NRAO TUCSON INTERNAL REPORT
MEMO NO. 7

National Radio Astronomy Observatory
Tucson, Arizona

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MEMORANDUM

To: NRAO Tucson Internal Report Series

From: P. R. Jewell

Subject: 12 m Antenna Performance at 345 GHz during the 1988 Observing Season

I. Introduction

This report summarizes the results of antenna performance measurements at 345 GHz during the 1988 season, including the results with the new, shaped subreflector machined at the University of Texas. Specifically, this report contains measurements of

- Aperture efficiency
- Beam efficiency
- Rear spillover efficiency
- Beam shape
- Beam width as a function of radial focus (astigmatism test).

II. Aperture Efficiency

Table 1 lists a series of aperture efficiency measurements made during the season using both the old and new subreflectors.

Table 1

Aperture Efficiencies

Date	Subreflector	Source	Meas. T_A	Calc. Flux	η_A
15 Feb 88	Old	Jupiter	16.0	6774	0.058
18 Feb 88	Shaped	Jupiter	23.8	6729	0.086
24 Feb 88	Shaped	Jupiter	17.3	6644	0.064
24 Feb 88	Shaped	Venus	4.58	4619	0.024
23 Mar 88	Shaped	Jupiter	8.94	6318	0.035
29 Mar 88	Old	Venus	4.40	8172	0.018
29 Mar 88	Old	Jupiter	5.46	7574	0.013

To calculate the fluxes, I assumed disk brightness temperatures of 164 K for Jupiter and 300 K for Venus. For the measurements from 15 Feb through 23 Mar, I assumed that the FWHM of the beam was 24". For the 29 Mar, I assumed a FWHM of 30" based on the astigmatism measurements discussed below. The drop-off in efficiencies are discussed at the end of this document. I note that on the day the shaped subreflector was installed (17 Feb 88), we experimented with the position of the North-South Translation Stage and were able to increase the measured flux density by over 30%. This improvement is not included in the aperture efficiencies quoted above.

III. Corrected Beam Efficiency

On 24 February 1988 I measured the corrected beam efficiency, defined as the fraction of power in the main beam relative to the error beam. This measurement is made by observing a planet with the spectral line system by measuring the DC offset of the planet in the filter bank. The data are calibrated with the chopper wheel and are on the T_R* scale which corrects for the atmosphere and the rear and forward spillover. It does not correct for any beam response within a disk the size of the Moon. The ratio of the measured T_R*, corrected for geometric coupling of the source to the beam, to the brightness temperature of the planet gives the fraction of power in the main beam relative to the error beam. The calibration scale factor was computed for a source with double sideband emission (TC = 400). The measurements were made in the beam-switched mode which, for reasons unknown, gave higher T_R*'s than did the position-switched mode. The results are given in Table 2.

Table 2

Corrected Beam Efficiency

Source	T_R*	η_C*	T_B	η_M*
Venus	16.1	0.284	300	0.189
Jupiter	32.1	0.763	164	0.256

In Table 2, η_C* is the geometric coupling efficiency and η_M* is the corrected beam efficiency. My best estimate of η_M* from measurements made in 1986 was 0.27.

IV. Rear Spillover Efficiency

The rear spillover, blockage, and ohmic loss efficiency, η_ℓ, was fit from tipping scan measurements. The measurements are listed in Table 3 and a fitted tipping scan is shown in Figure 1.

Table 3

Warm Spillover Efficiency

Date	Subreflector	η_ℓ	τ_o
23 Feb 88	Shaped	0.704 ± .013	0.505 ± .011
23 Mar 88	Shaped	0.796 ± .001	0.876 ± .001
29 Mar 88	Old	0.740 ± .009	0.312 ± .007

For the above fits, I assumed that the mean atmospheric temperature was 97% of the ambient temperature (FTM = 0.97) and that the spillover temperature was 95% of ambient temperature (FTSBR = 0.95). The results reported were for Receiver Channel 1 only. Fits for η_ℓ in Channel 2 were similar although the fitted opacity in Channel 2 (τ_o) was systematically smaller by about 15%.

On 23 Mar 1988 I measured the coupling of the beam to the subreflector by holding a large piece of absorber over the subreflector and comparing the response to that of the sky and the absorbing vane in the receiver box. The observations were with the shaped subreflector. The results are given in Table 4.

Table 4

Subreflector Coupling Efficiency

Measurement	Voltage Chan. 1	Voltage Chan. 2
Absorber over Subreflector	3.420	3.067
Sky	3.391	3.031
Regular Vane	3.427	3.076
$\frac{\text{[Absorber - Sky]}}{\text{[Vane - Sky]}}$	0.806	0.800

V. Beam Maps

On 24 Feb 1988 I made maps of Jupiter using the shaped subreflector. Note that on that date Jupiter had a diameter of 35", which is larger than the beam FWHM. The maps were taken in the dual-beam mode and were restored using NOD2 software. The fitted beamwidths are (Az x EL) 35" x 29" for Channel 1 and 35" x 28" for Channel 2. The maps are displayed in Figures 2 and 3. The contour levels are drawn at 5% increments.

VI. Measurements of Astigmatism

We made a series of measurements of the azimuth and elevation beamwidths as a function of radial focus throughout the season, with both the old and new subreflectors. The observations were made on

10 Feb 1988	Old Subreflector
17 Feb 1988	New Subreflector
23 Mar 1988	New Subreflector
29 Mar 1988	Old Subreflector

The curves are plotted in Figures 4 through 7. The 10 Feb 88 measurement (Fig. 4) with the old subreflector shows the classic sign of astigmatism: the beam in one coordinate is at a maximum at the focus for which the other is at a minimum, and vice versa. The 17 Feb 88 measurement (Fig. 5) with the new subreflector shows a much different shape although not that of two coincident parabolas that we might expect for a perfect dish with no astigmatism. On 23 Mar 88 with the shaped subreflector (Fig. 6), the curves looked almost like that of the 10 Feb 88 measurement with the old subreflector. This measurement, together with the drop-off in efficiencies prompted us to remove the new subreflector to see if it was deforming. To confuse matters, the curves of 29 Mar 88 with the old subreflector (Fig. 7) are different from the 10 Feb 88 measurements.

VII. Discussion

The results of system performance during the 1988 high frequency season are inconsistent and puzzling. The new, shaped subreflector definitely improved the antenna efficiencies, at least at the time it was installed. Unfortunately, the aperture efficiency seemed to drop off throughout the season and the improvement in astigmatism also disappeared. When the old subreflector was reinstalled, its efficiencies were also diminished, however. The drop-off in efficiencies could have two broad interpretations:

1. The drop-offs are real and are caused by

   a) degradation of the primary, or
   b) degradation of the secondaries (both new and old), or
   c) some other error in telescope optics.

2. The drop-offs are not real and are caused by
   a) Errors in the calibration scale or measurement technique, or
   b) errors in the calculated flux densities of the planets.

The flux density calculations may be suspect because of the inaccurately known planetary brightness temperatures (although that shouldn't matter for relative measurements) or because of errors in the correction of the flux for an object larger than the beam (Jupiter). The change in astigmatism characteristics suggest a real change in the telescope, however.

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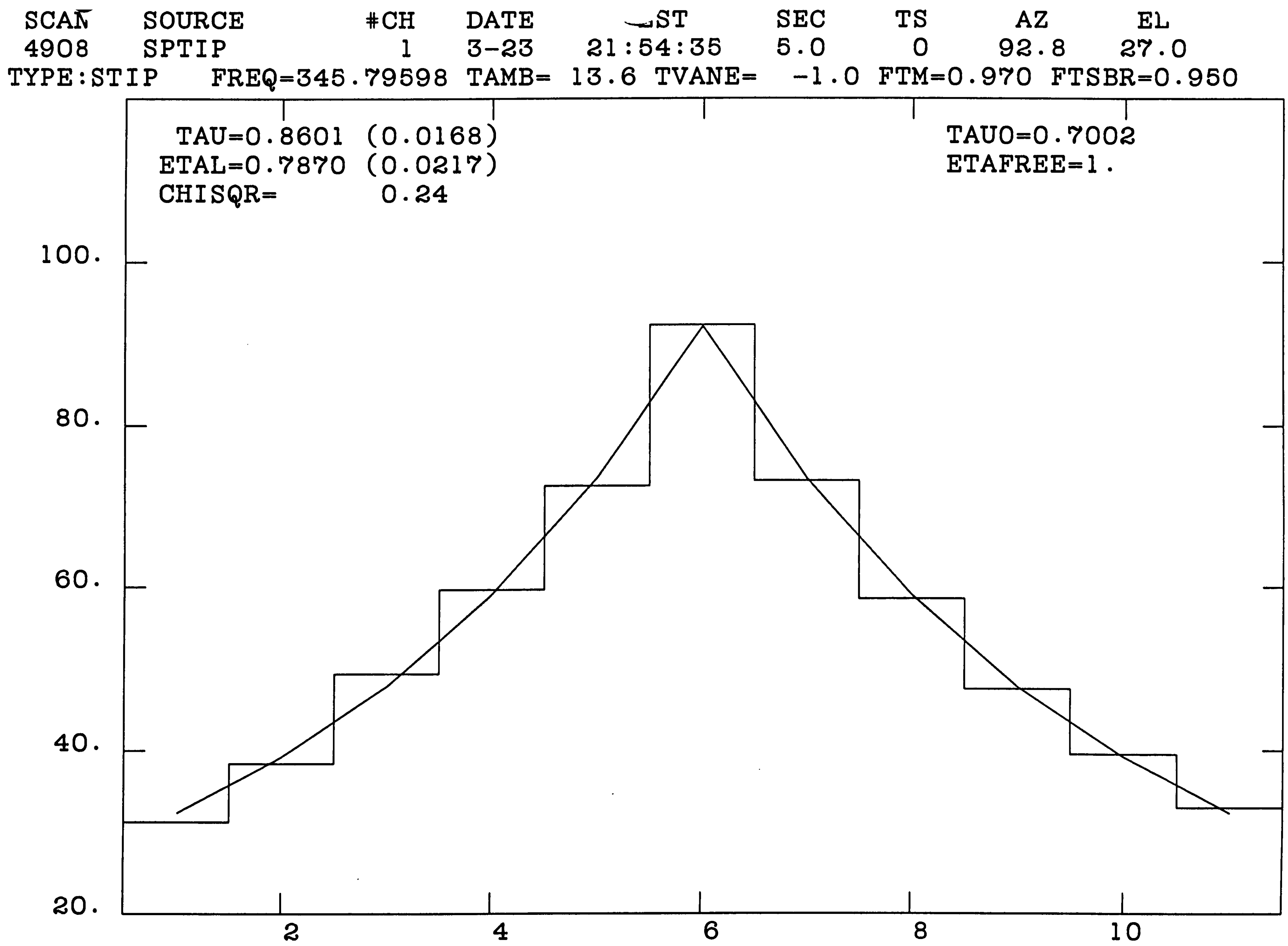
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40.
20.
2
4
6
8
10

FIGURE 1

Jupiter at 345 GHz (Feb 1988, ch. 1)

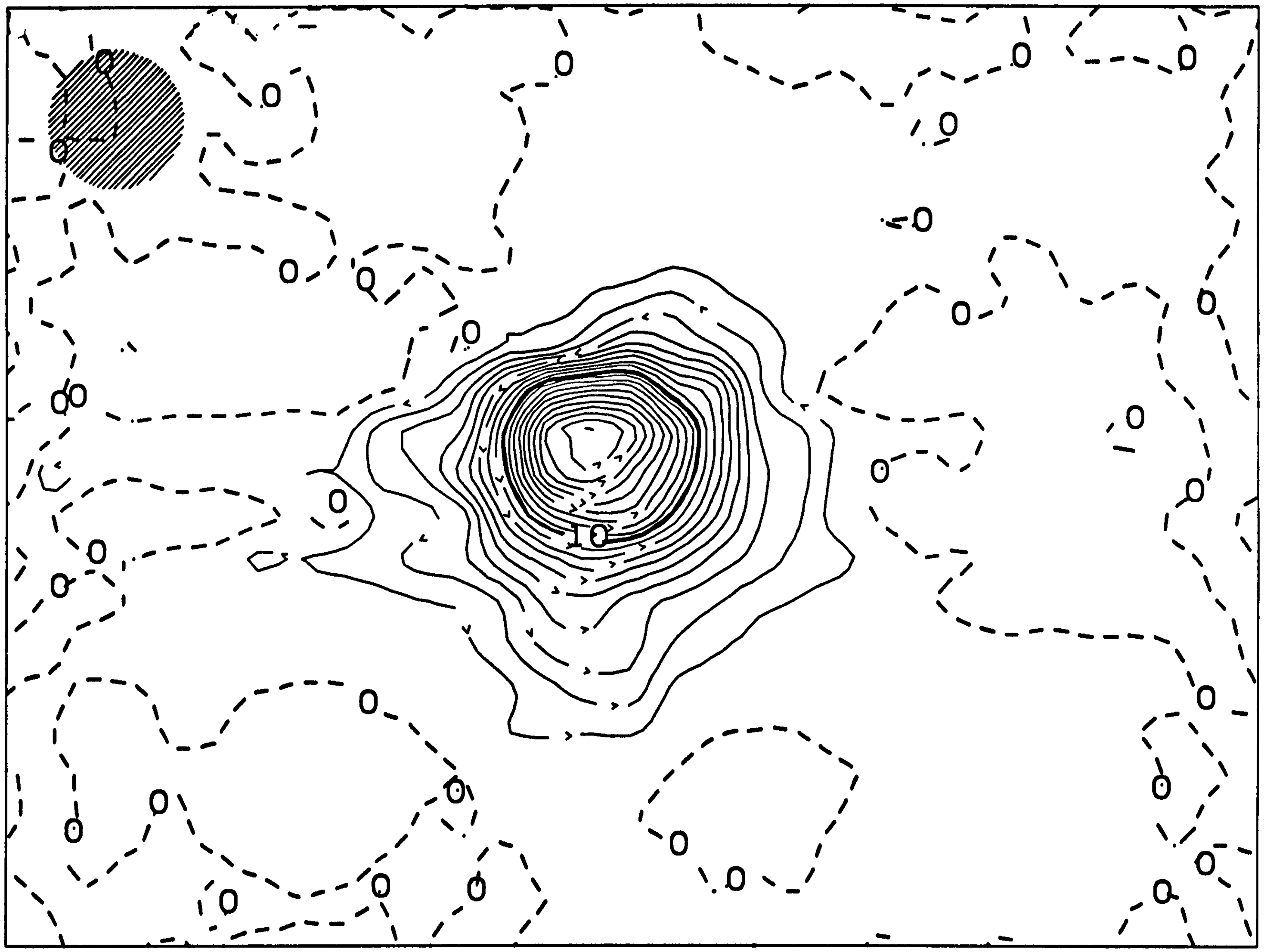


FIGURE 2

Jupiter at 345 GHz (Feb 1988, ch. 2)

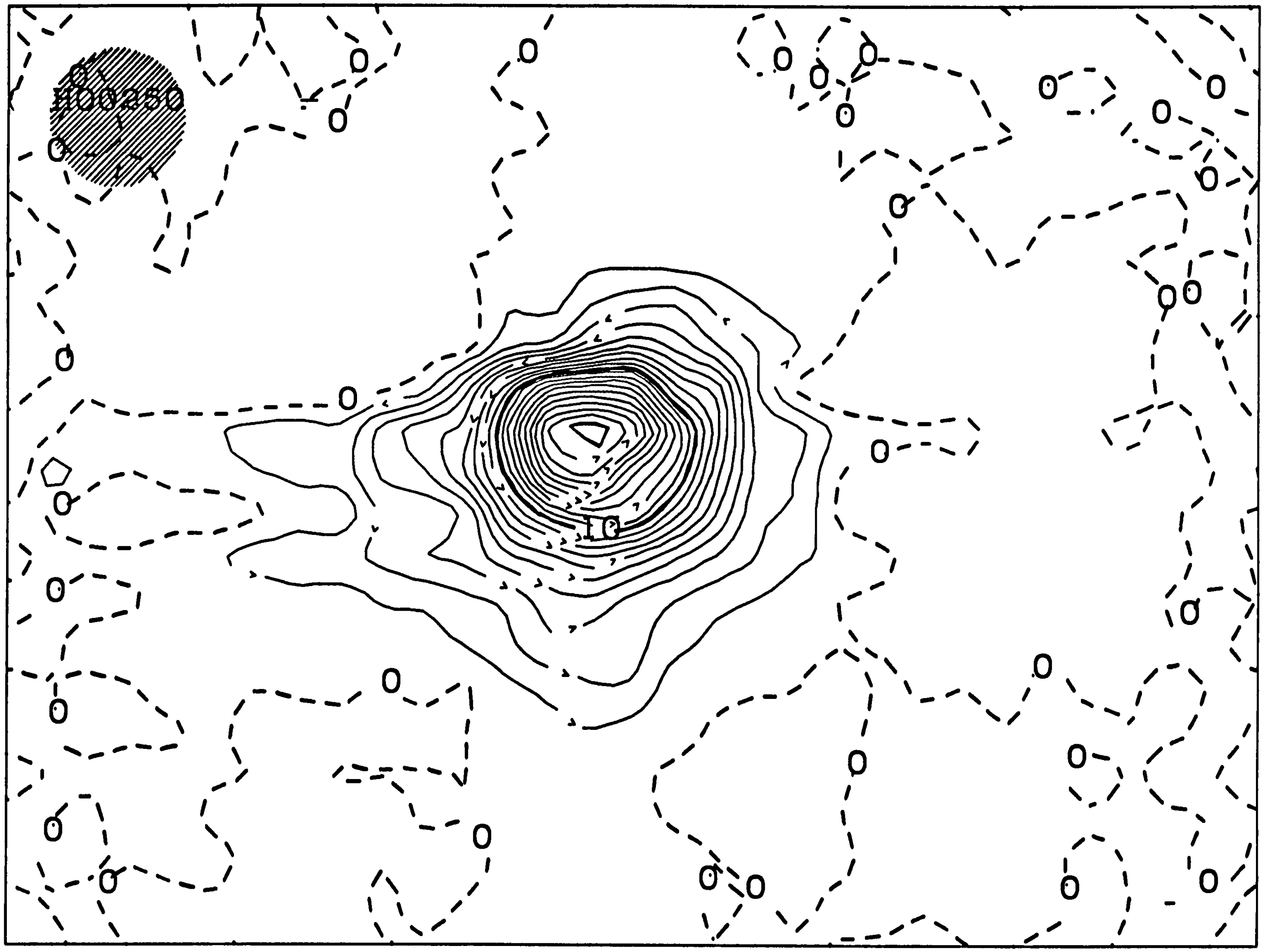


FIGURE 3

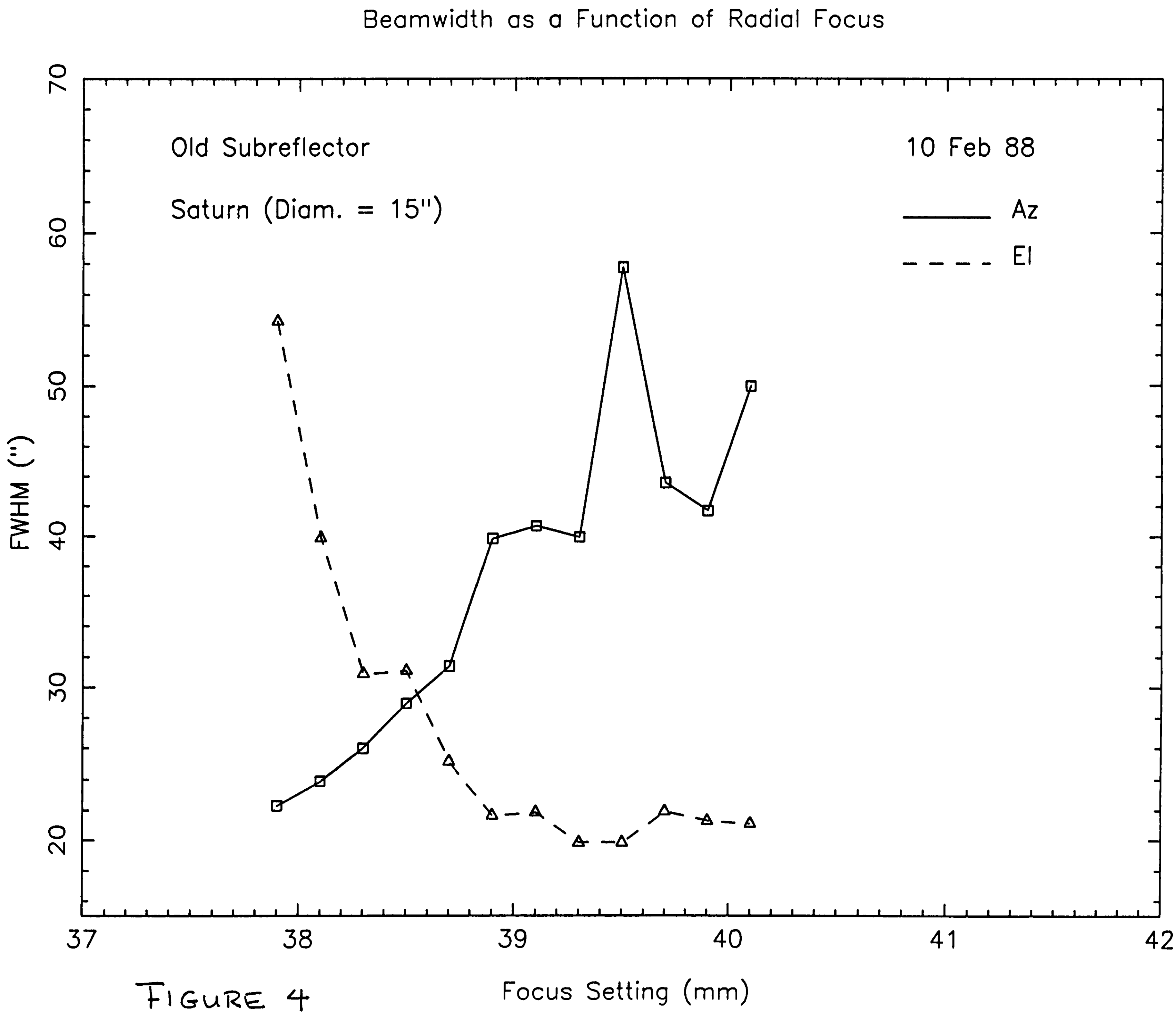
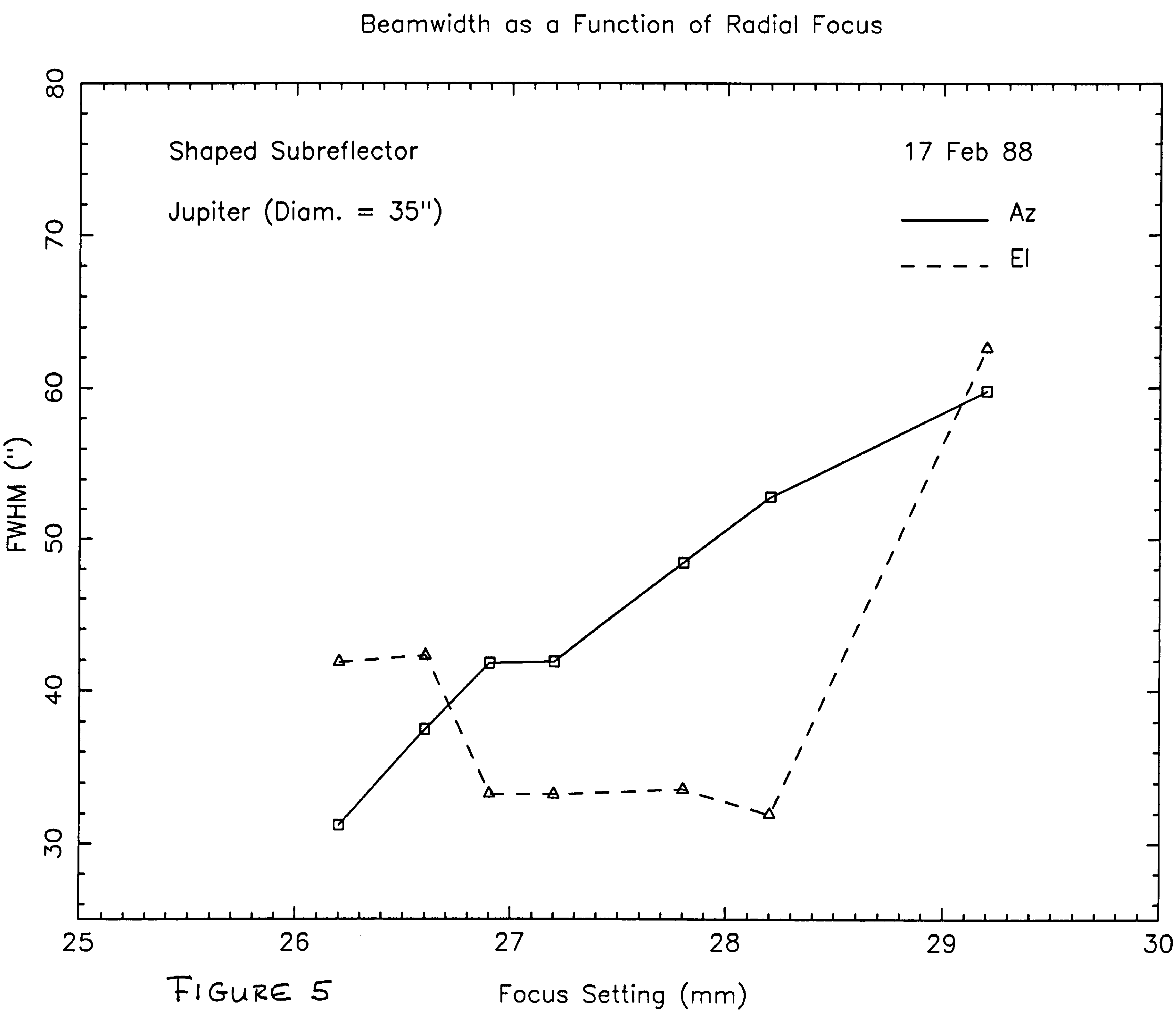

Beamwidth as a Function of Radial Focus
Old Subreflector
Saturn (Diam. = 15")
10 Feb 88
Az
El
FWHM (")
Focus Setting (mm)
20
30
40
50
60
70
37
38
39
40
41
42

FIGURE 4



Beamwidth as a Function of Radial Focus
Shaped Subreflector
Jupiter (Diam. = 35")
17 Feb 88
Az
El
FWHM (")
Focus Setting (mm)
30
40
50
60
70
80
25
26
27
28
29
30

FIGURE 5

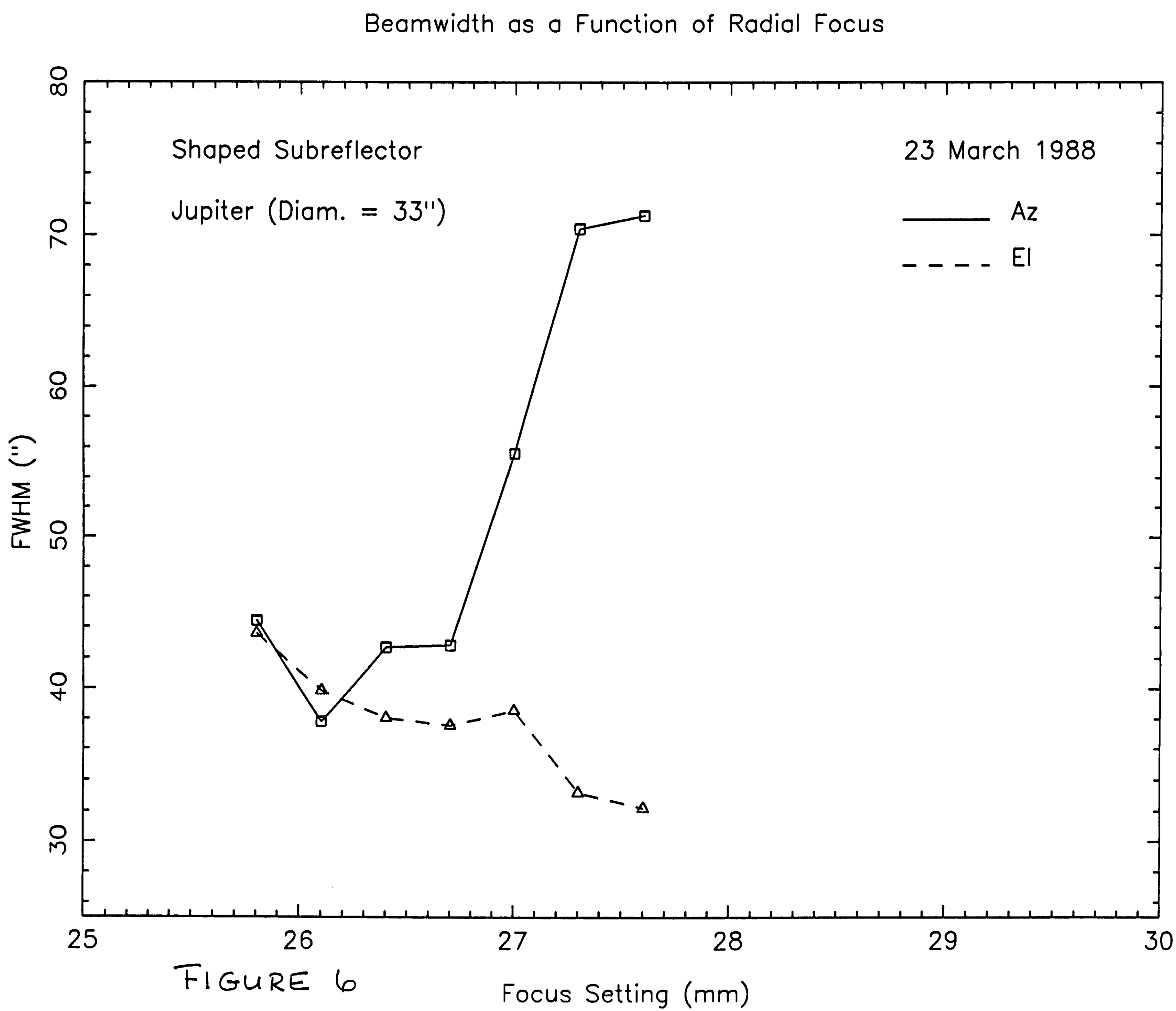

Beamwidth as a Function of Radial Focus
Shaped Subreflector
Jupiter (Diam. = 33")
23 March 1988
Az
El
FWHM (")
30
40
50
60
70
80
25
26
27
28
29
30
Focus Setting (mm)

FIGURE 6

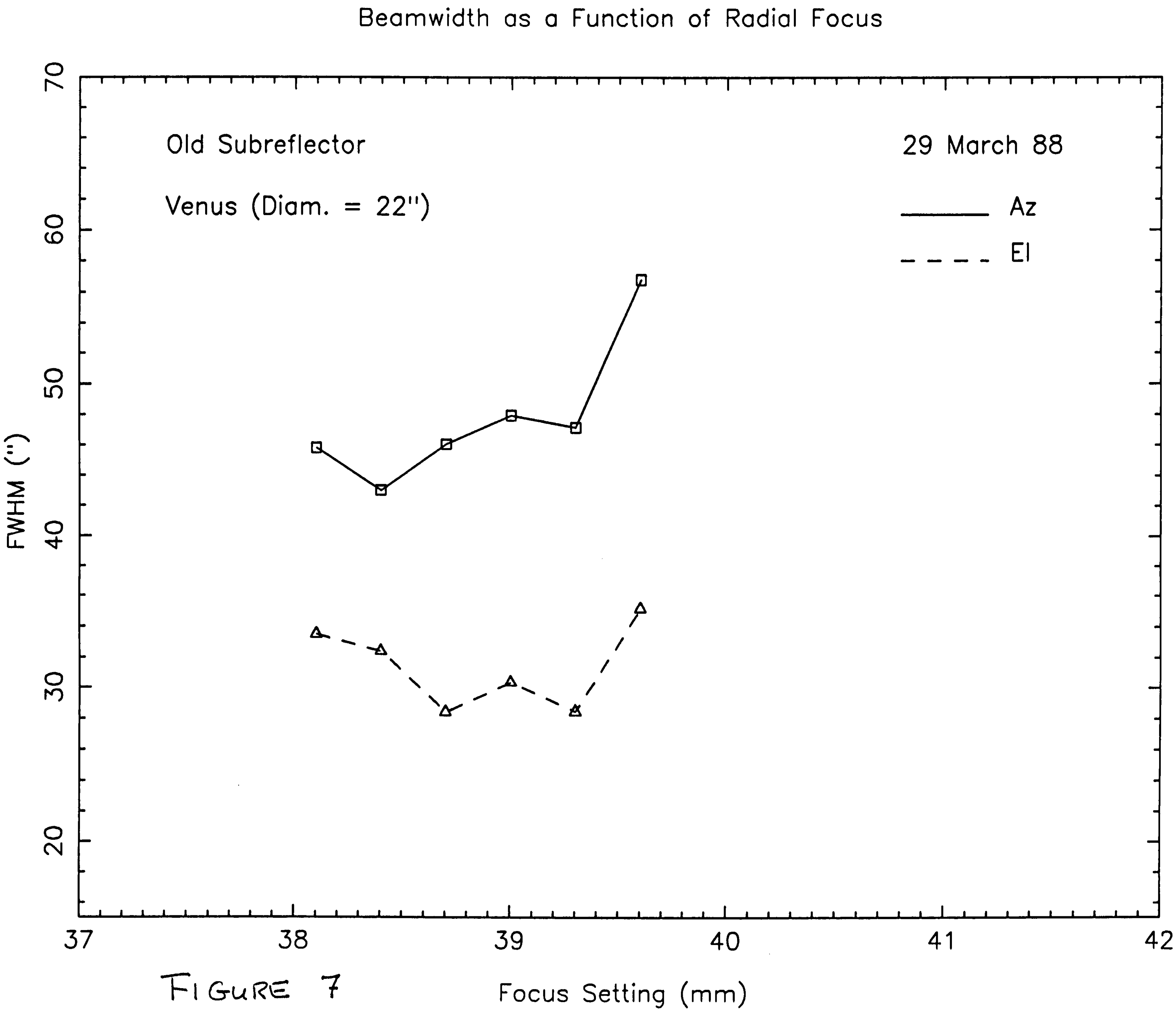

Beamwidth as a Function of Radial Focus
Old Subreflector
Venus (Diam. = 22")
29 March 88
Az
El
FWHM (")
70
60
50
40
30
20
37
38
39
40
41
42
Focus Setting (mm)

FIGURE 7