National Radio Astronomy Observatory
Socorro, NM

VLA TEST MEMO. 186

Zero-spacing flux-density measurements with the VLA

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ABSTRACT

This memo describes test observations to determine accuracy of zero-spacing flux-density measurements with the VLA using system temperature data on archive tapes. By combining system temperature data from all four IFs of the 27 antennas for 16 scans (1 min/scan–this can be easily reduced to 30 sec/scan) we obtained a SNR of more than 70 on a calibration source of half a Jy at X-band. We achieved measurement accuracy of $3 * 10^{-5}$ (rms) of the system temperature. This corresponds to 0.9° mK for the system temperature of 30° K. We also describe system temperature stability measurements at k-band over the New-year-day shutdown when the array was stowed.

INTRODUCTION

There is a general feeling that it is not practical to make meaningful zero spacing flux-density (total power type) measurements with the VLA. It is perhaps due to the fact that the electronics is fairly complicated and there is no serious effort to stabilize gain of the electronics before signals are detected. However the system temperature estimates are made by injecting known noise calibration signals at the inputs of the low noise amplifiers and synchroneously detecting it at IF (or baseband) for each antenna. If the noise calibration signal is stable and any gain variations donot affect the system temperature, then the system temperature changes should be representative of the antenna temperature variations. For a bandwidth of 50 MHz it should be possible to estimate the system temperature variations with an accuracy of 1 part in about 10^3 for an integration time of 2 sec and calibration signal (T_{cal}) about 10% of the system temperature. The monitor system quantization error is similar (5 mV quantization step for measuring synchroneous detector signal of nominal value of about 3 Volts). Therefore it should be possible to make individual measurement accurate to 10^{-3} of system temperature. Such measurements for all four IFs and all 27 antennas can be combined for several scans to get a reasonable accuracy.

OBSERVATIONS

(a) Zero-spacing flux-density measurements:

To investigate extent to which this approach can be used for measuring zero-spacing flux-density, and its limitations on accuracy achievable, we made T_{sys} measurements in December 1993 when the antennas were in D-array. All T_{sys} data in figures 1 to 3 were obtained from AIPS TY table. The data were averaged for all four IFs from an antenna, and normalized using average value.

Plots in figure 1 show T_{sys} data for antennas 1-4 (Figs. 1a to 1d) and average of antennas 1 to 4 (Fig. 1e) while tracking 2251+158 (about 10 Jy source) at X-band

Figure 2 shows T_{sys} data from antenna 1 while scanning ON and OFF 2251+158 in azimuth (keeping same elevation as that of the source) at X-band.

Figure 3: Trace 1 shows T_{sys} data averaged over all 27 antennas while scanning ON and OFF 2253+417 (a half jy source at X-band) in azimuth (at the souce elevation). Trace 2 shows LISTR amplitude from AIPS for baselines formed by antennas 1, 2, and 3 (IF A only). LISTR amplitude of about $3 * 10^4$ counts corresponds to position of 2253+417. Jump in the T_{sys} value near time 20 min is due to about 20% increase in the system temperature of antenna 8.

(b) System temperature stability measurements:

These measurements were made at k-band (except for antennas 4, 8, 12, and 27, which had Q-band system, were set at Q-band) default settings during 1994 New-year-day shut down when the array was stowed. The system temperature data were obtained from monitoring the frontend synchroneous detectors every 5 sec. Plots in figure 4a to 4d are normalized T_{sys} data for 3 hours starting from mid-night for four representative antennas at k-band (antennas 1, 5, 14, and 28). Each figure shows plots of T_{sys} data for all four IFs (IFs A, B, C, and D). Similarly figures 5a-5d are T_{sys} ata for the four Q-band antennas during the same period (IAT 7:00 to 10:00). From the T_{sys} plots it is clear that the T_{sys} values are also affected by factors other than atmosphere (which on average should be same on all antennas located within a km). Antenna 14 which showed fluctuations of about 2 % in T_{sys} with time scale of about 40 minutes did not show such variations (Fig. 6) a few hours later Nothing was changed in the system during this period. Many (but not all) antennas show different types of variations at this level on varying timescales. This suggests that the fluctuations are probably caused by several factors.

To get some feeling for the sources of T_{sys} variations we have plotted difference in T_{sys} values between IFs A-B, A-C, C-D, and B-D in figures 7a to 7d for the same antennas as in figures 4. From the data in figures 4 and 7 it appears that the T_{sys} fluctutations are caused by variations in T_{cal}, and also there are other sources of T_{sys} fluctuations.

To see the time scale of the fluctuations we Fourier transformed the T_{sys} fluctuation data (after removing constant term from T_{sys} data) for IF A. The T_{sys} fluctuations and its Fourier transform for one antenna are shown in figure 8. This shows that the T_{sys} fluctuations (due to receiver instabilities) did not show substantial power till about one hundred seconds during these tests.

DISCUSSIONS

Some of the factors which may affect accuracy of zero-spacing flux-density measurements are:

(a) Stability of T_{sys} measurements– For time scales of tens of seconds these donot seem serious.

(b) Atmospheric variations– During reasonable weather conditions rapidly scanning ON-OFF source at the same elevation should eliminate this problem, and such measurements should only be made when the atmospheric variations are not too bad. This can be recognized by atmospheric phase fluctuations on a calibration source at (say) k-band.

(c) Beam shape and pointing– These are important only at high frequencies, and using reference pointing should minimize errors due to this.

CONCLUSION

Estimating zero-spacing flux-density with a few percent accuracy for a one Jy (or stronger) source at X-band using T_{sys} data looks practical without much effort.

FIG 1 – Tsys data while tracking 2251+158 at X-band

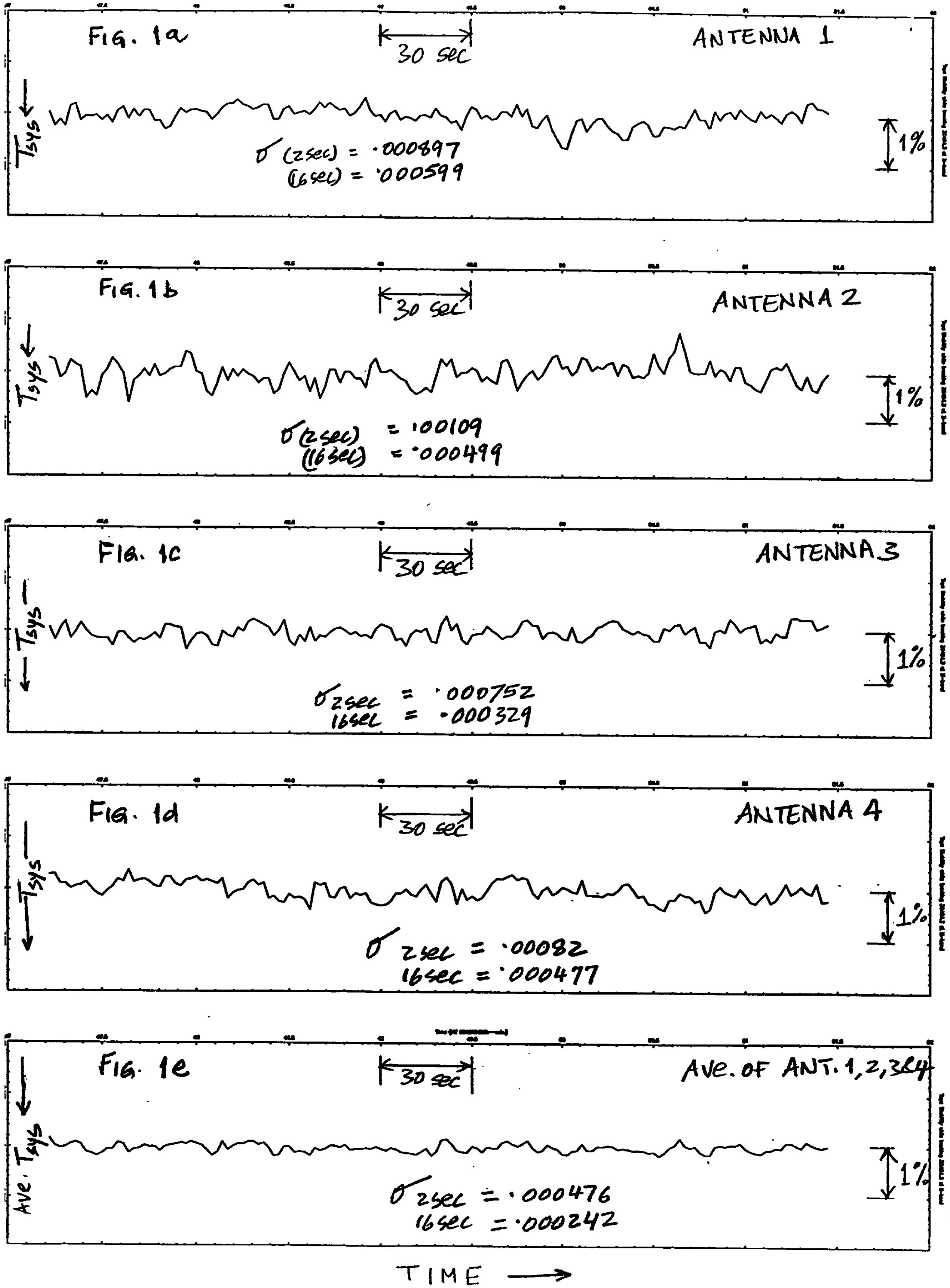
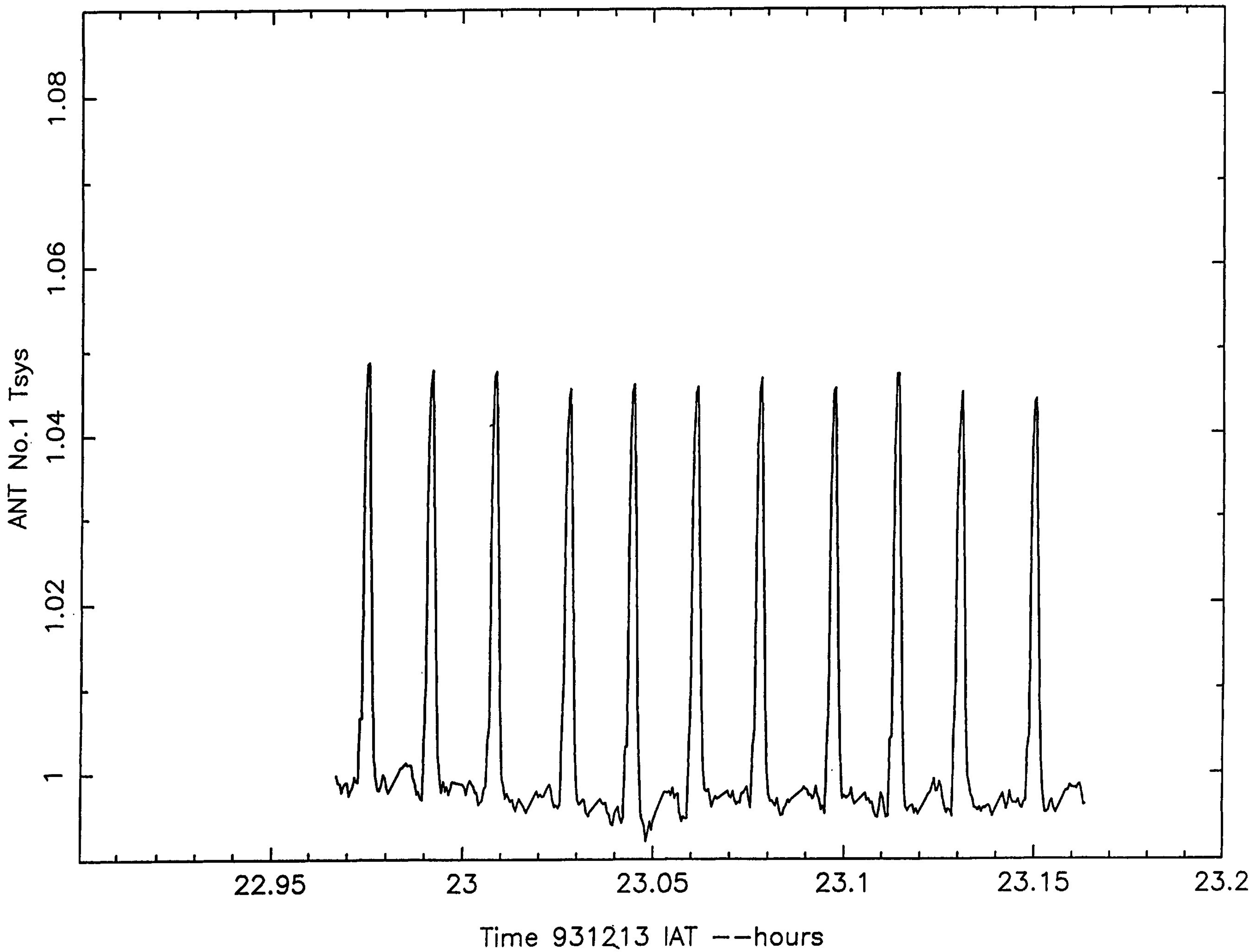
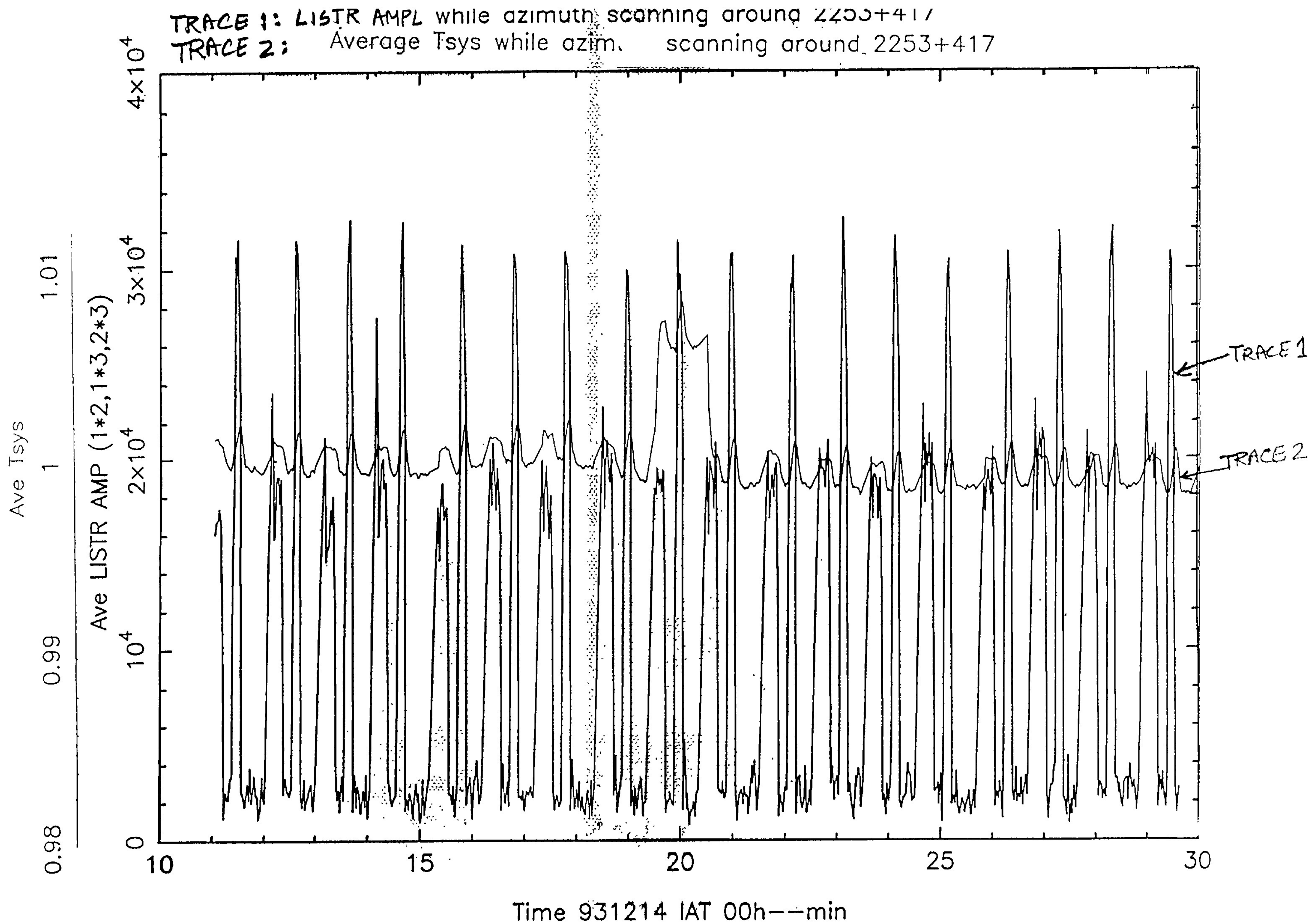


FIG. 2 Antenna 1 Tsys ~~on~~ while ~~tracking~~ AZ scanning 2251+158



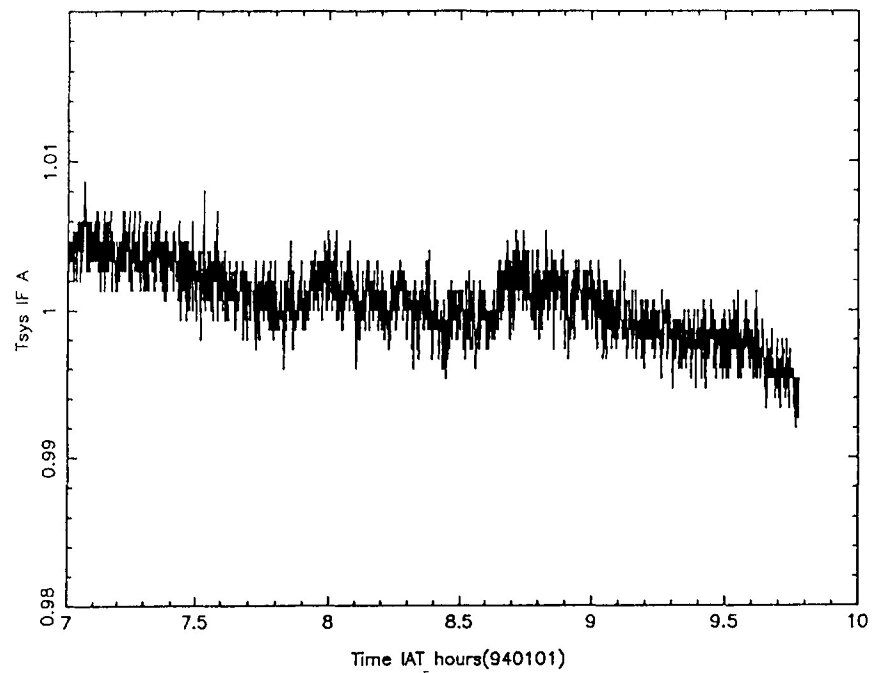


TRACE 1: LISTR AMPL while azimuth scanning around 2253+417
TRACE 2: Average Tsys while azim. scanning around 2253+417
Ave Tsys
Ave LISTR AMP (1*2,1*3,2*3)
0.98
0.99
1
1.01
0
10^4
2×10^4
3×10^4
4×10^4
10
15
20
25
30
Time 931214 IAT 00h--min
TRACE 1
TRACE 2

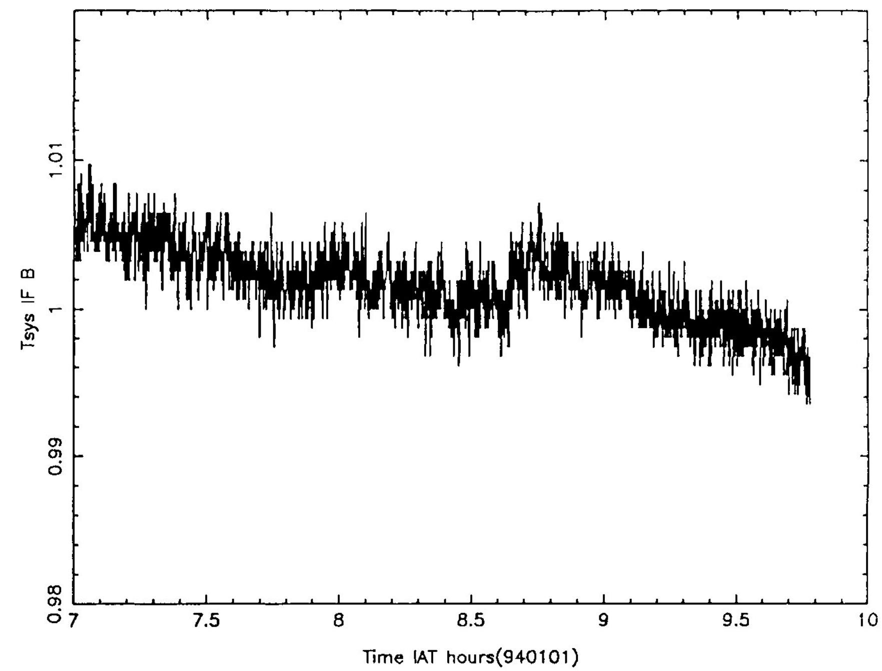
FIG. 3

N5

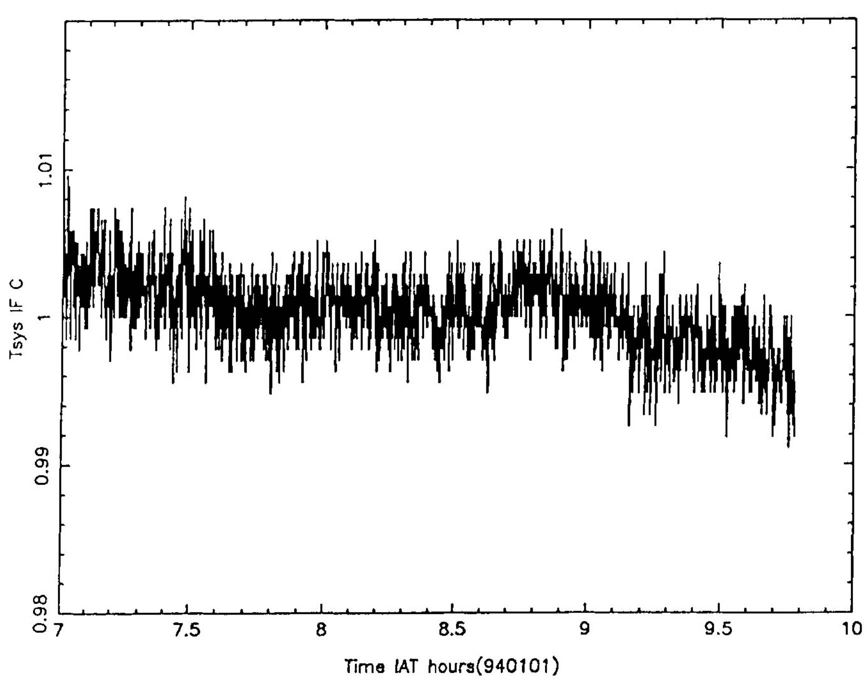
Tsys Stability Ant. 01 pointed zenith



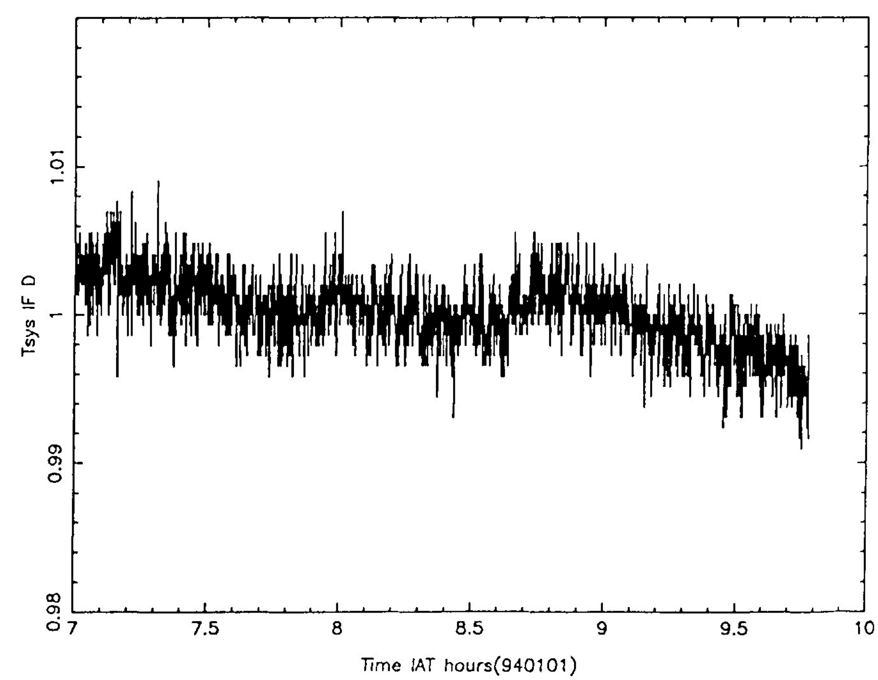
Tsys Stability Ant. 01 pointed zenith

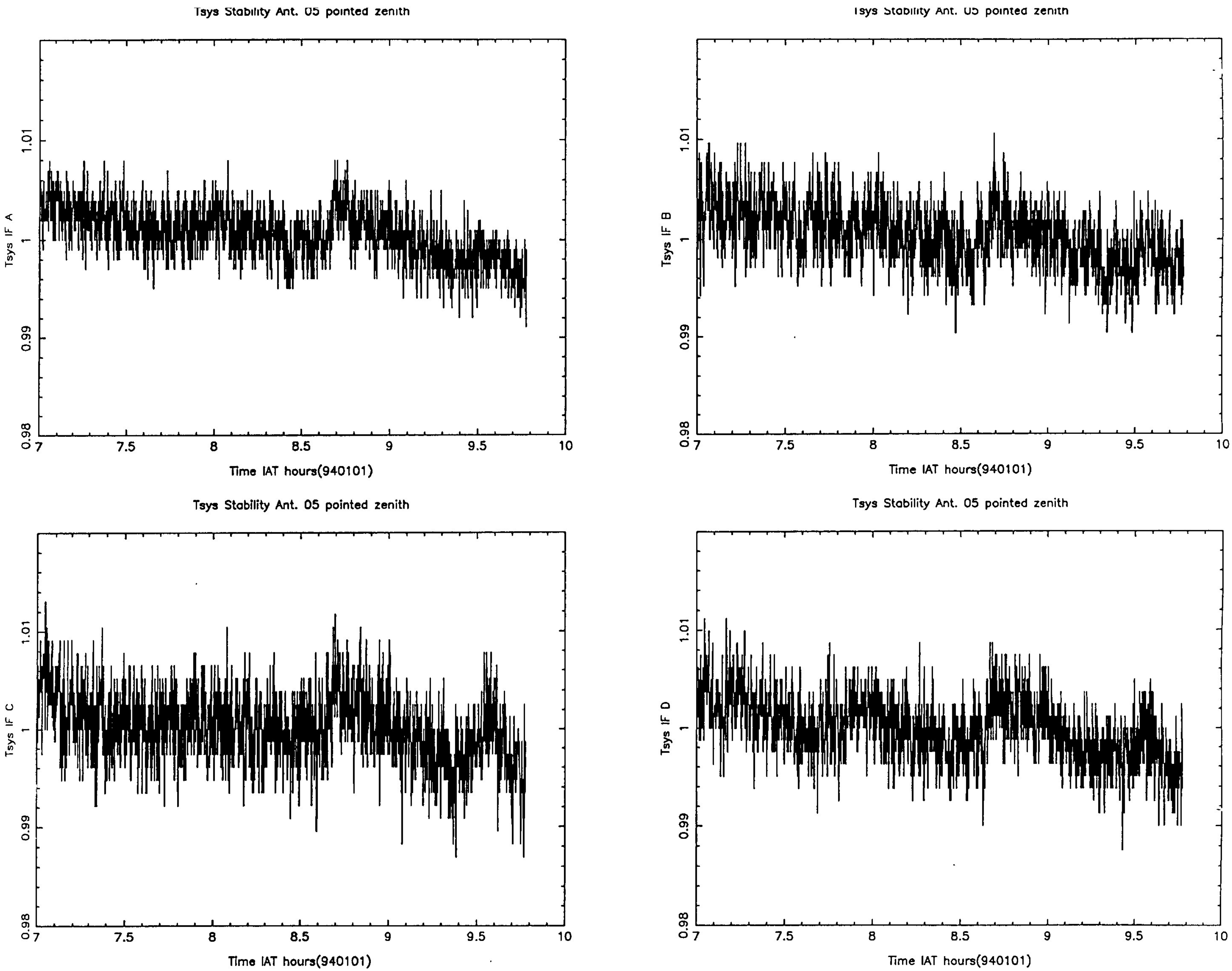


Tsys Stability Ant. 01 pointed zenith



Tsys Stability Ant. 01 pointed zenith



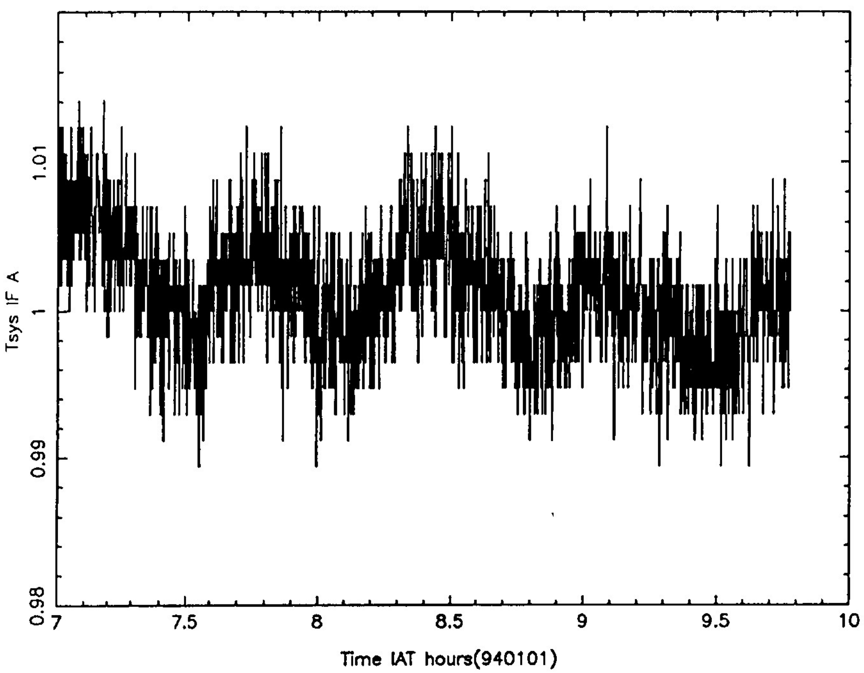


Tsys Stability Ant. 05 pointed zenith
Tsys IF A
0.98
0.99
1
1.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours(940101)
Tsys Stability Ant. 05 pointed zenith
Tsys IF B
Time IAT hours(940101)
Tsys Stability Ant. 05 pointed zenith
Tsys IF C
Time IAT hours(940101)
Tsys Stability Ant. 05 pointed zenith
Tsys IF D
Time IAT hours(940101)

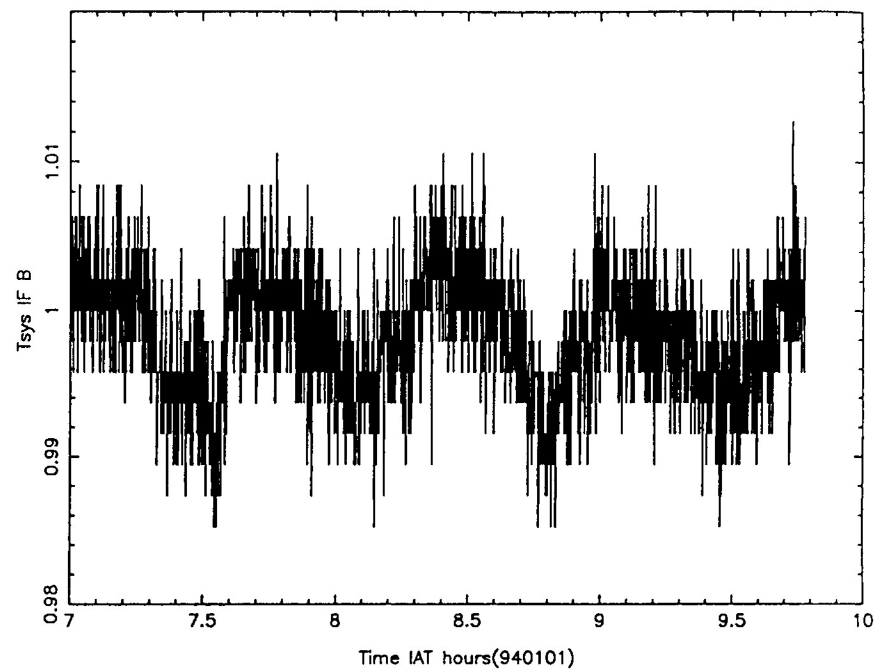
FIG 4b

N6

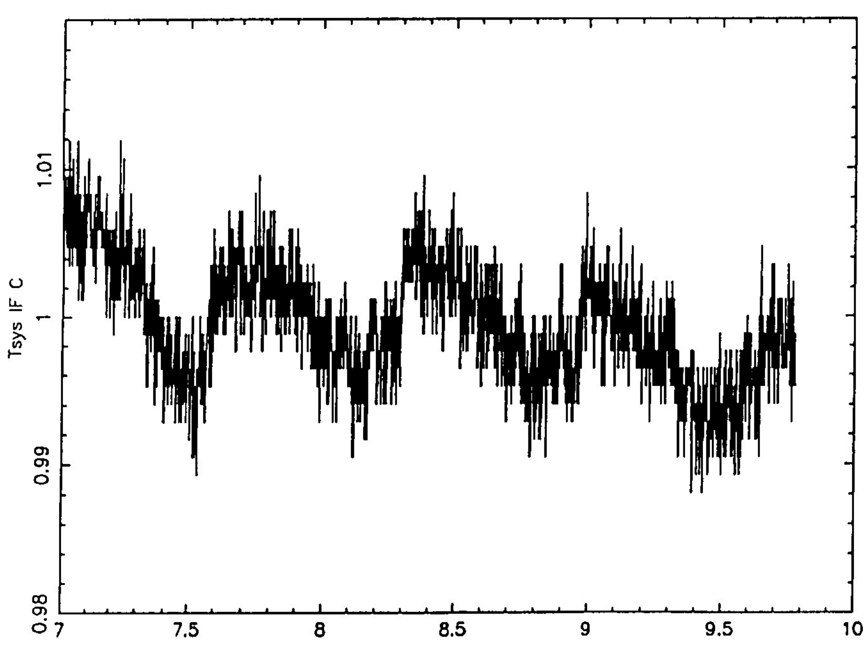
Tsys Stability Ant. 14 pointed zenith



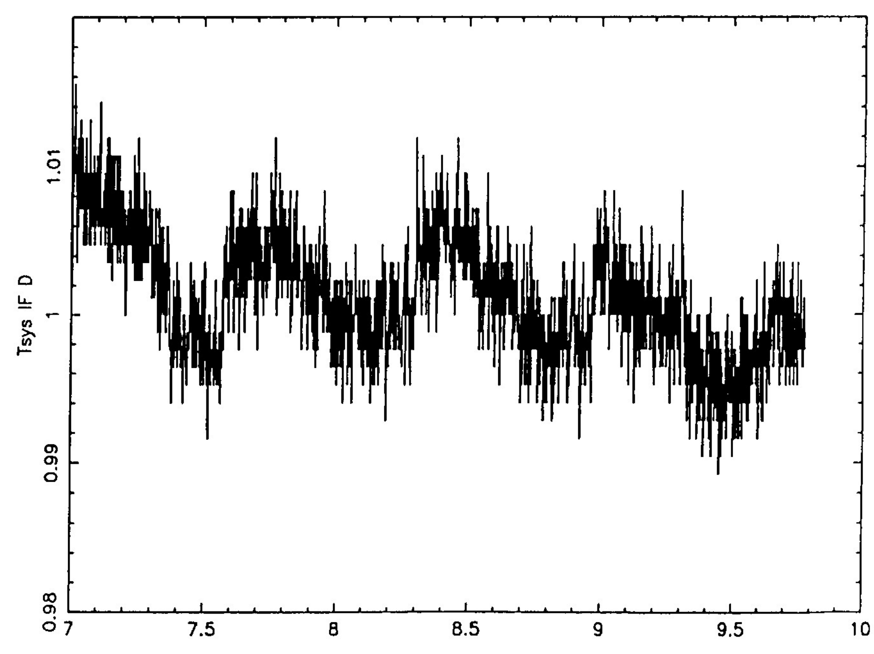
Tsys Stability Ant. 14 pointed zenith



Tsys Stability Ant. 14 pointed zenith



Tsys Stability Ant. 14 pointed zenith



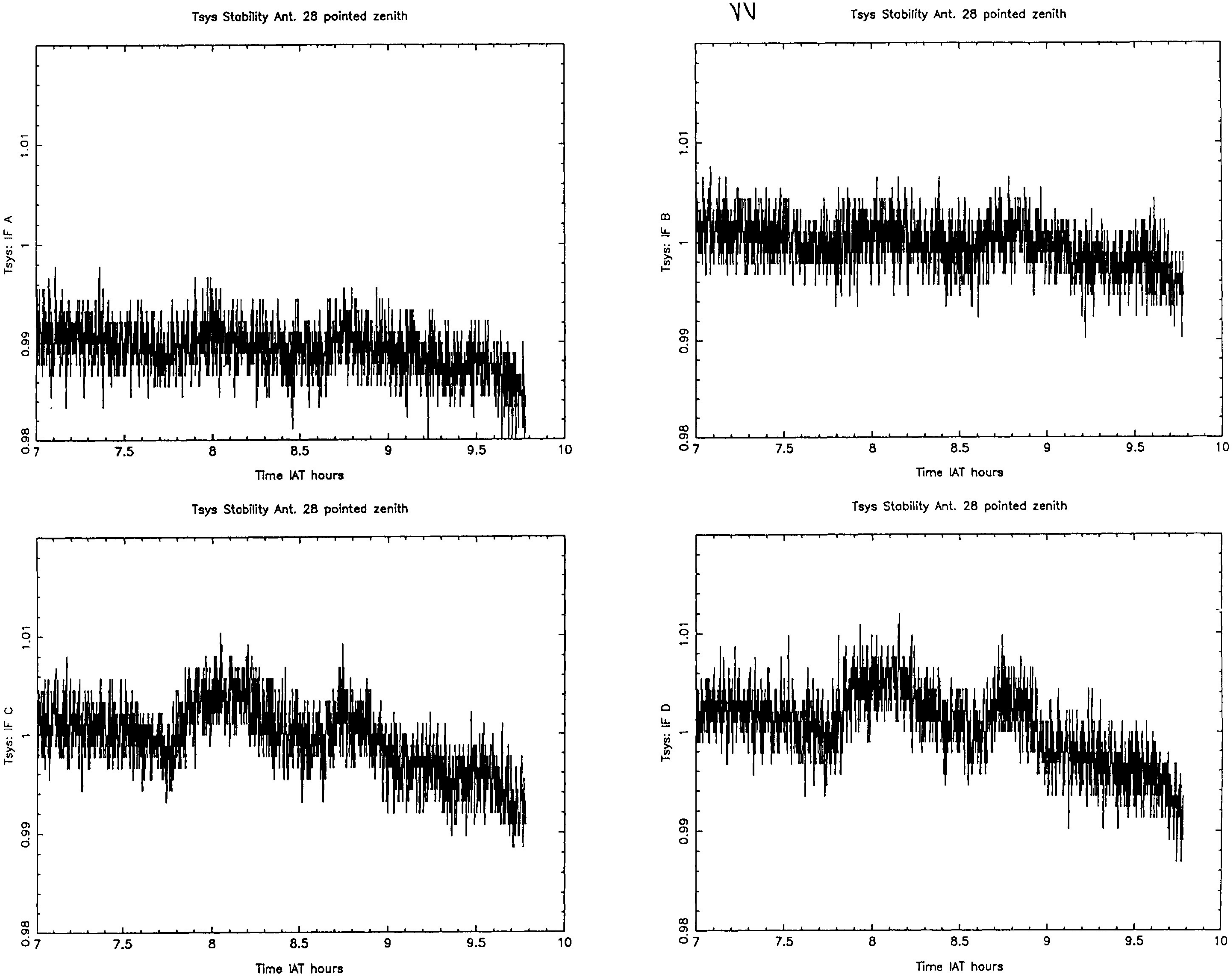
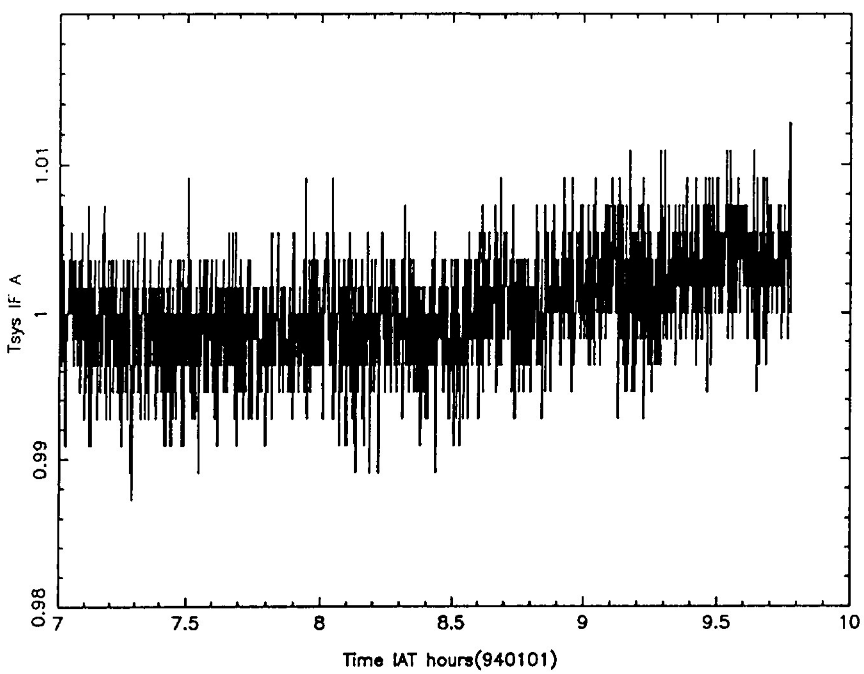

Tsys Stability Ant. 28 pointed zenith
Tsys: IF A
Time IAT hours
Tsys Stability Ant. 28 pointed zenith
Tsys: IF B
Time IAT hours
Tsys Stability Ant. 28 pointed zenith
Tsys: IF C
Time IAT hours
Tsys Stability Ant. 28 pointed zenith
Tsys: IF D
Time IAT hours
0.98
0.99
1
1.01
7
7.5
8
8.5
9
9.5
10

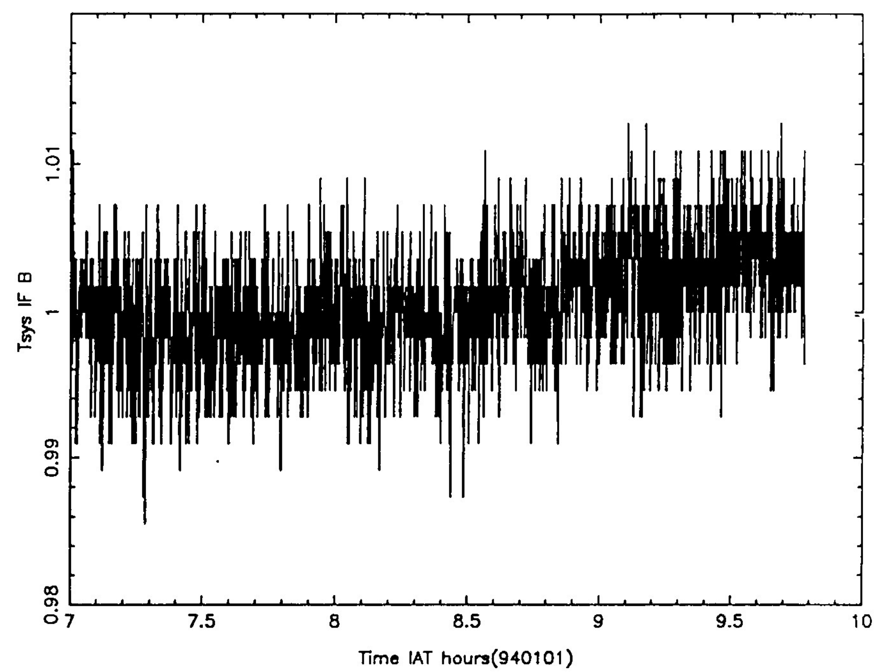
Fig. 4d

E4 @ Q

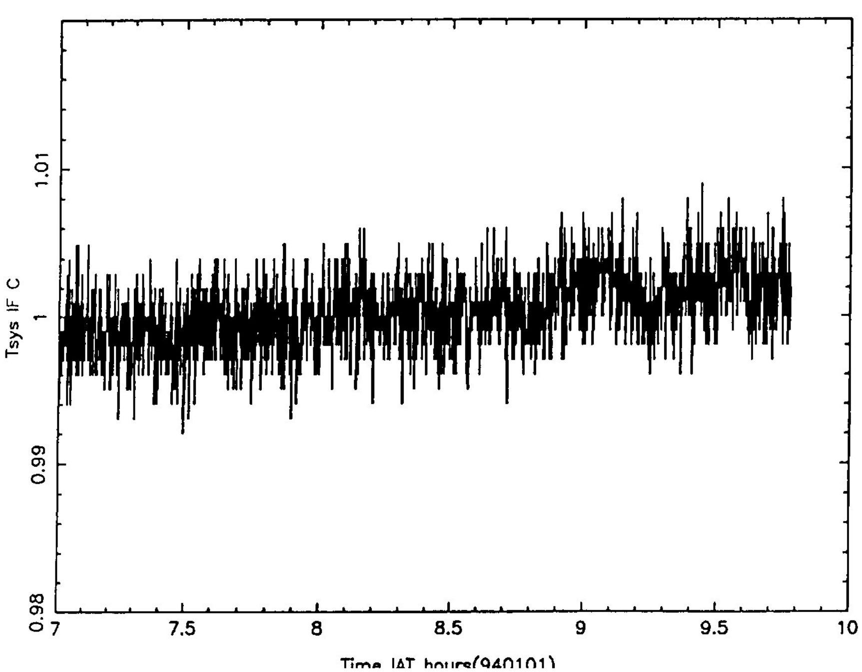
Tsys Stability Ant. 04 pointed zenith



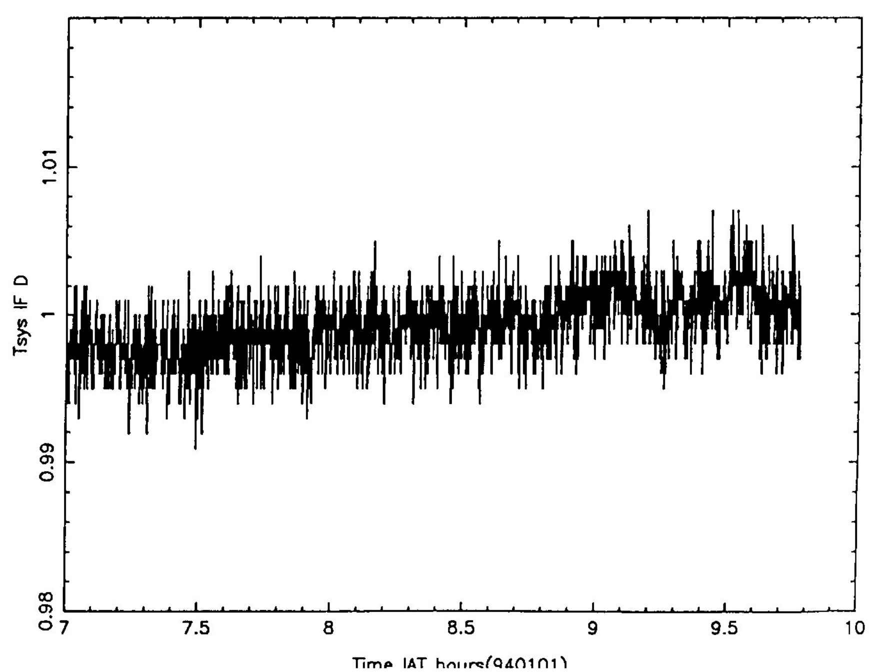
Tsys Stability Ant. 04 pointed zenith



Tsys Stability Ant. 04 pointed zenith



Tsys Stability Ant. 04 pointed zenith



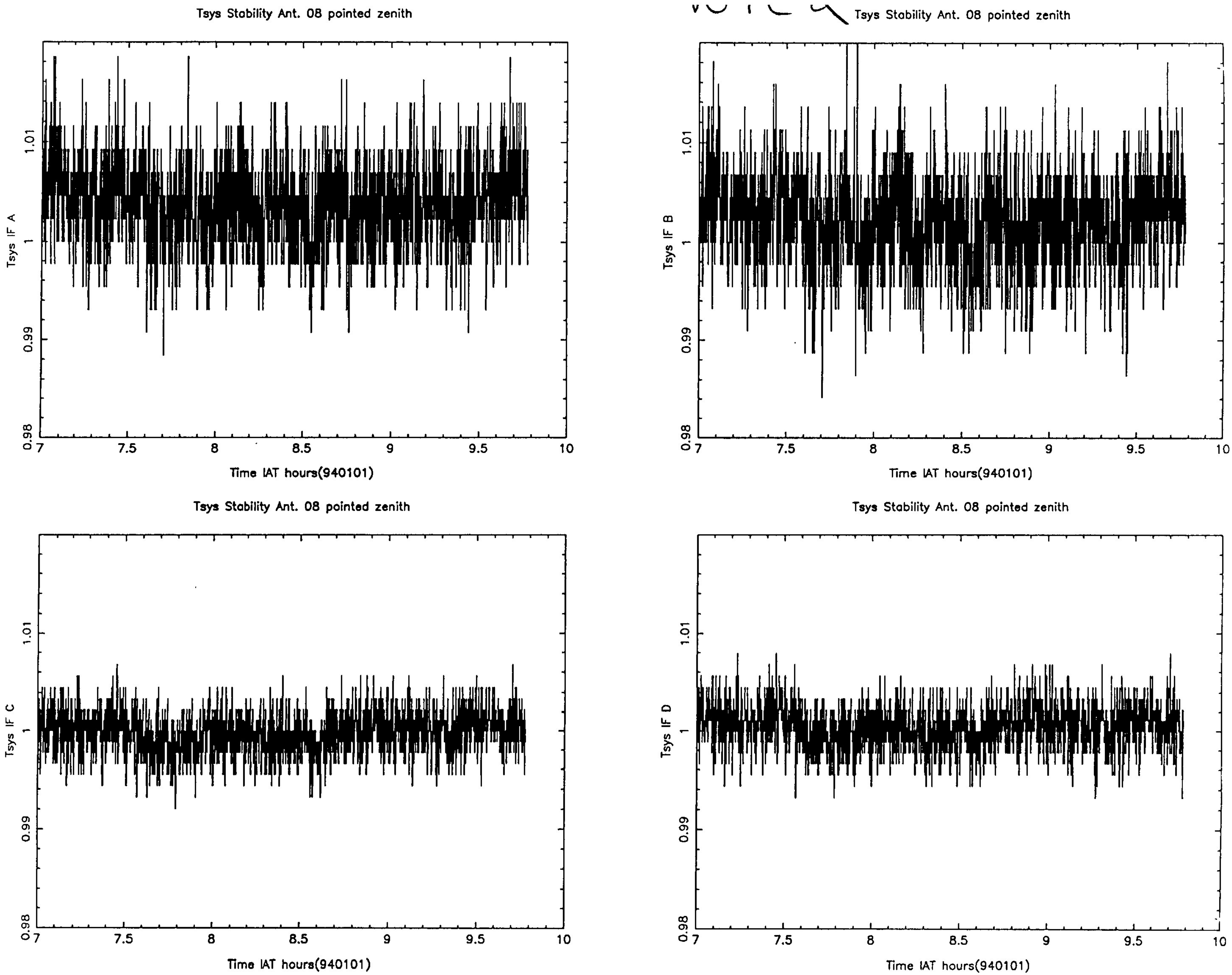
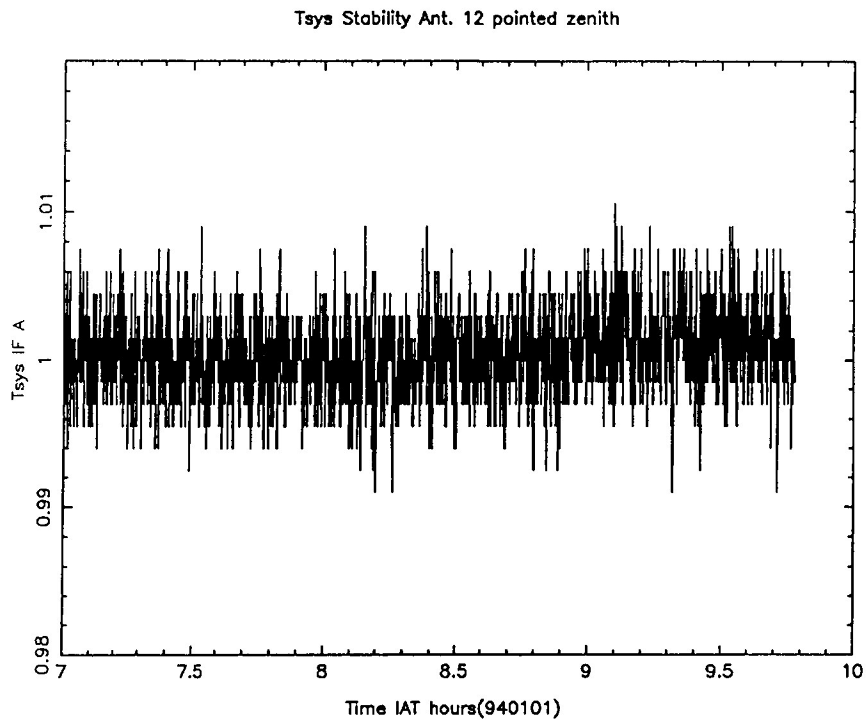
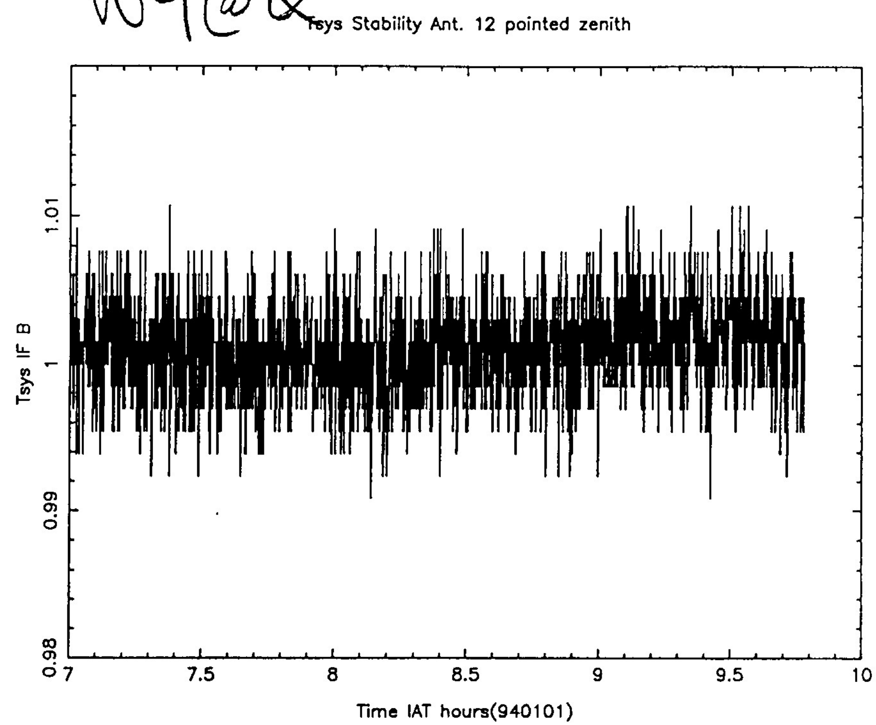
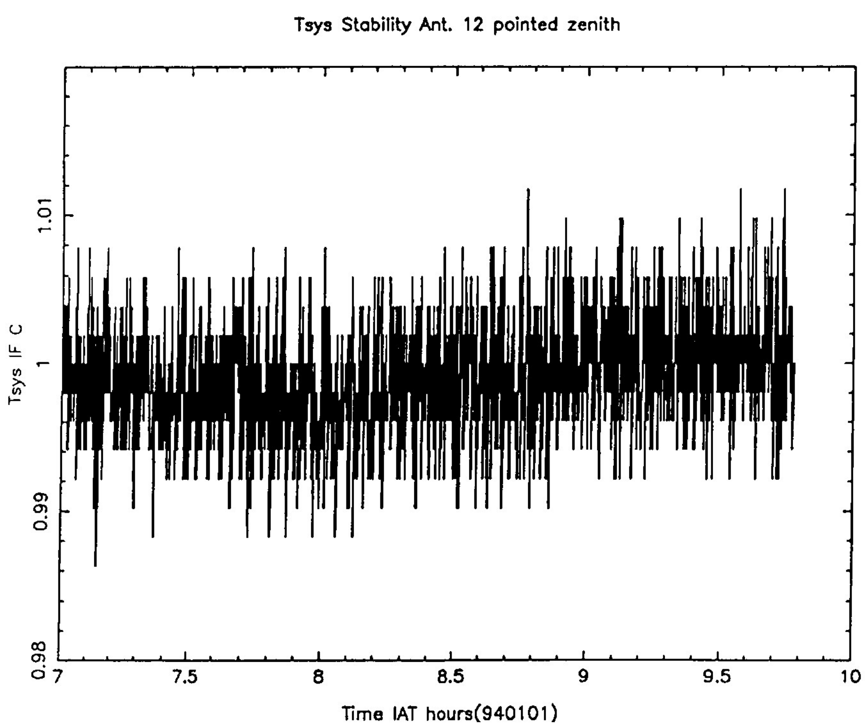

Tsys Stability Ant. 08 pointed zenith
Tsys IF A
Tsys IF B
Tsys IF C
Tsys IF D
0.98
0.99
1
1.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours(940101)

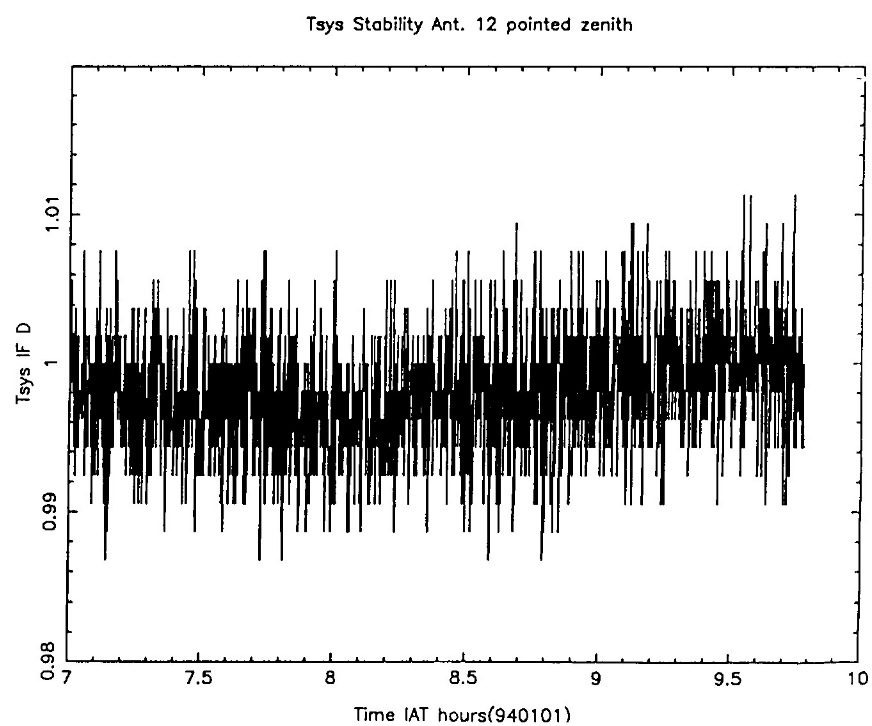
FIG. 5b

W9@Q


Tsys Stability Ant. 12 pointed zenith
Tsys IF A
1.01
1
0.99
0.98
7
7.5
8
8.5
9
9.5
10
Time IAT hours(940101)


Tsys Stability Ant. 12 pointed zenith
Tsys IF B
1.01
1
0.99
0.98
7
7.5
8
8.5
9
9.5
10
Time IAT hours(940101)


Tsys Stability Ant. 12 pointed zenith
Tsys IF C
1.01
1
0.99
0.98
7
7.5
8
8.5
9
9.5
10
Time IAT hours(940101)


Tsys Stability Ant. 12 pointed zenith
Tsys IF D
1.01
1
0.99
0.98
7
7.5
8
8.5
9
9.5
10
Time IAT hours(940101)

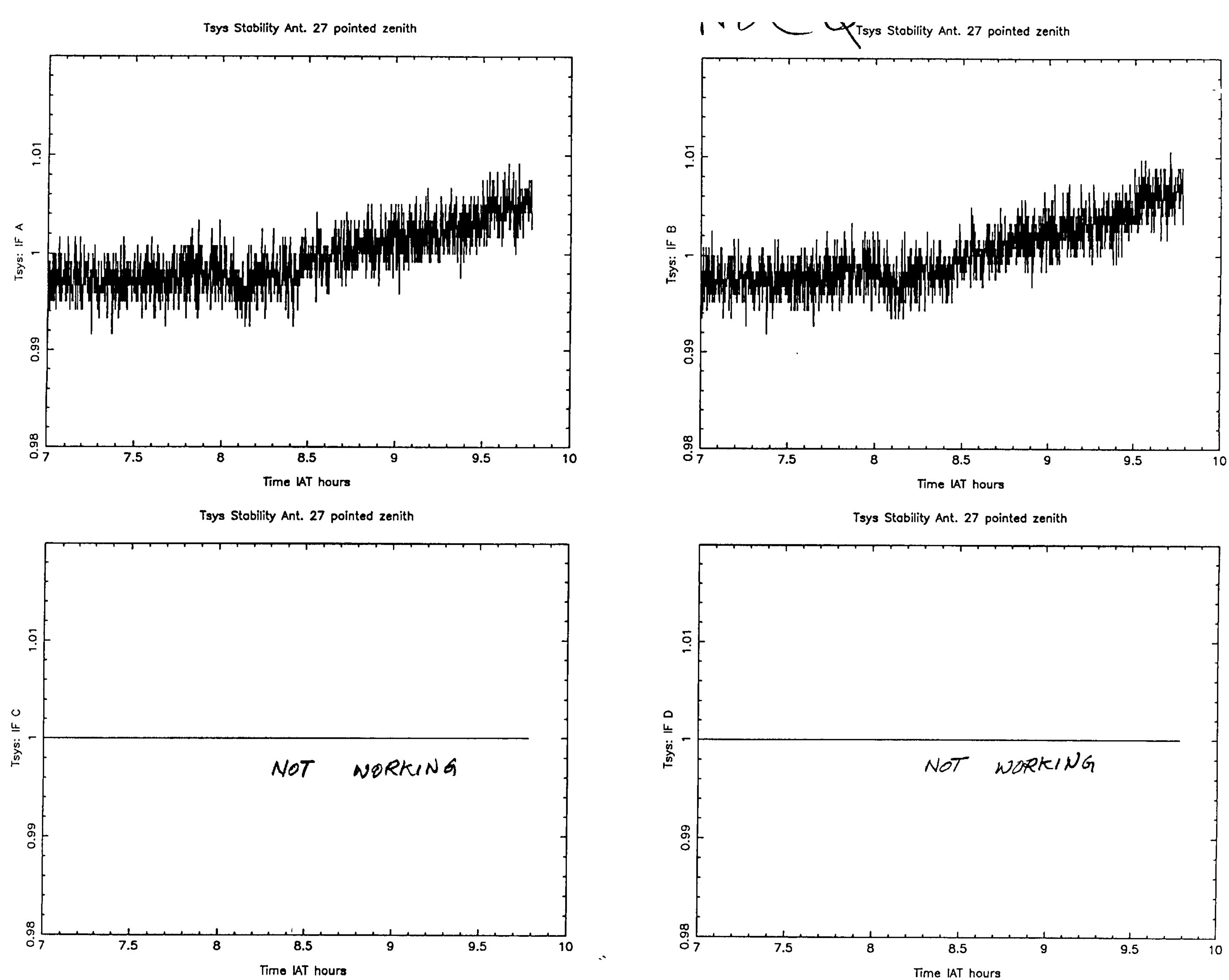
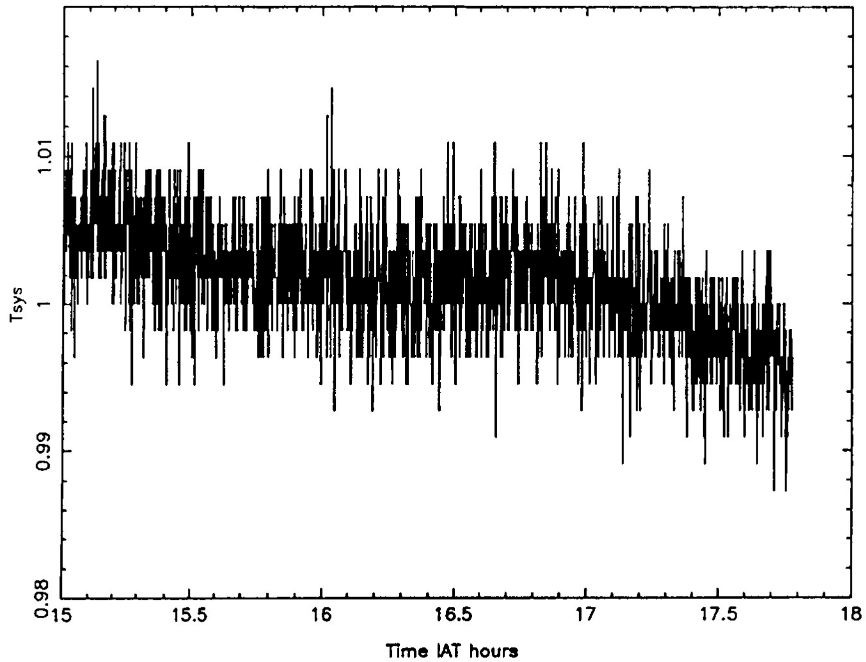

Tsys Stability Ant. 27 pointed zenith
Tsys: IF A
Time IAT hours
Tsys Stability Ant. 27 pointed zenith
Tsys: IF B
Time IAT hours
Tsys Stability Ant. 27 pointed zenith
Tsys: IF C
NOT WORKING
Time IAT hours
Tsys Stability Ant. 27 pointed zenith
Tsys: IF D
NOT WORKING
Time IAT hours
0.98
0.99
1
1.01
7
7.5
8
8.5
9
9.5
10

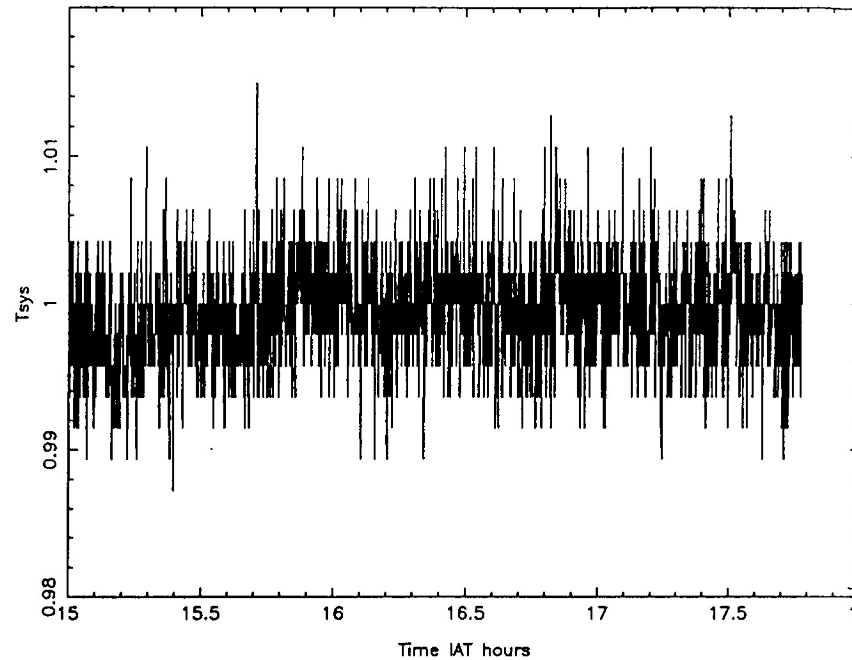
FIG. 5d

N6

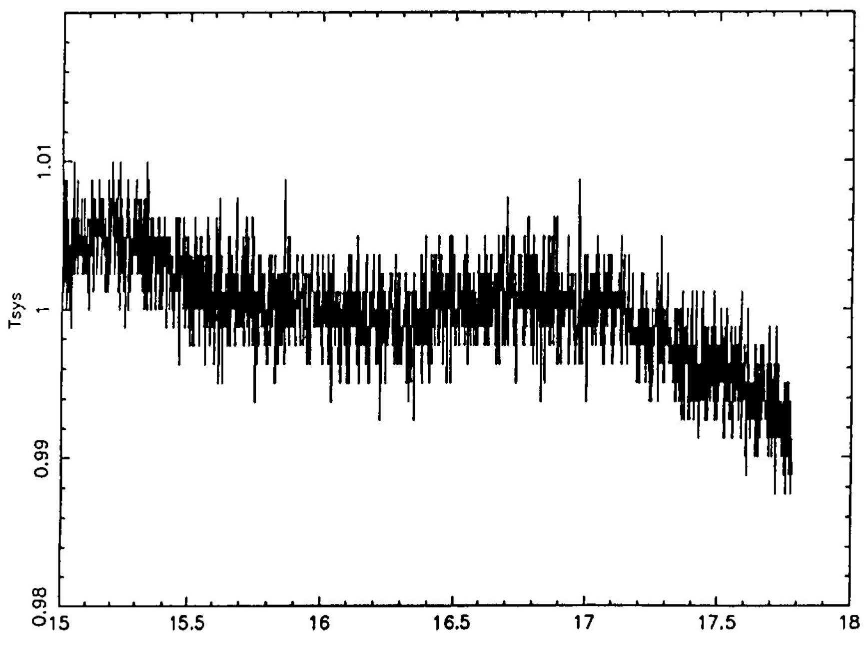
Tsys Stability Ant. 14 pointed zenith



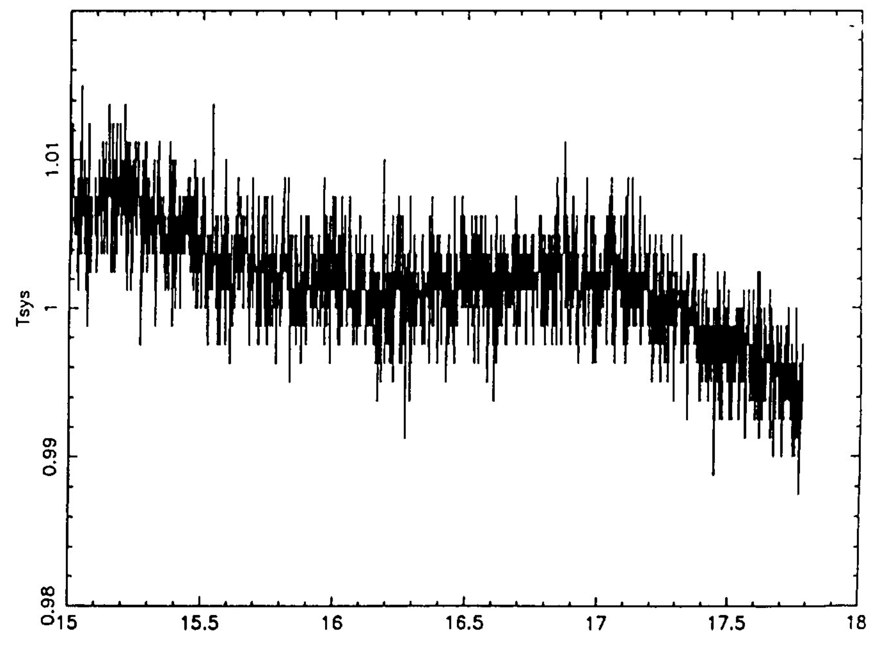
Tsys Stability Ant. 14 pointed zenith



Tsys Stability Ant. 14 pointed zenith



Tsys Stability Ant. 14 pointed zenith



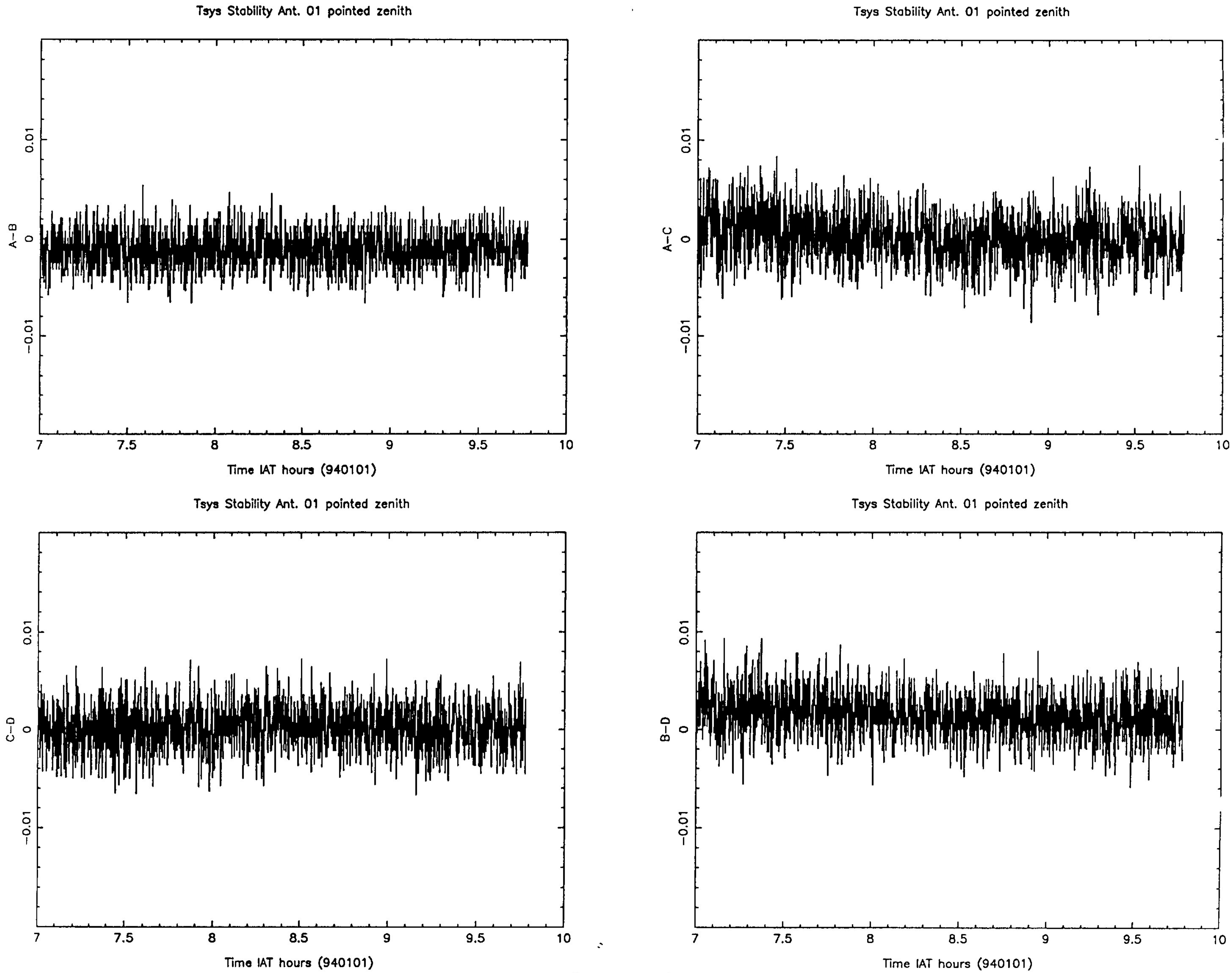
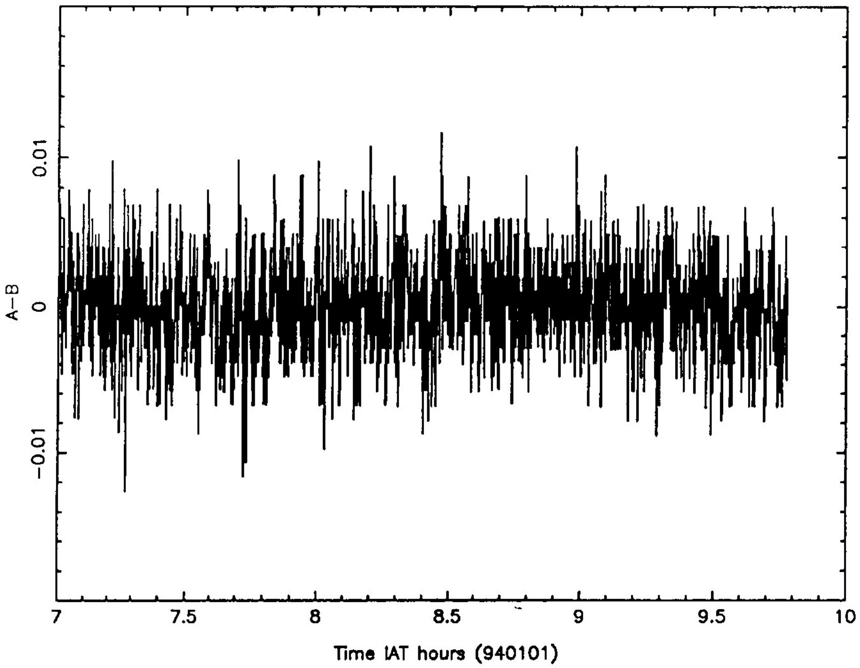
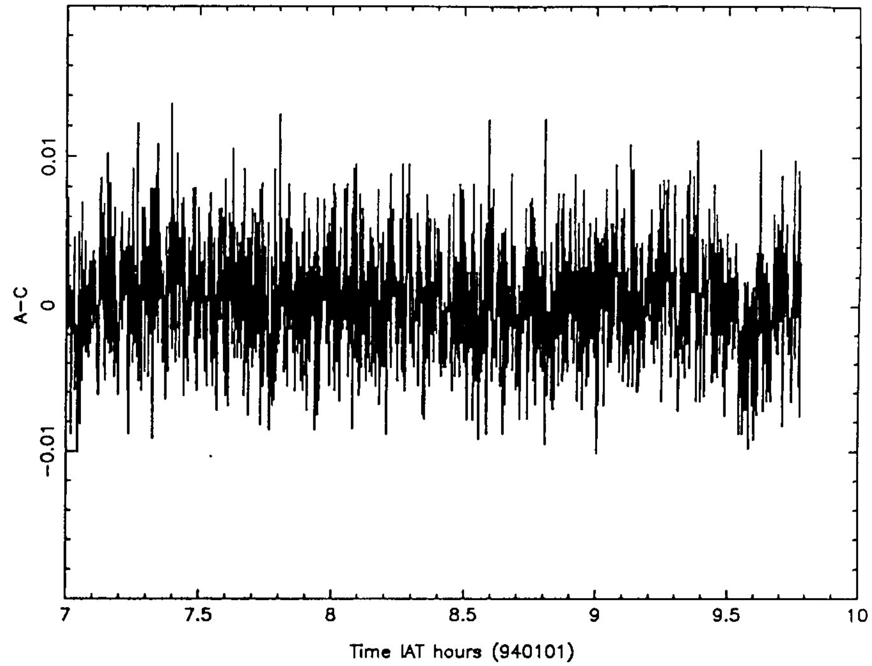

Tsys Stability Ant. 01 pointed zenith
A−B
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)
Tsys Stability Ant. 01 pointed zenith
A−C
Tsys Stability Ant. 01 pointed zenith
C−D
Tsys Stability Ant. 01 pointed zenith
B−D

FIG. 7a

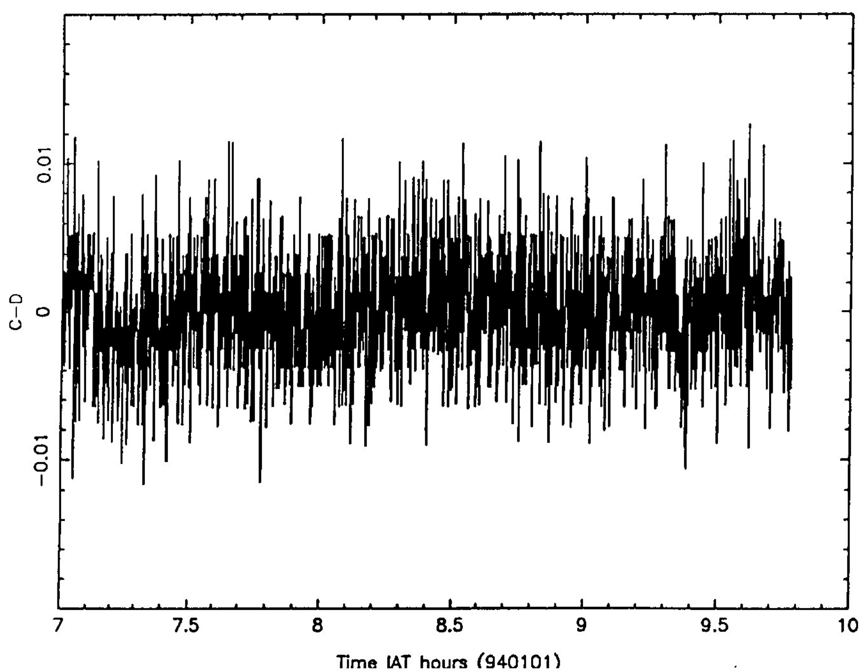
Tsys Stability Ant. 05 pointed zenith



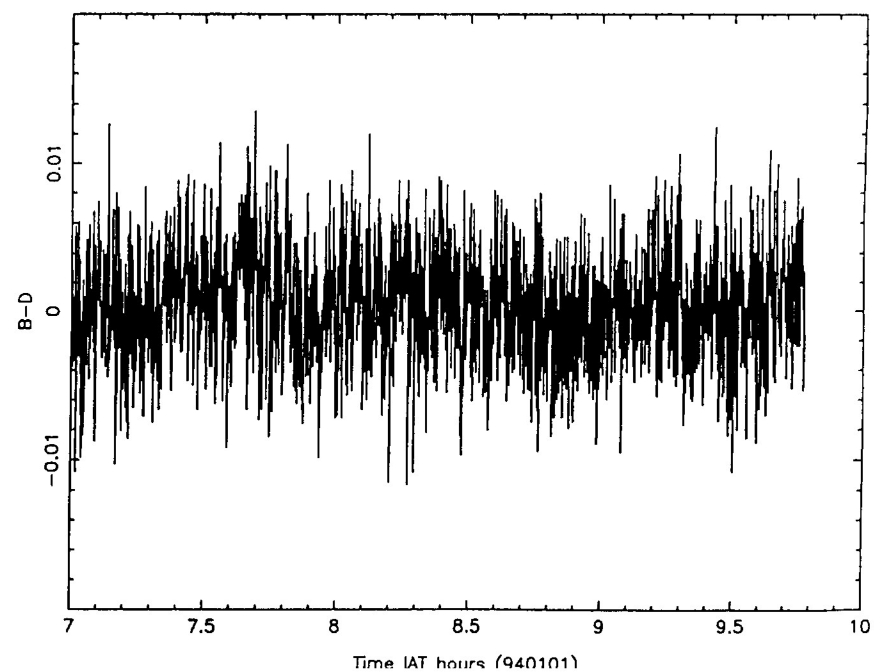
Tsys Stability Ant. 05 pointed zenith



Tsys Stability Ant. 05 pointed zenith



Tsys Stability Ant. 05 pointed zenith



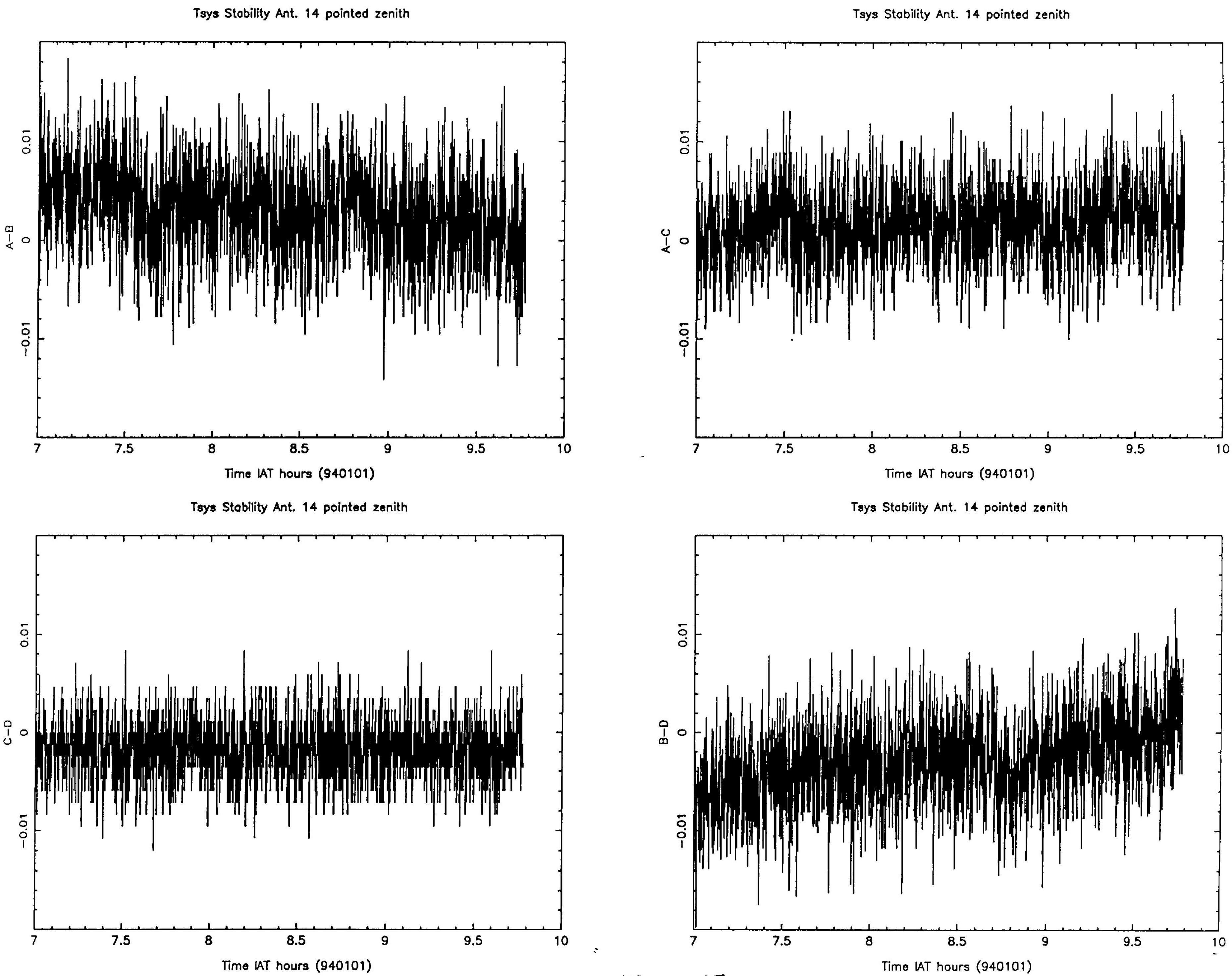
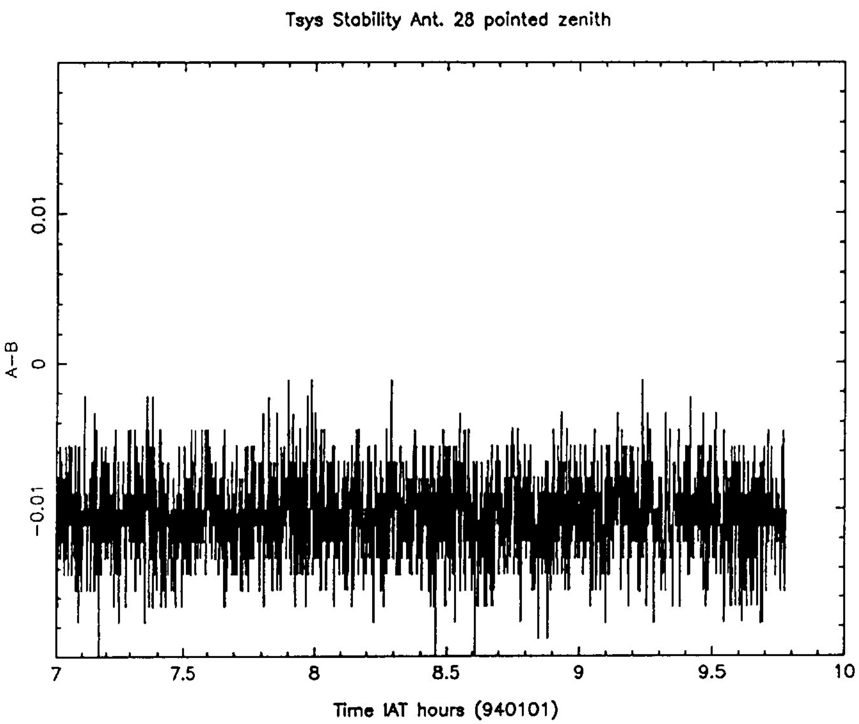
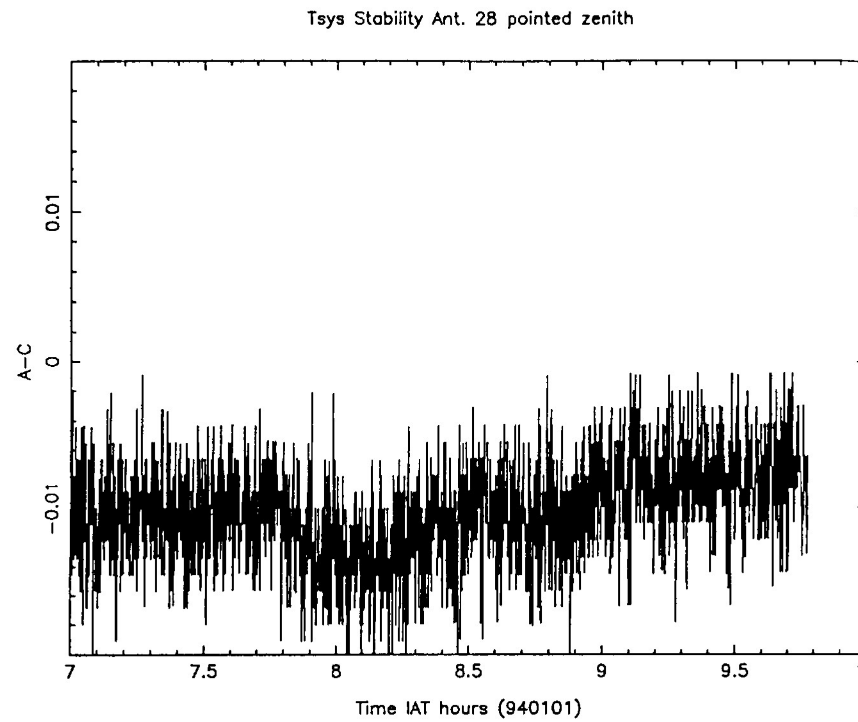
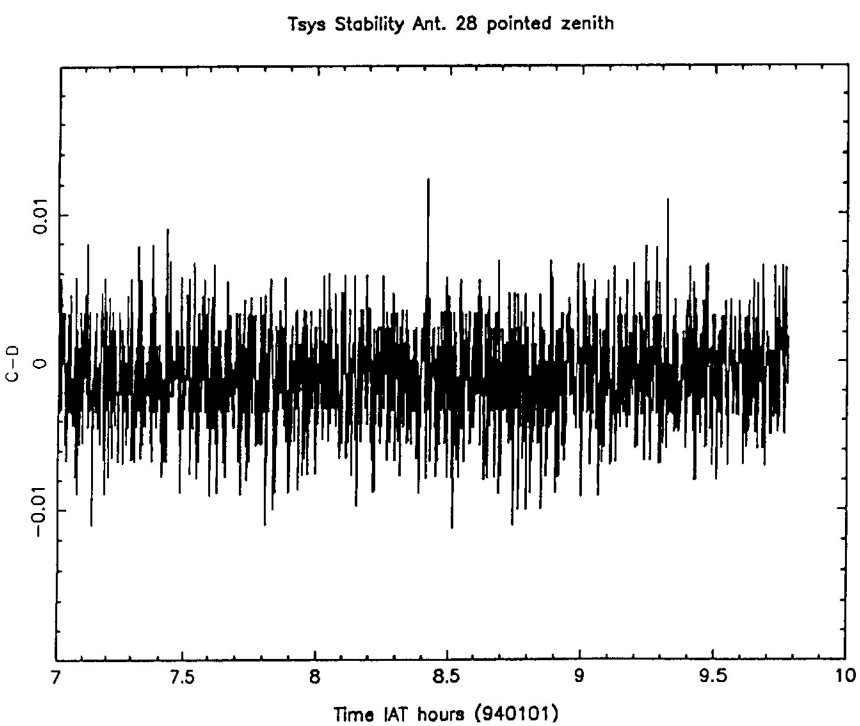
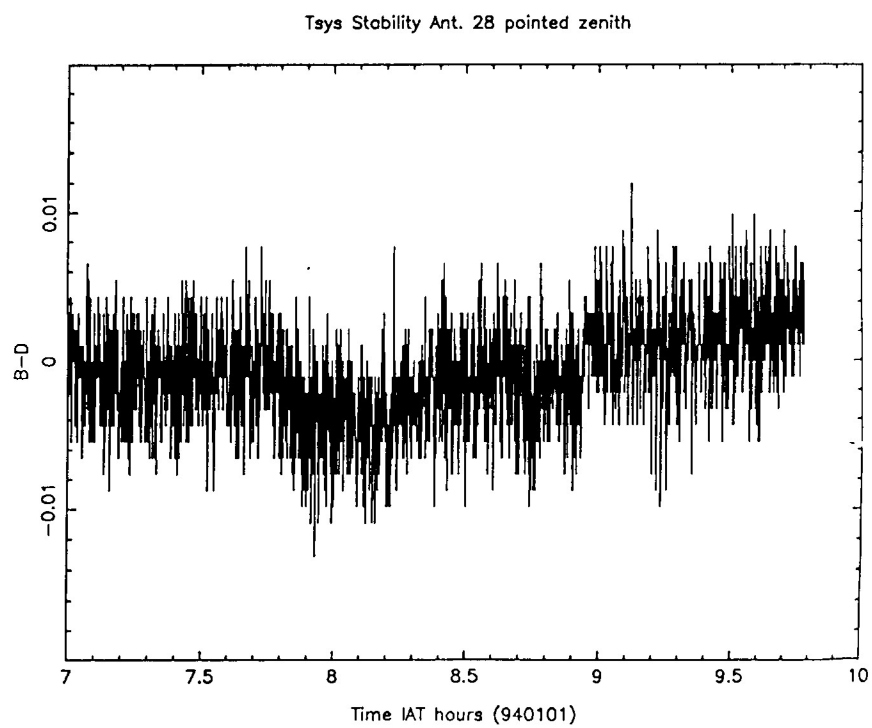

Tsys Stability Ant. 14 pointed zenith
A−B
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)
Tsys Stability Ant. 14 pointed zenith
A−C
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)
Tsys Stability Ant. 14 pointed zenith
C−D
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)
Tsys Stability Ant. 14 pointed zenith
B−D
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)

FIG. 7C


Tsys Stability Ant. 28 pointed zenith
A−B
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)


Tsys Stability Ant. 28 pointed zenith
A−C
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)


Tsys Stability Ant. 28 pointed zenith
C−D
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)


Tsys Stability Ant. 28 pointed zenith
B−D
0.01
0
−0.01
7
7.5
8
8.5
9
9.5
10
Time IAT hours (940101)

data := READPRN(VLA01)

$t := data^{\langle 0 \rangle}$ $N := \text{length}(t)$ $i := 0..N-1$ $N = 2.16 \cdot 10^3$

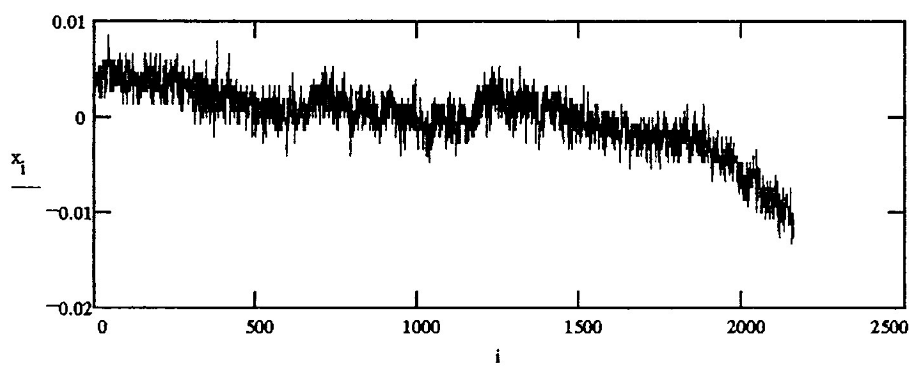
$x := data^{\langle 2 \rangle} - 1$

TAKE COMPLEX TRANSFORM

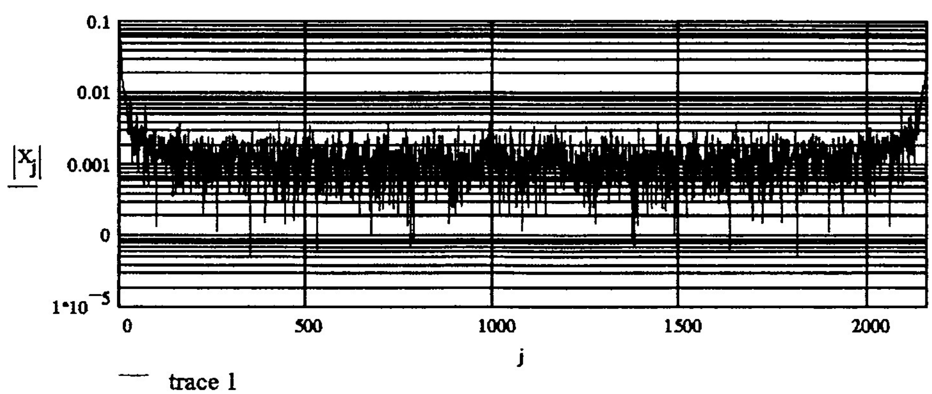
$X := \text{cfft}(x)$

$M := \text{last}(X)$ $M = 2.159 \cdot 10^3$

$j := 0..M$



Tsys Fluctuation Data (ANT. 1 IFA)



Fourier Transform of Tsys fluctuations

Figure 8