Australia Telescope Technical Note

The polarisation characteristics of the AT antennas

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Summary:

Polarisation observations with a single baseline were made in December 1988. A 5 hour run on the polarised source 0237-233 shows that the instrumental polarisation is less than 1%.

Introduction

A low level of instrumental polarisation was one of the design briefs for the antennas of the Compact Array. The pursuit of this goal lead, for example, to the rotating turret which allows us to place every receiver on the reflector's optical axis. An assessment of the success of this aspect of the design has not been possible until now, with the analysis of the first polarisation observations, made in December, 1988. The results are encouraging, and indicate that the instrumental polarisation is below the 1% mark.

The observations.

A five hour observation was made of the source 0237-233 on 14 December 1988, with a baseline of 260 m. The observing frequency was 4.8 GHz, and the bandwidth was 128 MHz. The conversion chain in each antenna was a modified prototype version; this meant that in each antenna the two IFs had identical phase control (and thus independant adjustment of the IF phase was not possible). This complicates slightly the analysis, but does not otherwise affect the operation.

Two IFs were returned from each antenna, one for each polarisation. The linearly polarised feeds were oriented at 45 degrees and 135 degrees. The data was processed in a four-module correlator, to produce four cross-spectra, each 32 channels long. These were dumped every 5 seconds, for subsequent analysis.

No on-line corrections were made to the data.

In figures 1 to 4 we show the raw cross-spectra, R_{xx}, R_{xy}, R_{yx} and R_{yy}. It is immediately clear from R_{xy} and R_{yx} that the instrumental polarisation is modest: a large phase step is seen at UT 11 hrs. This step would be 180 degrees if there were no instrumental contribution. The observed step of about 160 degrees means an antenna contribution of order 1%.

Discussion

These were effectively the first polarisation observations made with this array; the results are therefore preliminary, are should be taken with some care. The objectives of this note are to explore the polarisation potential of the instrument, rather than offer a detailed analysis of the source 0237-233.

In figs. 1 to 4 we have superimposed on the raw data the results of some computer modelling: we attempt to find a model which matches the observations. It is clear that a reasonable fit can be obtained. The ingredients of the modelling included:

- source polarisation characteristics;

- receiver gains and phase offsets.

The present observations were made with alt-az. antennas; this means that the interferometer responses will change with time, as the parallactic angle changes. A full treatment of the polarisation response of an interferometer was first given in Rhadakrishnan et al, 1964.

A first order expansion is adequate for the compact array, and allows us to derive the main polarisation properties from figures 1 to 4.

$$R_{xx} = I - p \sin 2(\chi - \Phi)$$

$$R_{xy} = - p \cos 2(\chi - \Phi) + \alpha_{xy} I$$

$$R_{yx} = - p \cos 2(\chi - \Phi) + \alpha_{yx} I$$

$$R_{yy} = I + p \sin 2(\chi - \Phi)$$

where p is the linearly polarised flux, at a position angle of Φ; the instrumental polarisation enters via the (small) complex coefficients α; (We ignore here the possibility that the source has significant circular polarisation. The complete derivation of the stokes parameters (discussed below in §5) confims the validity of this approximation).

We can obtain a first estimate of the various parameters from an examination of figs 1 to 4:

Note that the parallactic angle swings through ±70° for this source, so that all the trigonometric functions should swing through ±1.

1. I

Both R_{xx} and R_{yy} have a mean of about 0.54 (in PTILOOK units) :-

$I \sim 0.54$

2. The polarisation flux

The amplitude graphs for R_{xy} and R_{yx} show two peaks (of unequal magnitude); the mean of these two peaks gives the polarised flux:

$p \sim 5\%$

3. The position angle

The sharp null in R_{xy} and R_{yx} occurs when $(\chi-\Phi) \sim \pm 45°$; this indicates that Φ is either -30° or +60°. We distinguish between these two by the phasing in R_{xx} and R_{yy} : a maximum at 11:00 (UT) in R_{xy} means that $\Phi \sim +60°$ is the preferred solution.

4. Instrumental polarisation - feed misalignement

The difference between the peaks in R_{xy} and R_{yx} is related to the instrumental polarisation:

Let ϕ_1 and ϕ_2 be the feed orientations; then, $\Delta \text{Peak} = 2 * I * \sin(\phi_1 - \phi_2)$

We find $(\phi_1 - \phi_2) \sim 1°$. This a combination of two effects - a turret rotation, and a non-orthogonality between the two planes of polarisation. The sense of $(\phi_1 - \phi_2)$ for R_{xy} and R_{yx} indicates that turret rotation is the principal effect, but this needs further testing.

5. Instrumental polarisation - axial ratio.

The phase of R_{xy} and R_{yx} swings through about 160°; this sets the antenna's contribution relative to the polarised flux:

Let ξ be the difference between the expected and the observed phase swings; (~20°), and let θ_1 and θ_2 be the axial ratios of the polarisation ellipses. Then we have:

$$\tan(\xi/2) \sim \frac{I * \sin(\theta_1+\theta_2)}{p} \sim 0.2$$

With p ~ 5%, we have $(\theta_1 + \theta_2) \sim 0.5°$

5. <u>More sophisticated analysis:</u>

A more refined approach (outlined in AT/20.1.1/005, and its later revision) looks for the dependance on parallactic angle of the derived Stokes parameters. The model shown in figs. 1 to 4 was based on this analysis, and the best fit Stokes parameters are shown in fig. 5. The full model is listed in Table 1.

Table 1

Best fit model to the 14 December data

Source: I = 0.54 (PTI units); linear pol. = 3.4% at pa = 57°

antenna	gain	phase	feed	axial ratio
1, x	1.08	0°	45.4°	0.0°
1,y	1.04	-175°	135.2°	-0.12°
2,x	0.98	0°	44.8°	-0.12°
2,y	0.96	-82.5°	134.6°	0.05°

The "feed" column indicates a turret rotation of ~0.4° between the two antennas; and perhaps 0.2° non-orthogonality.

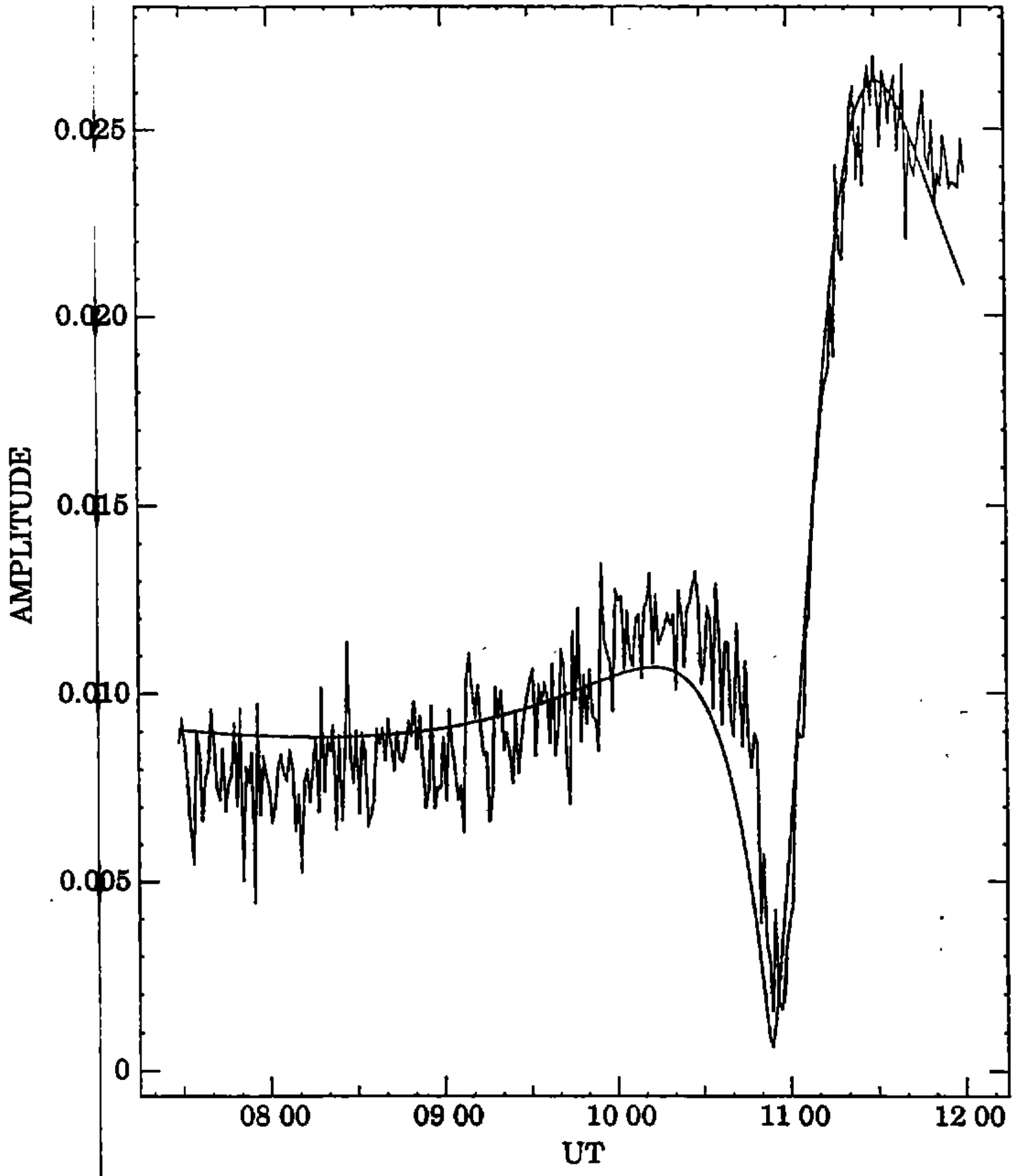
This source, 0237-233, was shown by Whiteoak et al (1967) to be polarised at 4.8 GHz with 5% linear polarisation, at a position angle of 150 degrees. Our observations are in good agreement with the earlier observations as far as the amplitude is concerned; our position angle differs by 90°; since the association of the cross-products to the planes of polarisation (x & y) was somewhat cavalier, the 90° is not surprising.

Conclusion

These preliminary results are pleasing, and suggest that the AT antennas have excellent polarisation properties - with the instrumental polarisation at a low level, below the 1% mark.

Figure captions.

1. The amplitude and phase of the correlation product R_{xy}. Also shown is the predicted product. The model for the predictions is described in the text, Table 1.
2. The product R_{yx}.
3. The product R_{xx}.
4. The product R_{yy}.
5. The stokes parameters (I, Q & U) computed from the raw cross-products, using the antenna parameters listed in Table 1.
6. The Stokes parameters Q, U & V.



file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 2 RXY buff 10

sources :

0237-233

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 28 BUFF 2 PHASE REF. BUFF 1 buff 6

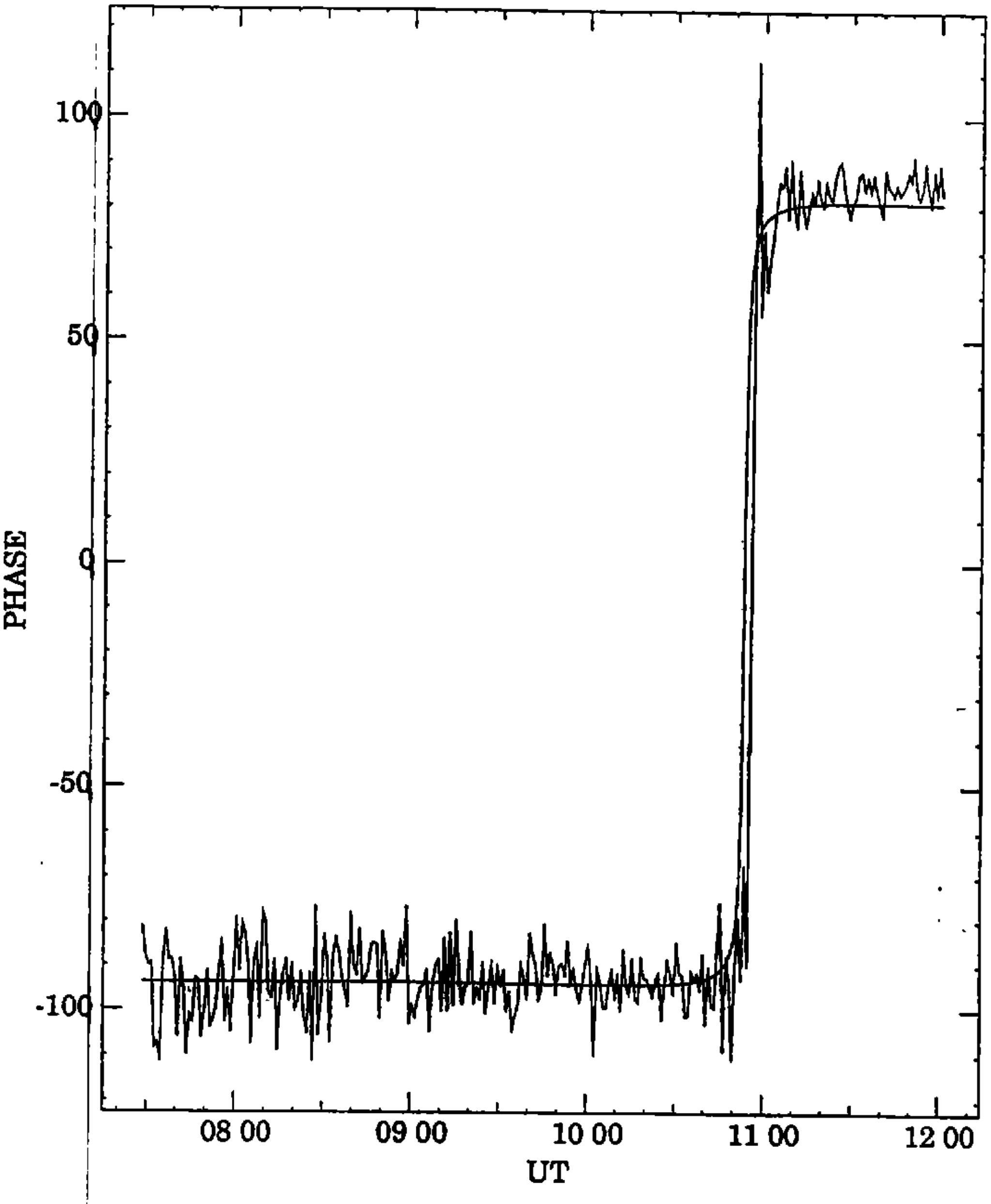
sources :

0237-233

Frequency: 4800.00 MHz

12-APR-89 00:26:23

Figure 1 a



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Channel id : 2 RXY buff 10

sources :

0237-233

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 28 BUFF 2 PHASE REF. BUFF 1 buff 6

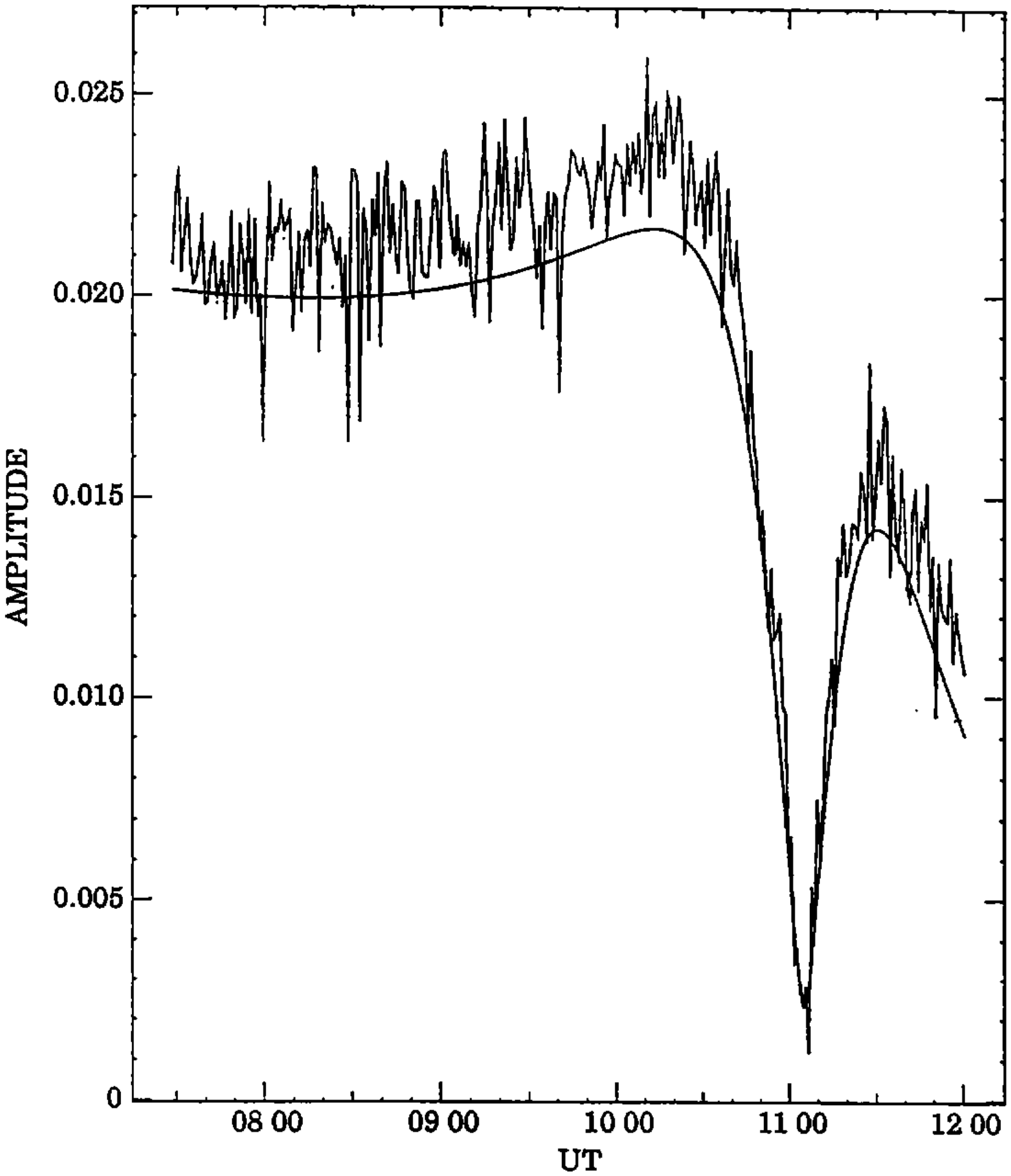
sources :

0237-233

Frequency: 4800.00 MHz

12-APR-89 00:26:29

Figure 1b



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Channel id : 3 RYX buff 11

sources :

0237-233

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 28 BUFF 3 PHASE REF. BUFF 1 buff 7

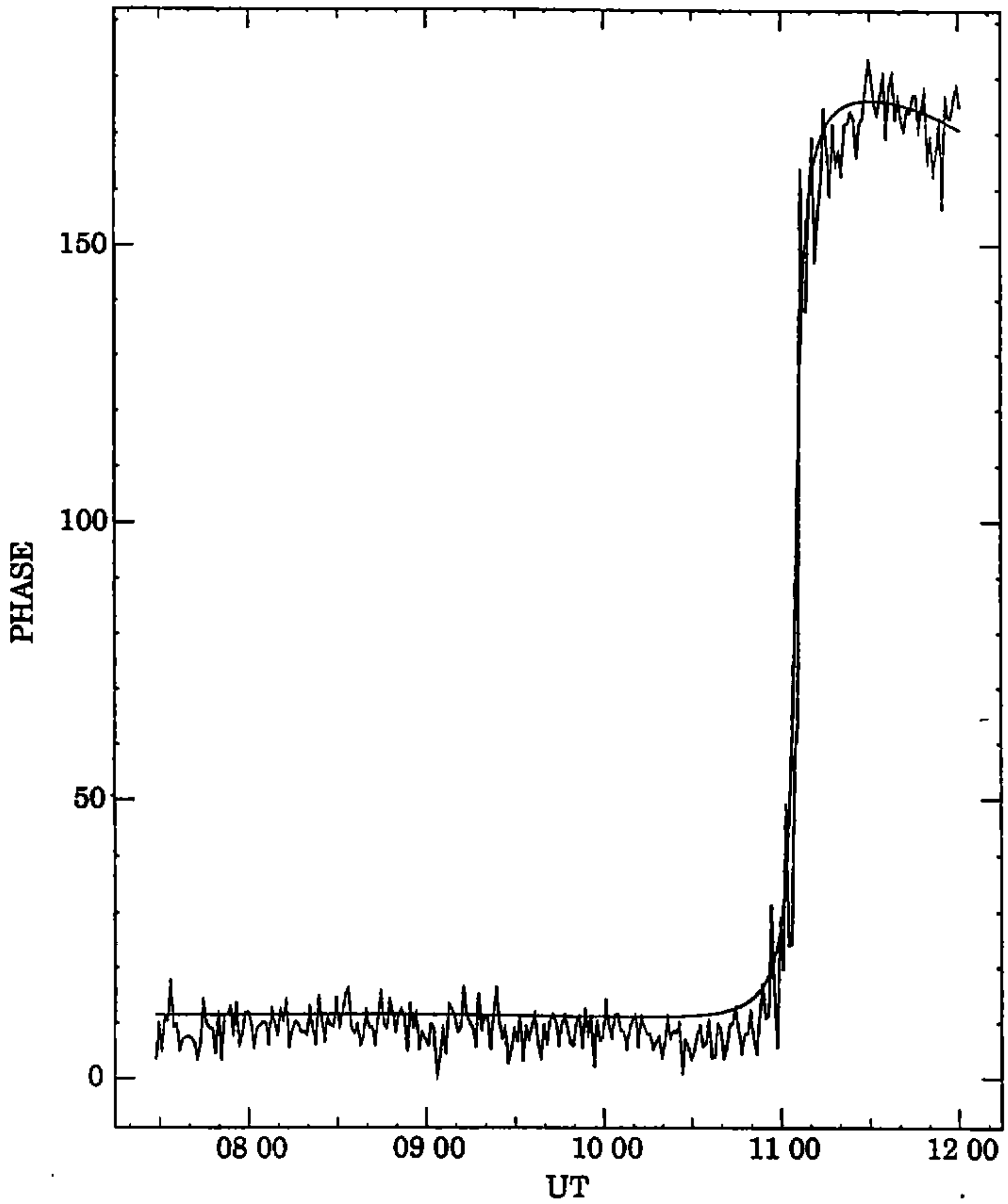
sources :

0237-233

Frequency: 4800.00 MHz

12-APR-89 00:25:59

Figure 2a



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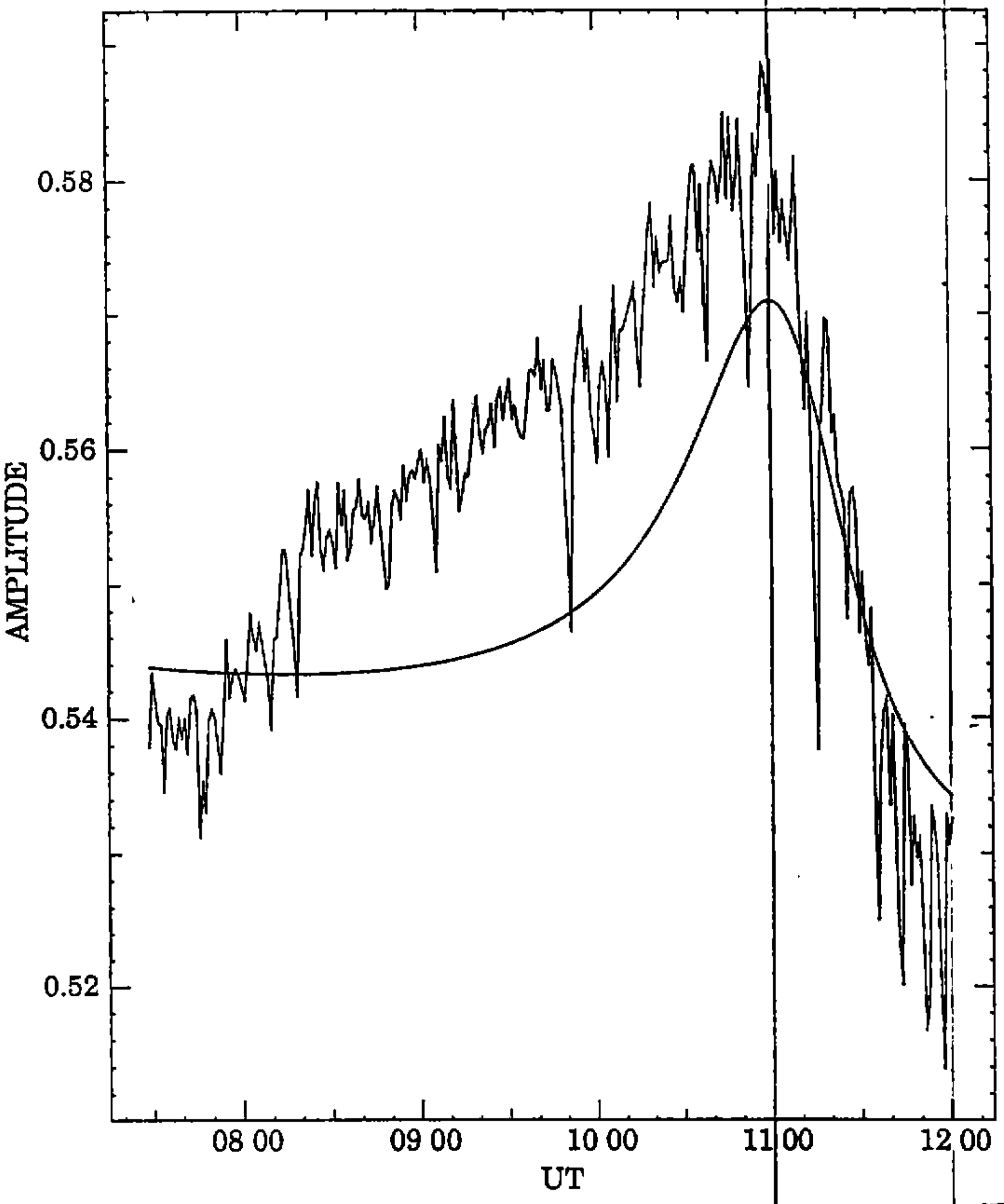
Channel id : 3 RYX buff 11
sources :
0237-233
file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 28 BUFF 3 PHASE REF. BUFF 1 buff 7
sources :
0237-233

Frequency: 4800.00 MHz

12-APR-89 00:26:03

Figure 2 b



Source

I = .54 Jy
3.75 % linear
at 150°
0 % circ

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 1 Rxy   buff 9

sources :
0237-233

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 28 BUFF 1 PHASE REF. BUFF 1 buff 5

sources :
0237-233

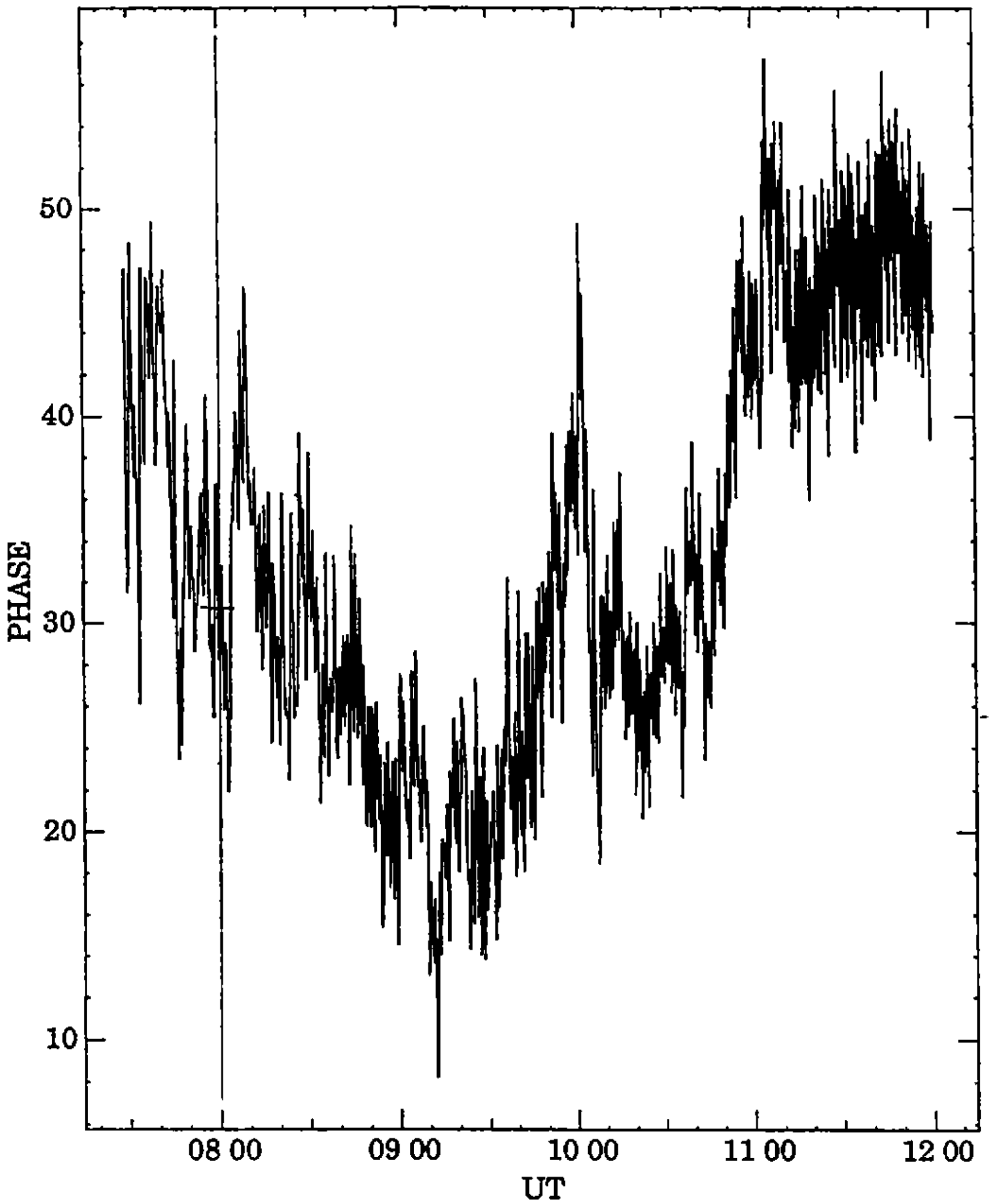
Frequency: 4800.00 MHz

10-APR-89 17:10:10

Antennas:

45.4	.09	1.04	20
135.25	-.12	1.02	-155
44.75	-.12	.98	20
134.60	.09	.96	-62.5

Figure 3a



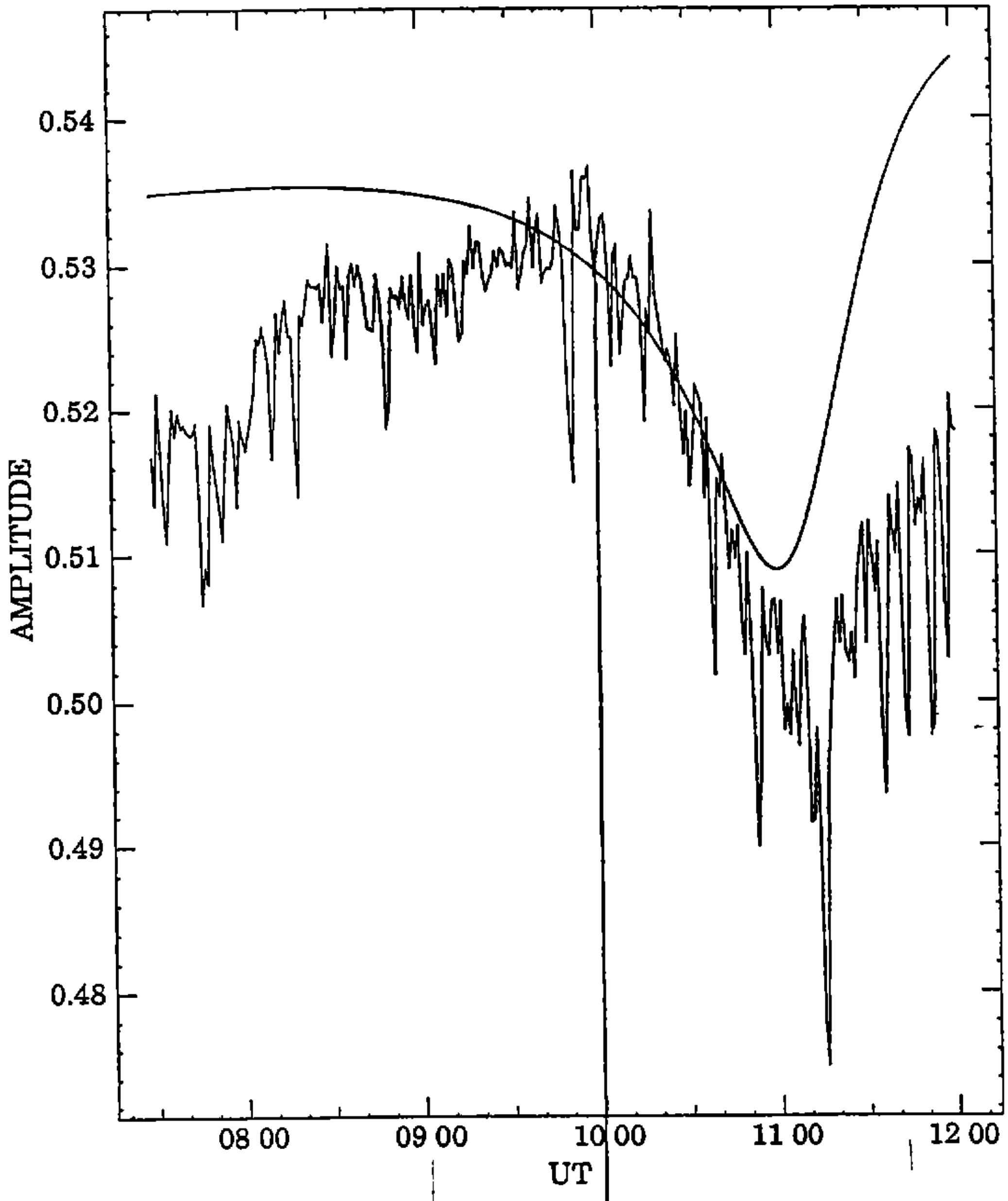
file : CUL2:[CAOBS.DAT]14DEC_06
from channel 4 to 28
sources :
0237-233

Frequency: 4800.00 MHz

28-FEB-89 13:59:26

Figure 3 a

Rxx I



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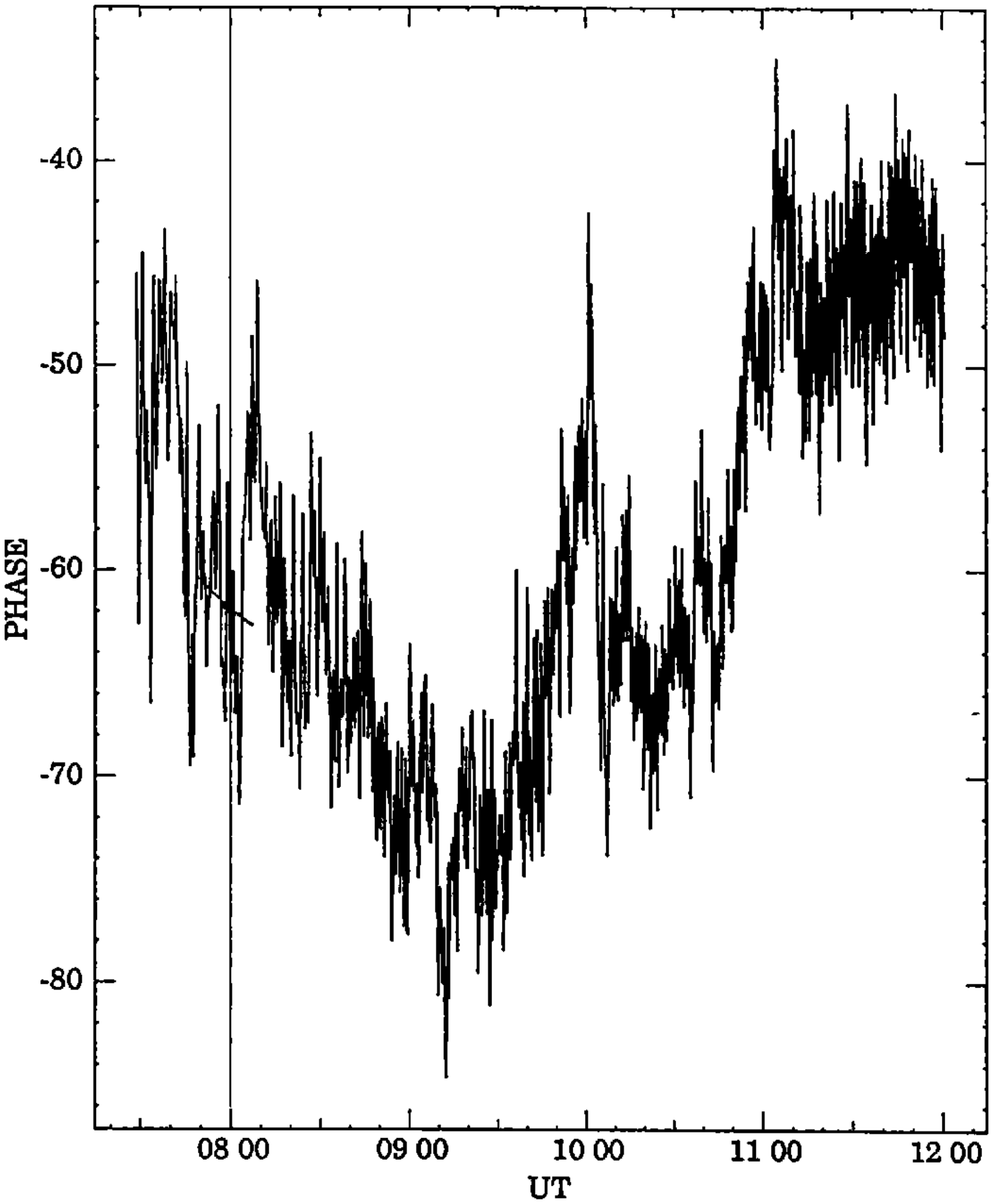
Channel id : 4 R YY buff 12
sources :
0237-233
file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 28 BUFF 4 PHASE REF. BUFF 1 buff 8
sources :
0237-233

Frequency: 4800.00 MHz

10-APR-89 17:10:59

Figure 4



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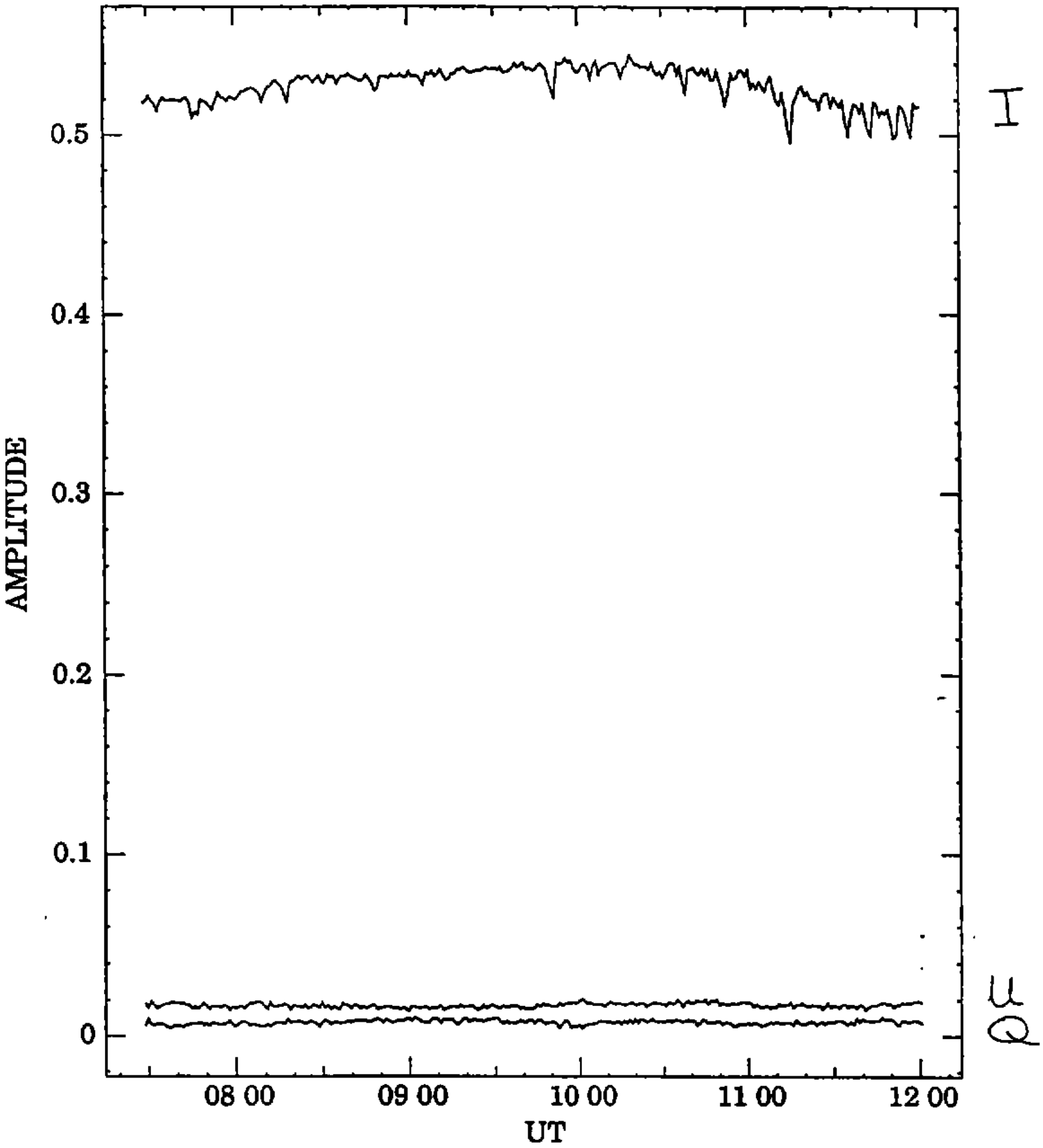
0237-233

Frequency: 4800.00 MHz

28-FEB-89 14:01:16

Figure 4b

Ryy



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Channel id : 1 I buff 13
sources :
0237-233
file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

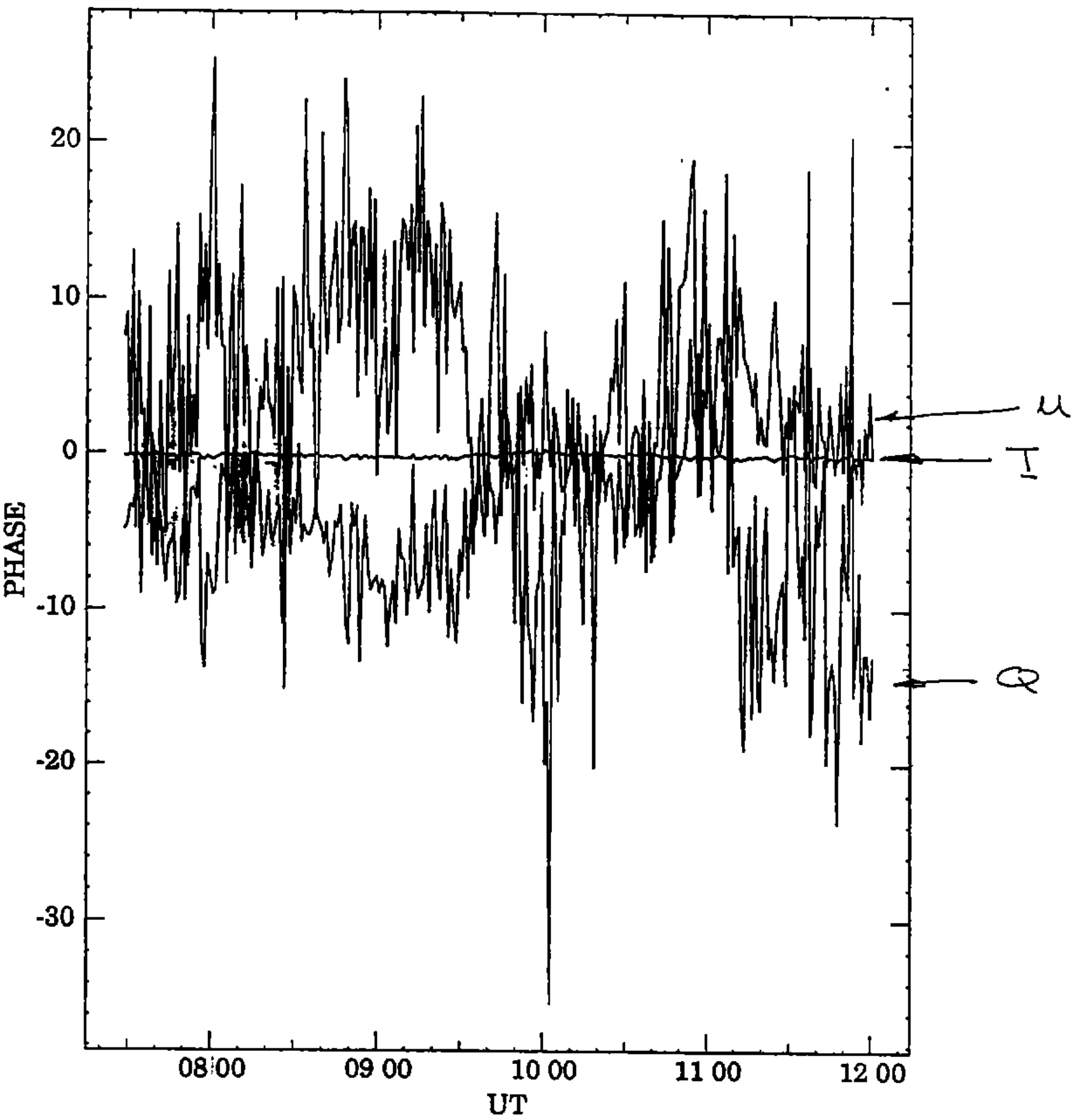
Channel id : 2 Q buff 14
sources :
0237-233
file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 3 U buff 15
sources :
0237-233

Frequency: 4800.00 MHz

12-APR-89 00:31:04

Figure 5a



file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 1 I buff 13

sources :

0237-233

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 2 Q buff 14

sources :

0237-233

file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 3 U buff 15

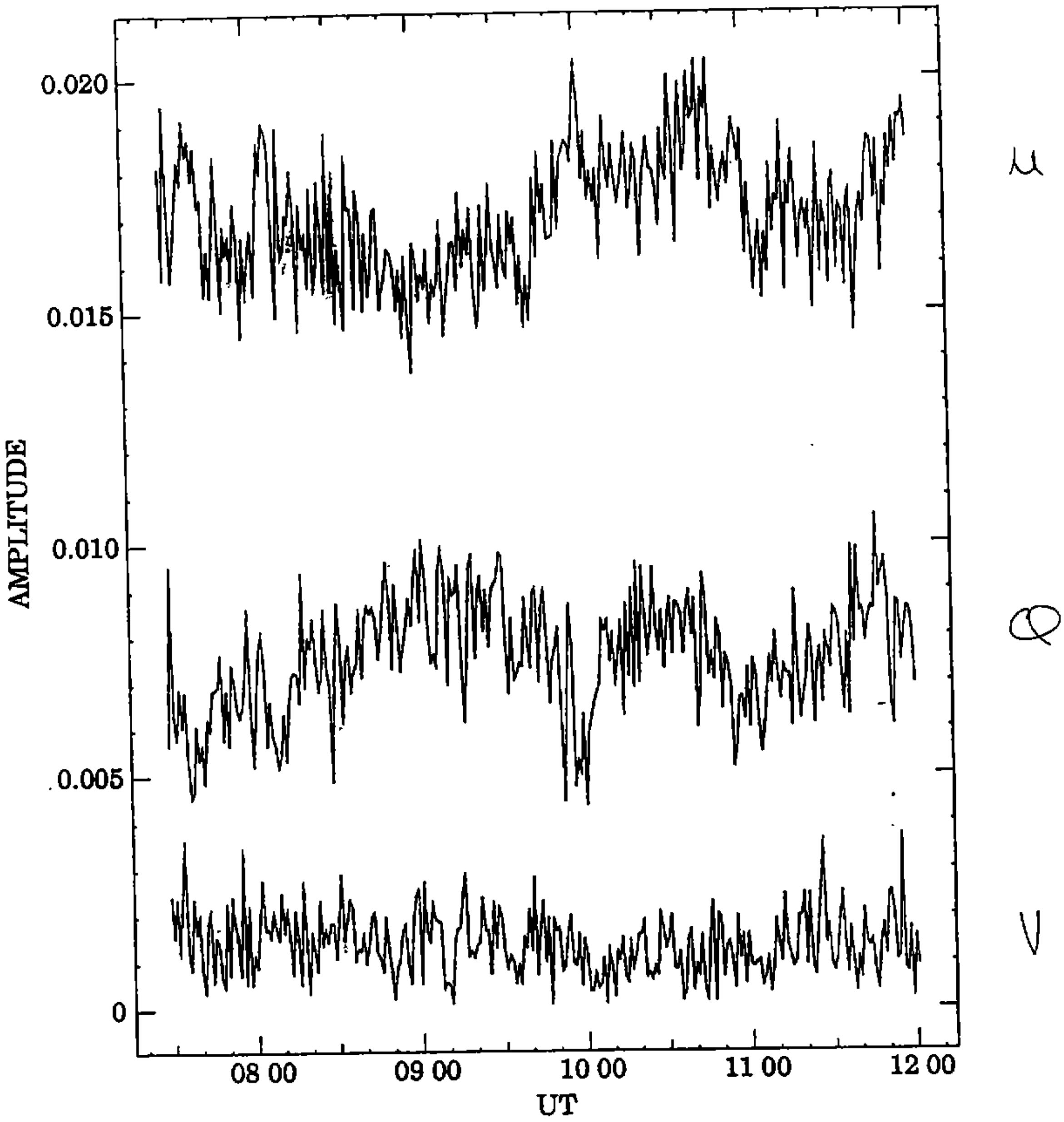
sources :

0237-233

Frequency: 4800.00 MHz

12-APR-89 00:31:09

Figure 5 b



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Channel id : 2 Q buff 14
sources :
0237-233
file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 3 U buff 15
sources :
0237-233
file : CUL1:[MKESTEVE.POLARISATION]14DEC_06

Channel id : 4 V buff 16
sources :
0237-233

Frequency: 4800.00 MHz

12-APR-89 00:31:35

Figure 6