Q-band (40-52 GHz): Spectral Baselines
Project TQRCO_01DEC04

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December 6, 2004

Introduction

During the summer of 2004, the Q-band (40-52 GHz) receiver was significantly modified. There were two main problems. (1) Hot/Cold load calibration measurements on the telescope were unable to produce reasonable results (see PTC-SPN 37.1)[1]; and (2) the spectra in some channels contained unacceptable baseline ripples. The hot/cold load tests may have been the result of non-linearities in the IF system, independent of the receiver; nonetheless these will compromise aperture efficiency measurements used to characterize the telescope performance. The spectral baselines were investigated primarily by Roger Norrod and documented in a series of memos.[2]

During the summer season the four-beam receiver was converted into two beams as the best components were cannibalized to produce a two-beam receiver. The second amplifier stage was removed from inside the dewar and is now at room temperature. Engineering tests indicate that the receiver has reasonable performance between 41-48 GHz and that the RCP channels have lower expected system temperatures.

The main purpose of this report is to assess the spectral baselines for the current list of astronomical proposals. We observed under good weather conditions (clear cold skies) with light wind. The pointing was excellent. We observed in total power using position switching to obtain a reference spectrum. The spectrometer was configured in 800 MHz bandwidth mode with a total of 8 IFs tuned to four different frequencies at both circular polarizations (see Table 1). Note that only the first feed was used and we have only explored ~ 3 GHz of the total bandwidth. The data were reduced using both glish scripts and IDL via SDFITS.

[1] http://wiki.gb.nrao.edu/bin/view/PTCS/ProjectNotes
[2] http://www.gb.nrao.edu/GBT/baseline/subpages/reports/QbandProjects/

Table 1:

BACKEND	BANK	PORT	FEED	POL	SIDEBAND	SKY FREQ	BANDWIDTH
Spectrometer	A	1	1	L	U	4.40070103e+10	800000000
Spectrometer	A	2	1	R	U	4.40070103e+10	800000000
Spectrometer	B	3	1	L	U	4.47970099e+10	800000000
Spectrometer	B	4	1	R	U	4.47970099e+10	800000000
Spectrometer	C	5	1	L	U	4.55870136e+10	800000000
Spectrometer	C	6	1	R	U	4.55870136e+10	800000000
Spectrometer	D	7	1	L	U	4.63770132e+10	800000000
Spectrometer	D	8	1	R	U	4.63770132e+10	800000000

Observations

Observations were made towards blank sky (RA=02:03:25.52, Dec=61:38:30.9) with a scan time of 2 minutes OFF source and 2 minutes ON source. Figure 1 shows eight consecutive, individual total power (TP) pairs for sampler A1 which is centered at a rest frequency of 44000 MHz from receptor L1. Some spectral baseline structure exists but overall the data look reasonable over an 800 MHz bandwidth. Notice that the zero point level fluctuates by $\pm$ 0.1 K. This could be due to the atmosphere. Figures 2–9 show an averaged spectrum for 8 TP pairs for each sampler. The rms noise over the 800 MHz is close to the theoretical value and approximately integrates down as expected with time. This analysis is complicated by the fact that the noise diode calibration value varies across the 800 MHz band. Also, some baseline structure does exists and appears to cancel out over time, lowering the rms noise more than theoretically expected.

Observations were also made towards the continuum source W3OH. Figure 10 plots nine consecutive, individual total power (TP) pairs for sampler A1 which is centered at a rest frequency of 44000 MHz from receptor L1. As with other front ends there is significant spectral baseline structure when observing a continuum source. The dominant spectral baseline structures typically have wavelengths of 100-200 MHz, although smaller scales do exist. The continuum level appears to fluctuate between 1-2 K. Given that the weather conditions did not rapidly change between the W3OH and blank sky observations it is very unlikely that these fluctuations are due to weather. Figures 11–18 show the average spectrum for the 8 different samplers (four frequencies at both LCP and RCP). Various spectral lines are detected towards W3OH.

The fluctuations in the continuum level have been observed with other receivers and their origin is unknown. Several possibilites include non-linearities and zero-level offsets that may change with time. Figure 19 shows 6 TP pair at X-band towards the HII region S206 using the spectrometer with a bandwidth of 50 MHz. The continuum level fluctuates by more than 10%. This is clearly not due to weather at these frequencies. The spectral line near channel 2800 is the H89α recombination line. The rms fluctuations of the line intensity are about 5%. This is probably reasonable given the signal-to-noise ratio and the quality of the baseline. Observations of this object were made on 8 different

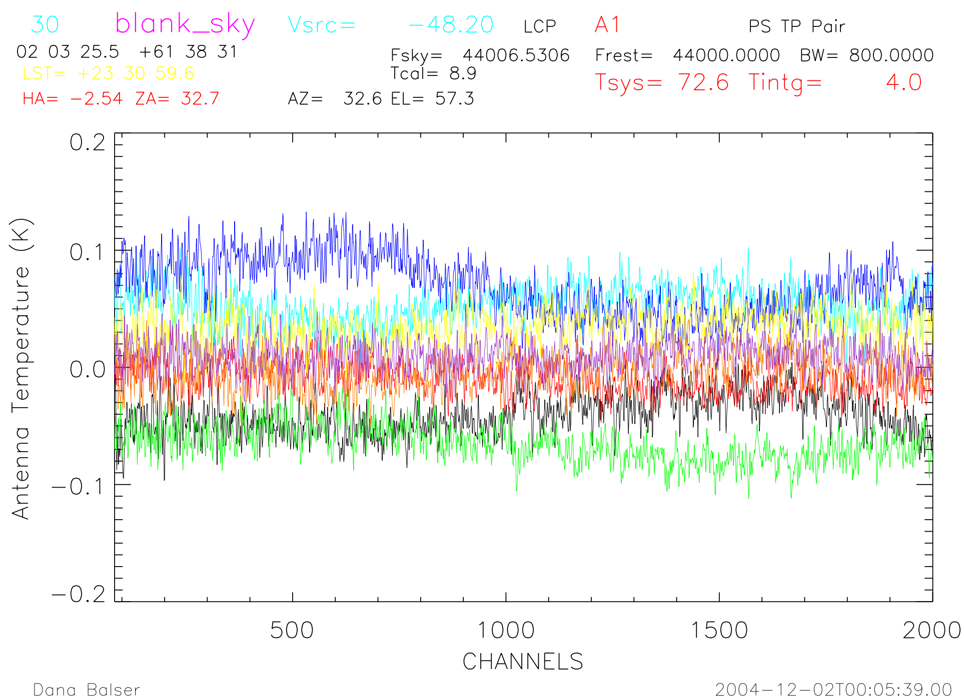

Figure 1: Eight consecutive total power position switched observations towards blank sky centered at a rest frequency of 44000 MHz with a bandwidth of 800 MHz. The ON and OFF scans are 2 minutes each for a total integration time of 4 minutes.

days spanning about 20 days with integration times between 3-8 hours. Averaging over each day produces signal-to-noise ratios better than 50. The rms fluctuations in the line intensity are less than 3%. Although expected to be small at X-band no corrections were made for changes in gain with elevation or the atmospheric opacity.

Conclusion

The spectral baselines of the Q-band receiver appear to be no worse than other receivers although only a portion of the total system has been explored. At least two main problems persist. (1) Significant spectral baseline structure exists when observing sources with significant continuum intensity with wavelengths typically on the order of 100 MHz. Previous investigations with other receivers have shown that much of this baseline structure, but not all, is upstream of the first mixer and this structure is approximately constant in time. (2) Fluctuations in the continuum level with time.

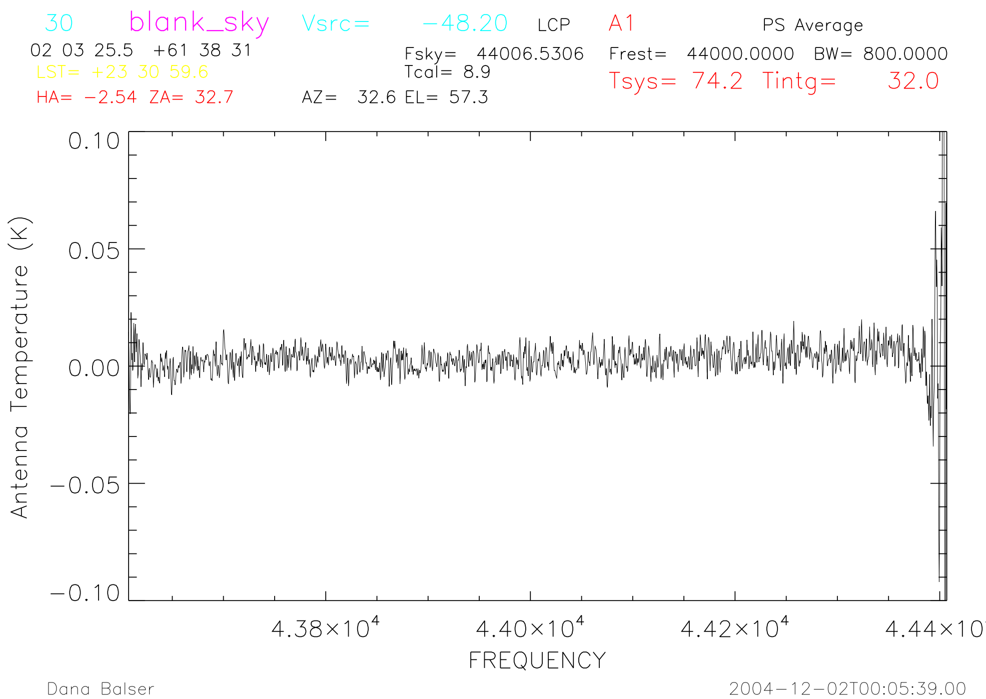

Figure 2: Total power position switched observations towards blank sky centered at a rest frequency of 44000 MHz with a bandwidth of 800 MHz for sampler A1 from receptor L1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

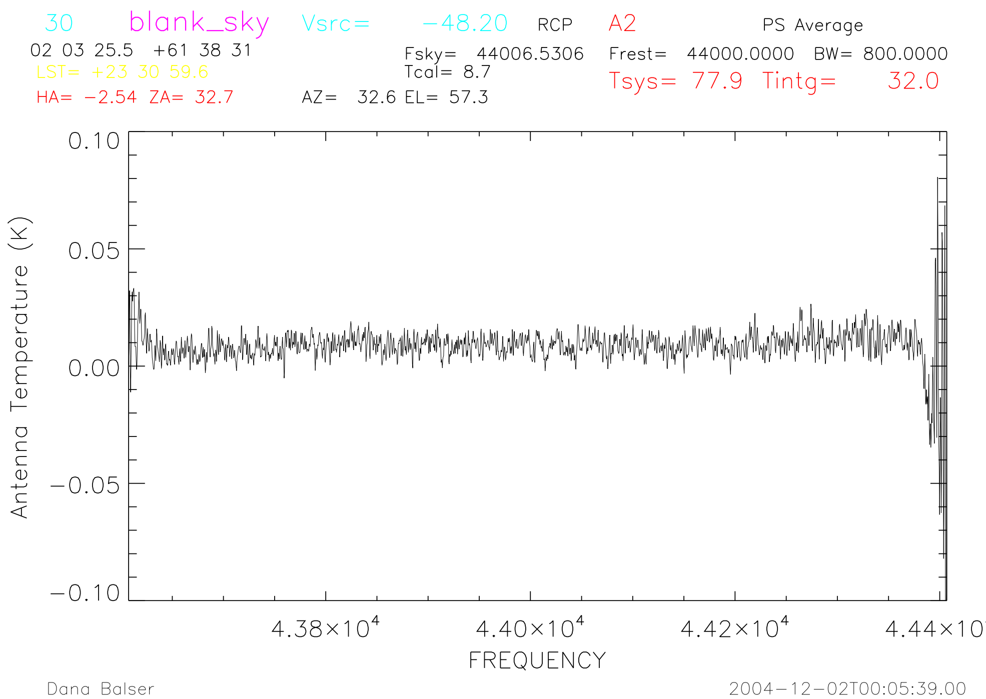

Figure 3: Total power position switched observations towards blank sky centered at a rest frequency of 44000 MHz with a bandwidth of 800 MHz for sampler A2 from receptor R1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

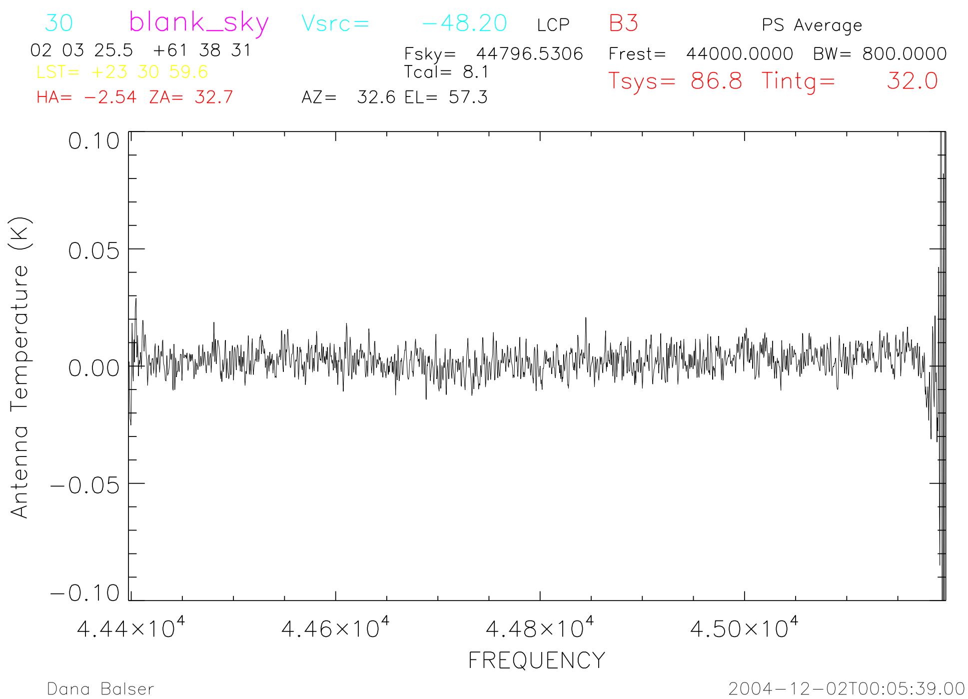

Figure 4: Total power position switched observations towards blank sky centered at a rest frequency of 44790 MHz with a bandwidth of 800 MHz for sampler B3 from receptor L1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

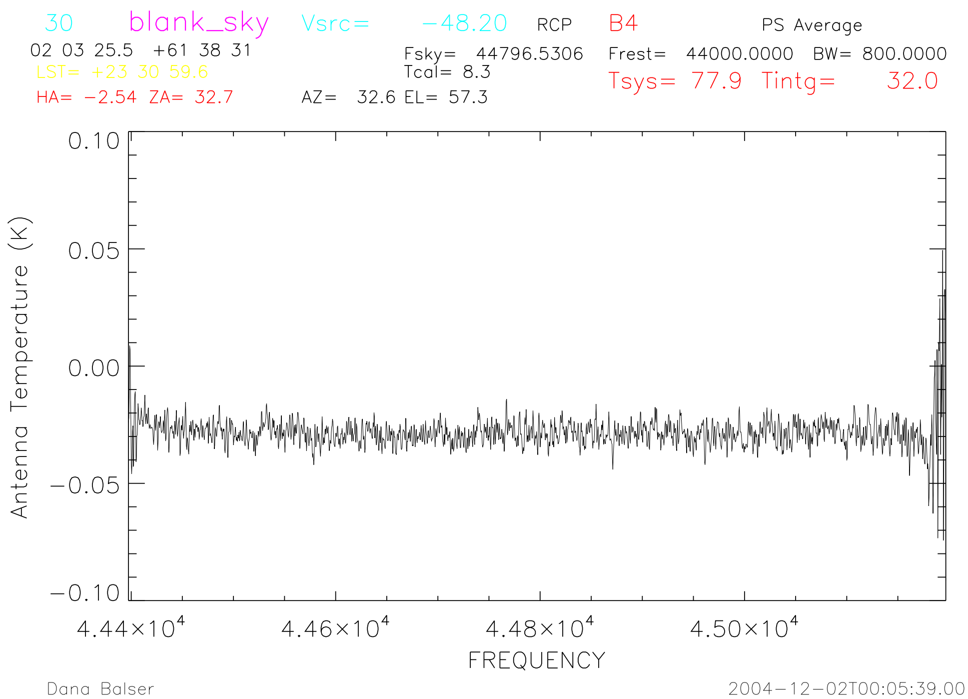

Figure 5: Total power position switched observations towards blank sky centered at a rest frequency of 44790 MHz with a bandwidth of 800 MHz for sampler B4 from receptor R1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

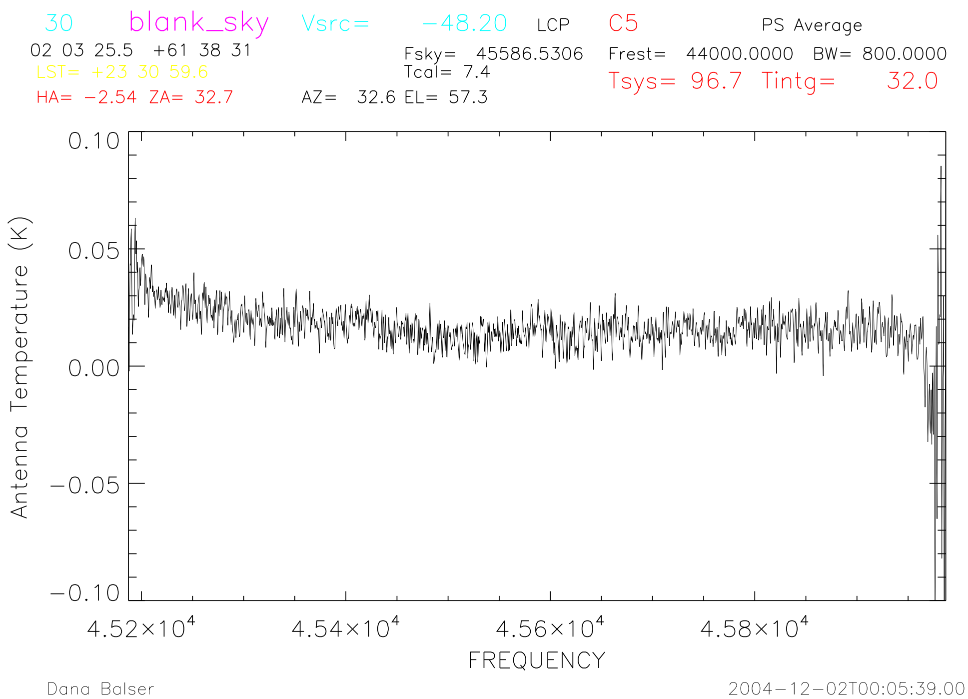

Figure 6: Total power position switched observations towards blank sky centered at a rest frequency of 45580 MHz with a bandwidth of 800 MHz for sampler C5 from receptor L1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

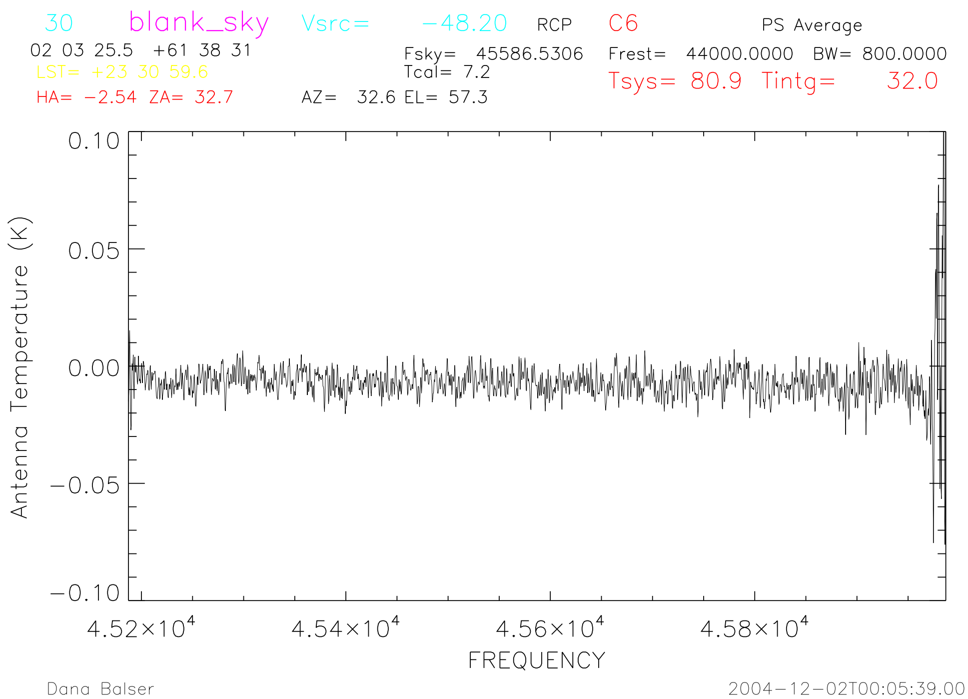

Figure 7: Total power position switched observations towards blank sky centered at a rest frequency of 45580 MHz with a bandwidth of 800 MHz for sampler C6 from receptor R1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

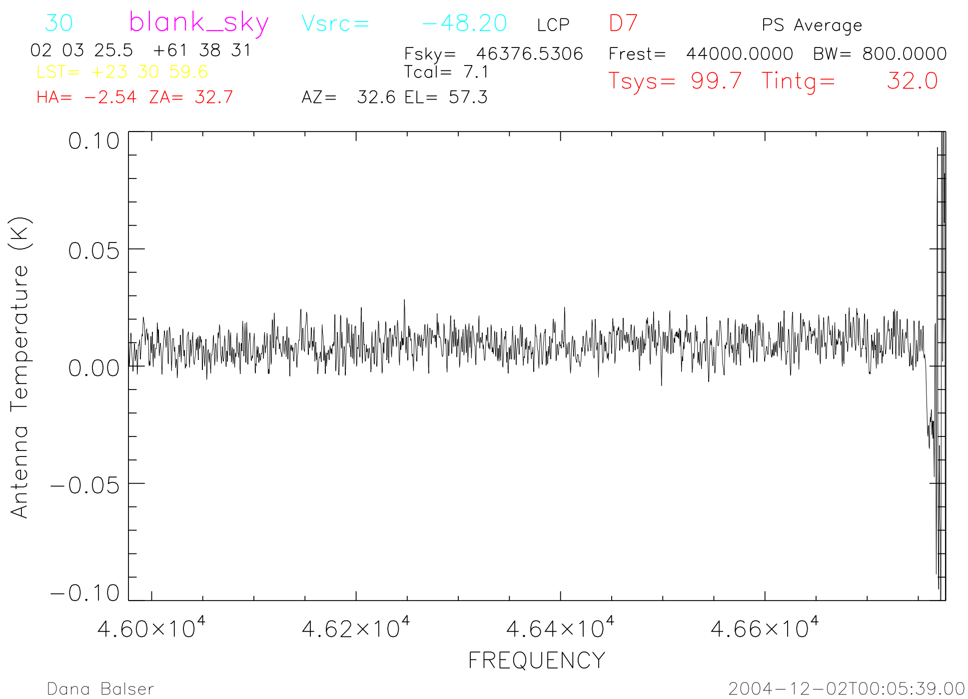

Figure 8: Total power position switched observations towards blank sky centered at a rest frequency of 46370 MHz with a bandwidth of 800 MHz for sampler D7 from receptor L1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

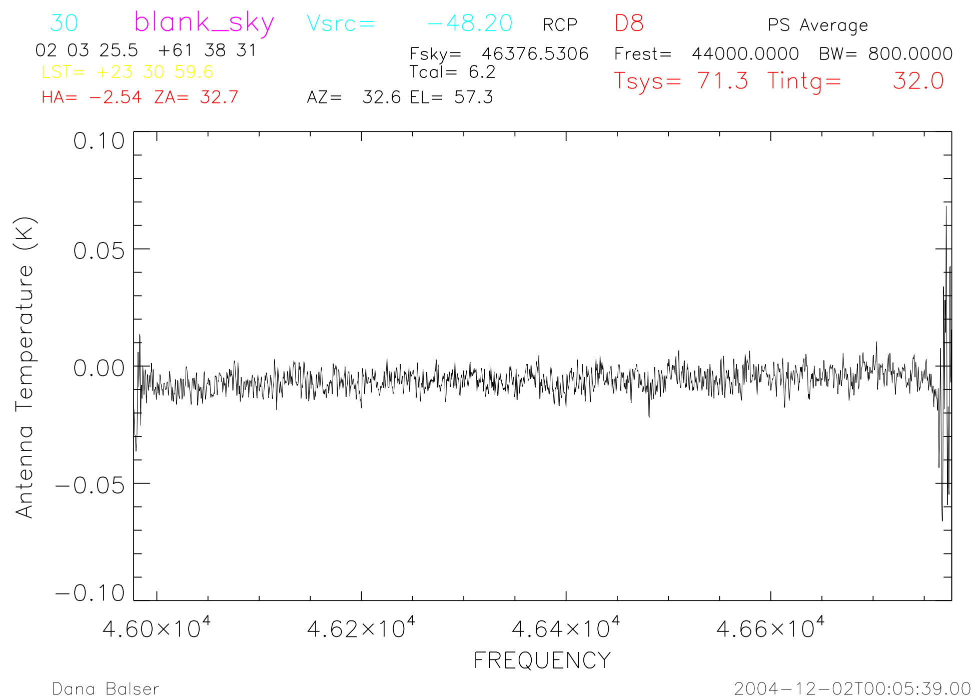

Figure 9: Total power position switched observations towards blank sky centered at a rest frequency of 46370 MHz with a bandwidth of 800 MHz for sampler D8 from receptor R1. Eight ON/OFF scans have been averaged together for a total integration time of 32 minutes.

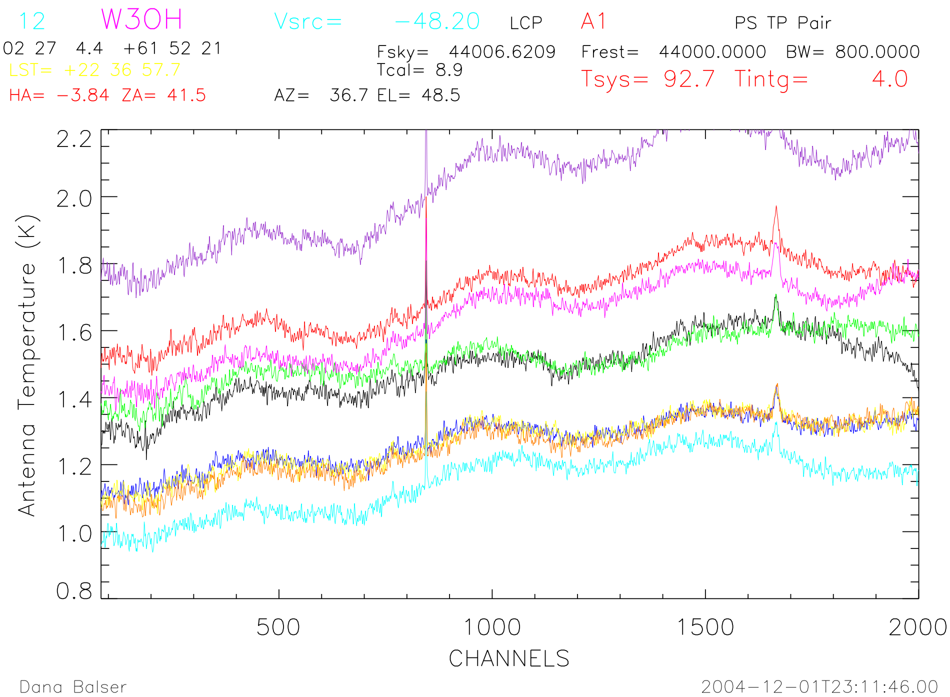

Figure 10: Nine consecutive total power position switched observations towards W3OH centered at a rest frequency of 44000 MHz with a bandwidth of 800 MHz. The ON and OFF scans are 2 minutes each for a total integration time of 4 minutes.

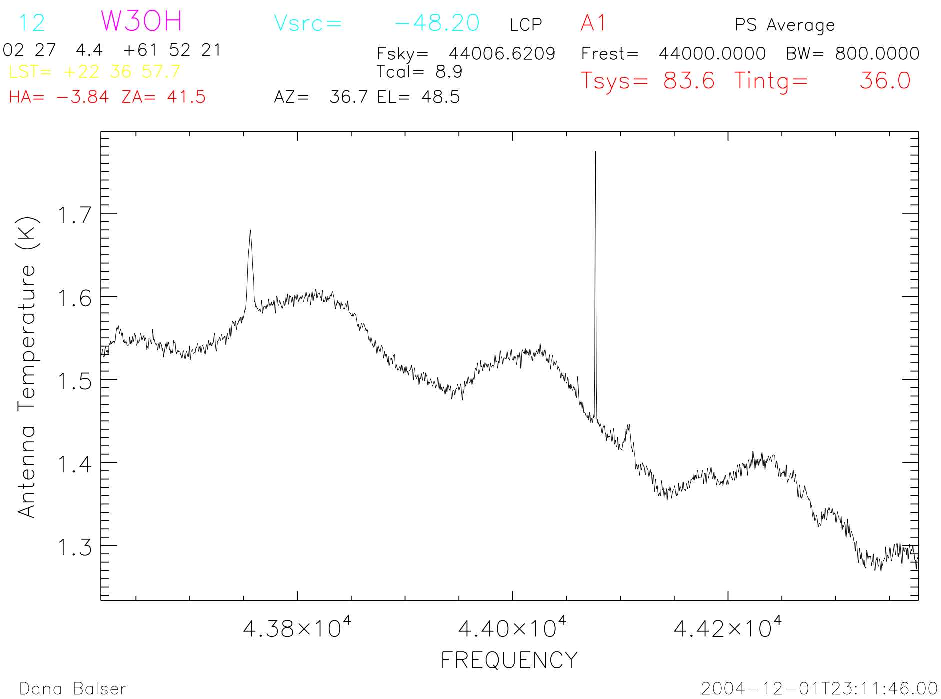

Figure 11: Total power position switched observations towards W3OH centered at a rest frequency of 44000 MHz with a bandwidth of 800 MHz for sampler A1 from receptor L1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

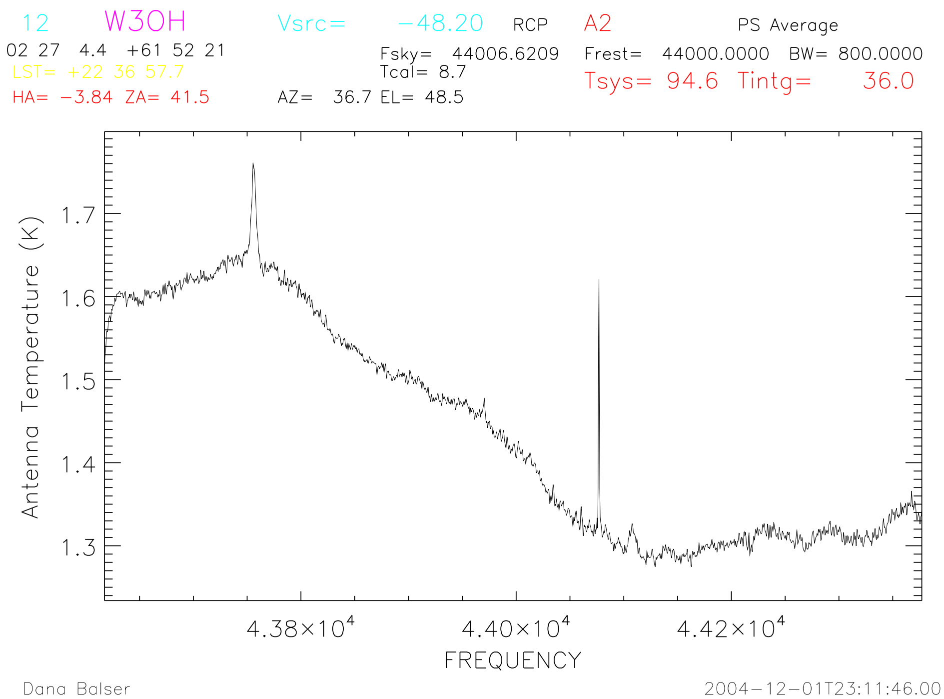

Figure 12: Total power position switched observations towards W3OH centered at a rest frequency of 44000 MHz with a bandwidth of 800 MHz for sampler A2 from receptor R1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

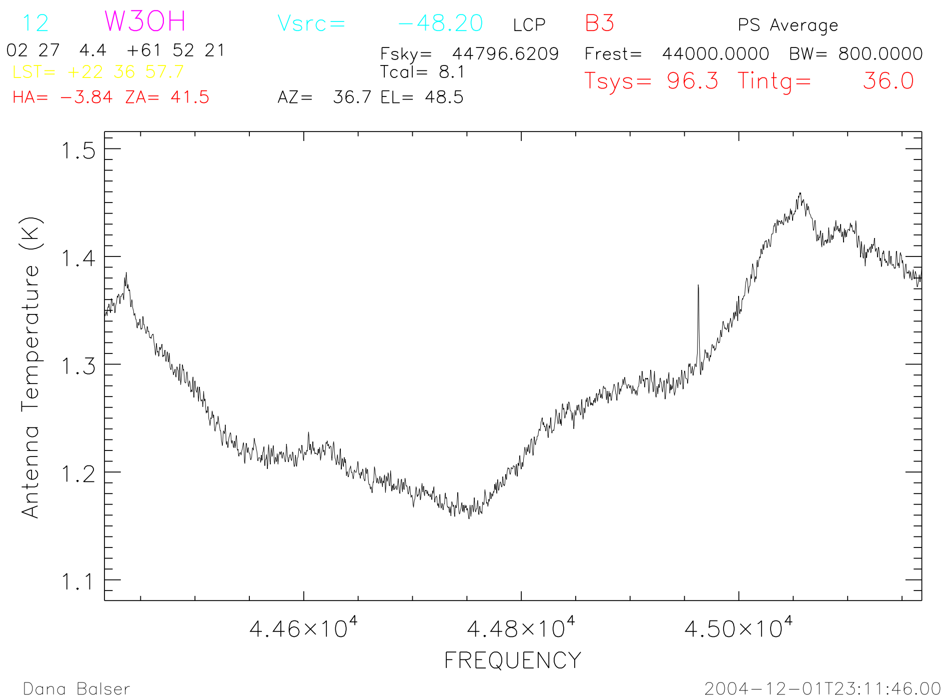

Figure 13: Total power position switched observations towards W3OH centered at a rest frequency of 44790 MHz with a bandwidth of 800 MHz for sampler B3 from receptor L1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

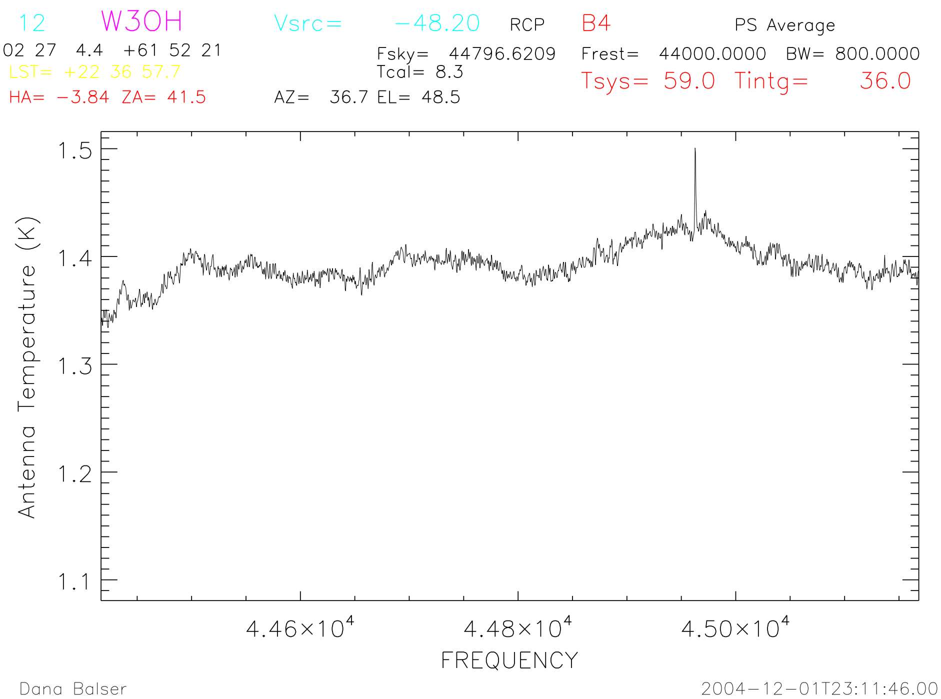

Figure 14: Total power position switched observations towards W3OH centered at a rest frequency of 44790 MHz with a bandwidth of 800 MHz for sampler B4 from receptor R1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

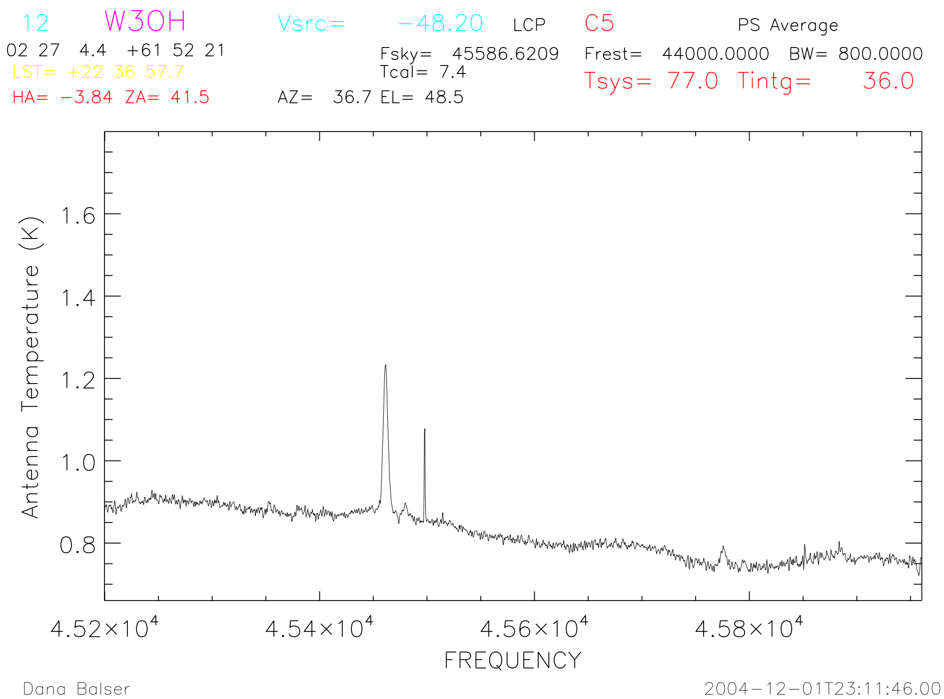

Figure 15: Total power position switched observations towards W3OH centered at a rest frequency of 45580 MHz with a bandwidth of 800 MHz for sampler C5 from receptor L1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

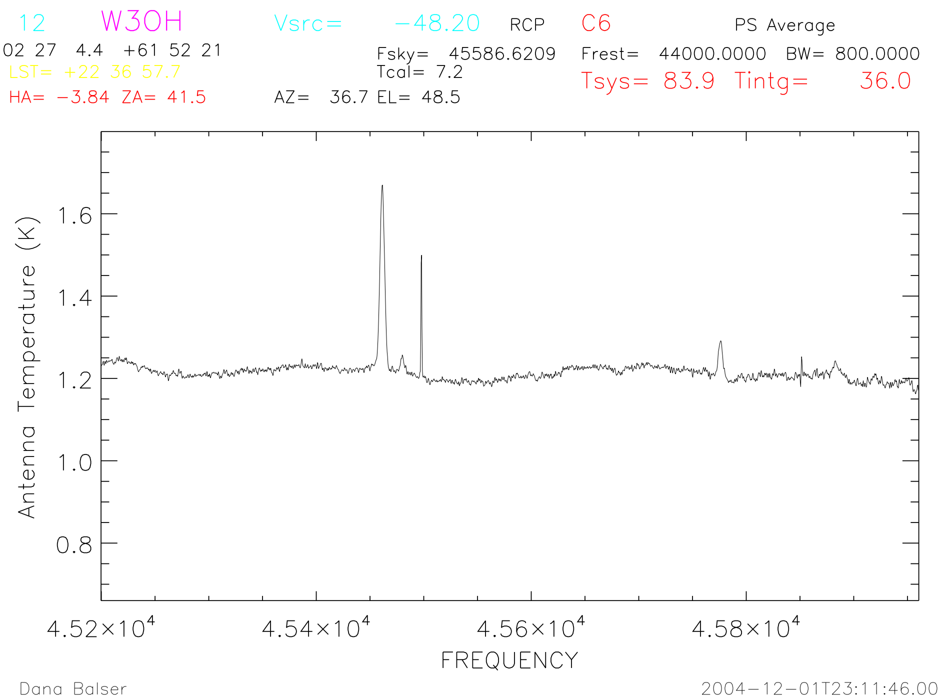

Figure 16: Total power position switched observations towards W3OH centered at a rest frequency of 45580 MHz with a bandwidth of 800 MHz for sampler C6 from receptor R1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

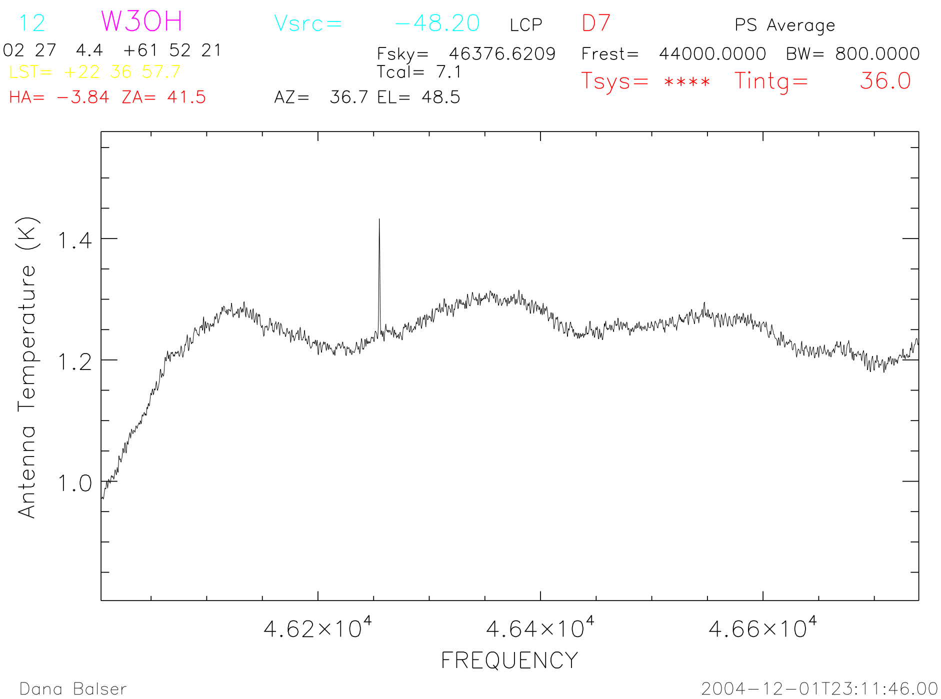

Figure 17: Total power position switched observations towards W3OH centered at a rest frequency of 46370 MHz with a bandwidth of 800 MHz for sampler D7 from receptor L1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

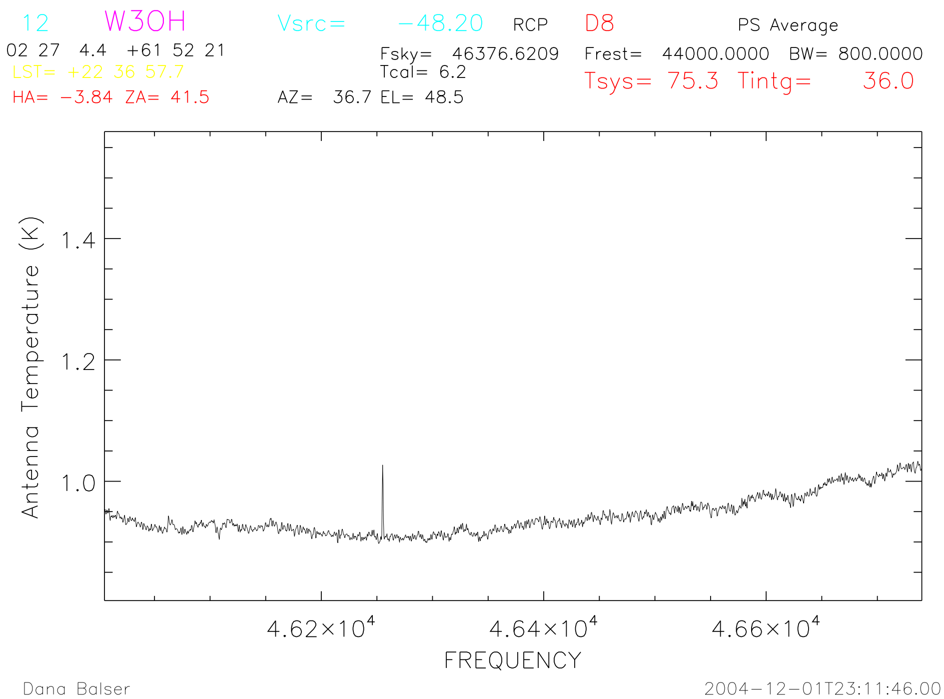

Figure 18: Total power position switched observations towards W3OH centered at a rest frequency of 46370 MHz with a bandwidth of 800 MHz for sampler D8 from receptor R1. Nine ON/OFF scans have been averaged together for a total integration time of 36 minutes.

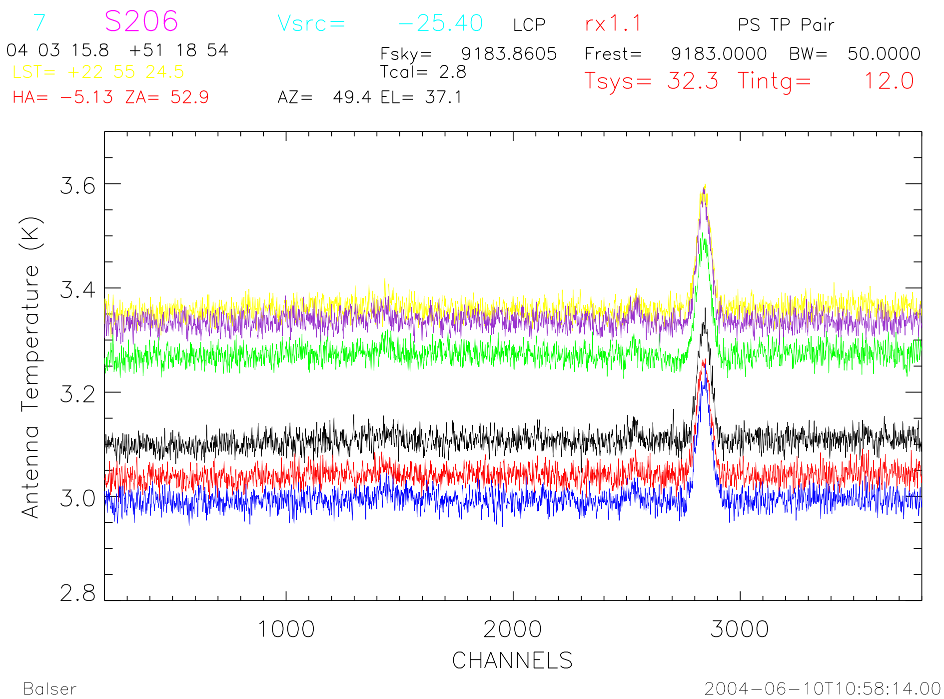

Figure 19: Six consecutive total power position switched observations towards S206 centered at a rest frequency of 9183 MHz with a bandwidth of 50 MHz. The ON and OFF scans are 6 minutes each for a total integration time of 12 minutes. The spectral line near channel 2800 is the H89α recombination line.