-source spectra were taken, hence the sky contribution was not subtracted (as instead typically done during ‘real’ astronomical spectral measurements) likely motivating the baseline ripples present in the spectra. Then, taking profit of the narrow methanol maser line in IRAS06058+2138, we tested also the XARCOS zoom modes by decreasing the observed bandwidth from 125 MHz down to 4 MHz, thus going from a channel spacing of ~60 kHz (≈3 km/s) to 2 kHz (≈0.1 km/s). The line profile was clearly better resolved in our high-resolution spectrum (Fig. 7).

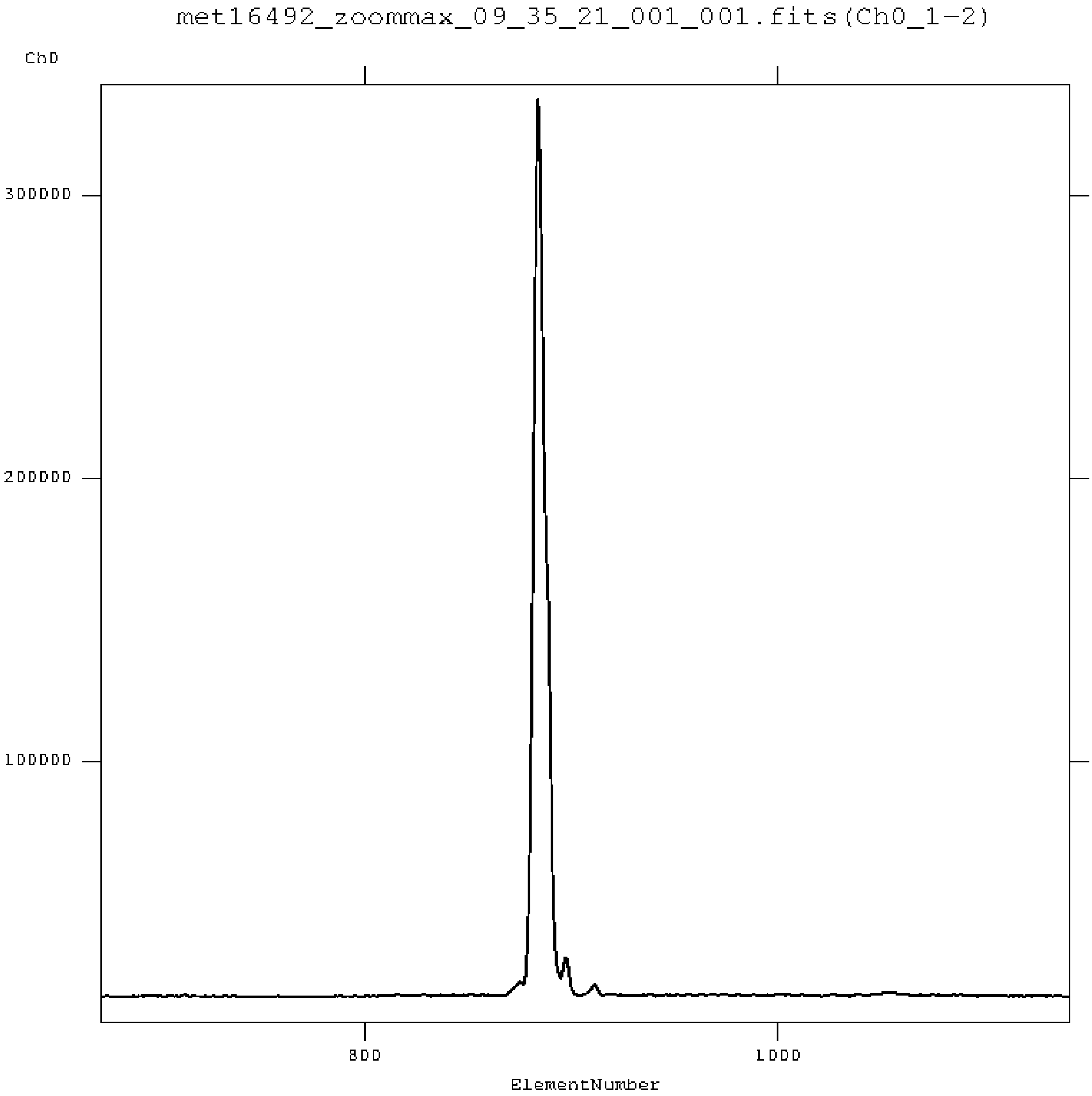

Figure 7: *Uncalibrated on-source spectrum of the 6.7 GHz methanol maser emission in IRAS06058+2138 in 'zoom mode'. The X and Y axis are channels and counts, respectively.*

Acronyms

ACS: ALMA Common Software

ADC: Analog to Digital Converter

EER: Elevation Equipment Room

FFT: Fast Fourier Transform

FPGA: Field Programmable Gate Array

NODDING: This is a version of position switching for receivers with multiple beams, e.g. two beams A and B. When A is on source, B is off source (on blank sky). Then the telescope is moved so that B is on source and A is on blank sky for an equal time. This allows position switching with no lost time while performing the off-source observations

NURAGHE: Control software for the Sardinia Radio Telescope

SMA: SubMiniature version A

SRT: Sardinia Radio Telescope

4 References

[1] G. Comoretto, A. D'Ambrosi, R. Nesti, A. Russo, F. Palagi: "*A modular multichannel spectrometer - design study"*, Arcetri internal report 4/2006

[2] G. Comoretto, A. Russo: "*Software di comunicazione con il correlatore Altera*", Arcetri internal report 2/2007

[3] A. Maccaferri A. Cattani A. Scalambra F. Fiocchi "*The SRT multifeed, Multifocus Total power Back-End*", GAI08 FR-1.0 19/05/2011;

[4] R. Verma, G. Maccaferri, A. Orfei I. Prandoni, L. Gregorini :" *A new K-band (18-26 GHz) 7-horn multi-feed receiver: Calibration campaign at Medicina 32 m dish*", IRA internal report 430/09

[5] Jim Braatz :"*Calibration of GBT Spectral Line Data in GBTIDL v 2.1*", October 30, 2009

[6] Xu, Y., et al.: "*Rapid time variations of water maser emission in W3(OH) and NGC 6334*", 2000, A&A, 364, 232

[7] P. Di Ninni, G. Comoretto: "*Osservazioni spettropolarimetriche di due sorgenti di formazione stellare*" , Arcetri internal report 4/2012

[8] M. Szymczak, G. Hrynek, A.J. Kus: "*A survey of the 6.7 GHz methanol maser emission from IRAS sources. I. Data*" , 2000, A&AS, 143, 269

Contents