PRE-COSTAR FOS APERTURE THROUGHPUT VARIATIONS DUE TO OTA FOCUS CHANGES

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ABSTRACT

Since the throughput of the FOS entrance apertures depends on the HST focus, estimates of absolute fluxes from observed count rates require a correction for focus effects. For the larger apertures, the throughput is nearly independent of wavelength, while for the smaller apertures, the dependence on wavelength is important. Differences in the red and blue side transmissions are typically less than 1% for the same aperture and wavelength. Since January 1991, the historic record of the effect of desorption on the HST focus shows deviations of -25 to +15 microns from the nominal value. The 4.3 arcsec aperture throughput observed by a 1.43 arcsec high diode array varies by approximately 10% over this range. The 1.0 arcsec aperture suffers the worst photometric throughput variations of nearly 20%. Throughput corrections are modeled using calculations of the aberrated PSF at the FOS entrance apertures in conjunction with a desorption model and a history of secondary mirror movements.

This correction procedure will leave OTA breathing as a dominant source of photometric uncertainty, which can still be almost 10% in the 1.0 arcsec aperture.

THROUGHPUT VARIATIONS WITH FOCUS

Figure 1 is a plot of the HST focus position versus time, computed using a desorption model by Hasan (1993). The focus position is given in microns from the nominal focus and has varied between -25 to +15 microns since January 1991. Since January 1993 the focus has remained within 5 microns of the nominal position. Extrapolation of the desorption model shows that the focus will remain within 5 microns of nominal until the end of 1993.

As the focus changes, the throughput of the FOS apertures varies. The Telescope Image Modeling (TIM) version 27 software package (Burrows, 1991) is used to compute a point spread function (PSF) for three wavelengths at the positions of the FOS entrance apertures for the red and blue sides. The throughput for each aperture is computed by integrating the PSFs over the area of the FOS apertures. For the 4.3 arcsec square aperture and the 0.25 x 2.0 arcsec slit, the area is limited to only the portion observed by a 1.43 arcsec high diode array. For the blue and red sides, respectively, Figures 2 and 3 show the computed throughput for a target centered in the 4.3 arcsec square aperture, the 0.25 by 2.0 arcsec slit, and the 1.0 and 0.3 arcsec diameter circular apertures. The focus variations for the 4.3 and 1.0 arcsec apertures are approximately linear and show little wavelength dependence (less than 1 percent for the 4.3 arcsec aperture and 3 percent for the 1.0 arcsec aperture). The slit and the 0.3 arcsec aperture both show curvature versus focus position and significant variation with wavelength.

PROPOSED CORRECTION TECHNIQUE

Using average inverse sensitivity curves for the 4.3 arcsec aperture and a model of time variations in the inverse sensitivity curves due to changes in the efficiencies of the detectors and optical elements (Lindler and Bohlin (1993), the following process can be used to convert an observed net count rate spectrum taken in an arbitrary aperture to absolute flux units.

1) Correct the net count rates to nominal focus=0 position using the throughput changes for the aperture as a function of focus (see Table 1). Table 1 gives the computed throughput variations for the 5 most used FOS apertures relative to the nominal focus position. The focus position can be computed for the observation date using the data plotted in Figure 1.

2) Compute the expected count rates for the 4.3 arcsec aperture using the relative aperture throughputs at the nominal focus. The relative aperture throughputs computed for TIM point spread functions are tabulated in Table 2. However, relative throughputs from observed data may be more accurate (Bohlin 1993).

3) Multiply the count rates computed for the 4.3 arcsec aperture by the average inverse sensitivity curve for the 4.3 arcsec aperture.

4) Correct for time variations in the sensitivity using the time changes in the efficiencies of the detector and optical elements determined for nominal focus (Lindler and Bohlin 1993).

A significant source of error in applying the above process is the Optical Telescope Assembly (OTA) "breathing", which is short term variation in the telescope focus. Monitoring of the breathing shows focus variations up to 14 microns from the focus position predicted with the desorption model (Hasan 1993). A 14 micron error in the predicted focus position can result in a 5 percent error in the throughput estimate for the 4.3 arcsec aperture and almost a 10 percent error for the 1.0 arcsec circular aperture. Analysis of the FOS sensitivity monitoring data corrected to nominal focus with our calculated throughputs show deviations from a smooth model of time dependent efficiency variations that are on the same order as those expected due to

OTA "breathing" (Lindler and Bohlin 1993)

A second source of error, which we can not presently quantify, is in the model PSFs computed by TIM. These errors may be signficant in the computation of the actual throughput values (Table 2). Since our correction process only uses the throughput variations relative to the nominal focus (Table 1), the errors in the model may not be significant when compared to other error sources including OTA "breathing", errors in centering the target in the aperture, and errors in the YBASE of the spectral observations.

REFERENCES

Bohlin, R. 1993, FOS Instrument Science Report, in preparation.

Burrows, C. and Hasan, H. 1991, Telescope Image Modelling User Manual, Version 7, Release 25 and updates through Release 27.

Hasan, H. 1993, Instrument Science Report, No. OTA 12.

Lindler, D. and Bohlin, R. 1993, FOS Instrument Science Report, in preparation.

FIGURE CAPTIONS

Fig. 1 -- A plot of the history and extrapolation of the HST focus position versus time computed using the desorption model computed by Hasan (1993). The position is given in microns from the nominal focus.

Fig. 2 -- A plot of the relative throughput observed with a 1.43 arcsec high diode array for the FOS Blue Side 4.3 arcsec square, 0.25 x 2.0 arcsec slit, and 1.0 and 0.3 arcsec circular apertures versus focus position computed from model point spread functions. The focus position is given in microns from the nominal position.

Fig. 3 -- same as Fig. 2 for the Red Side.

Fig. 1

HST FOCUS HISTORY

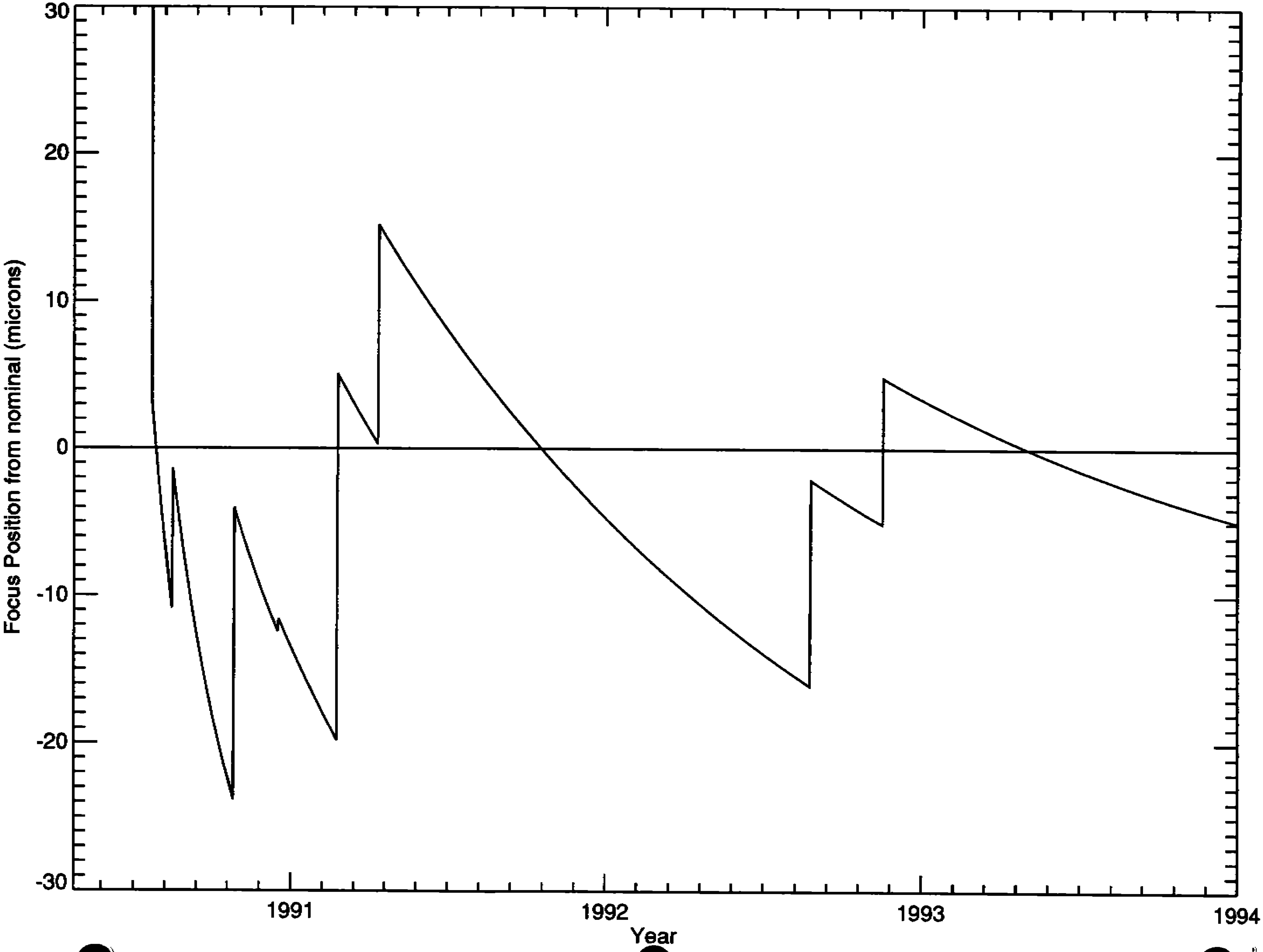


Fig. 2

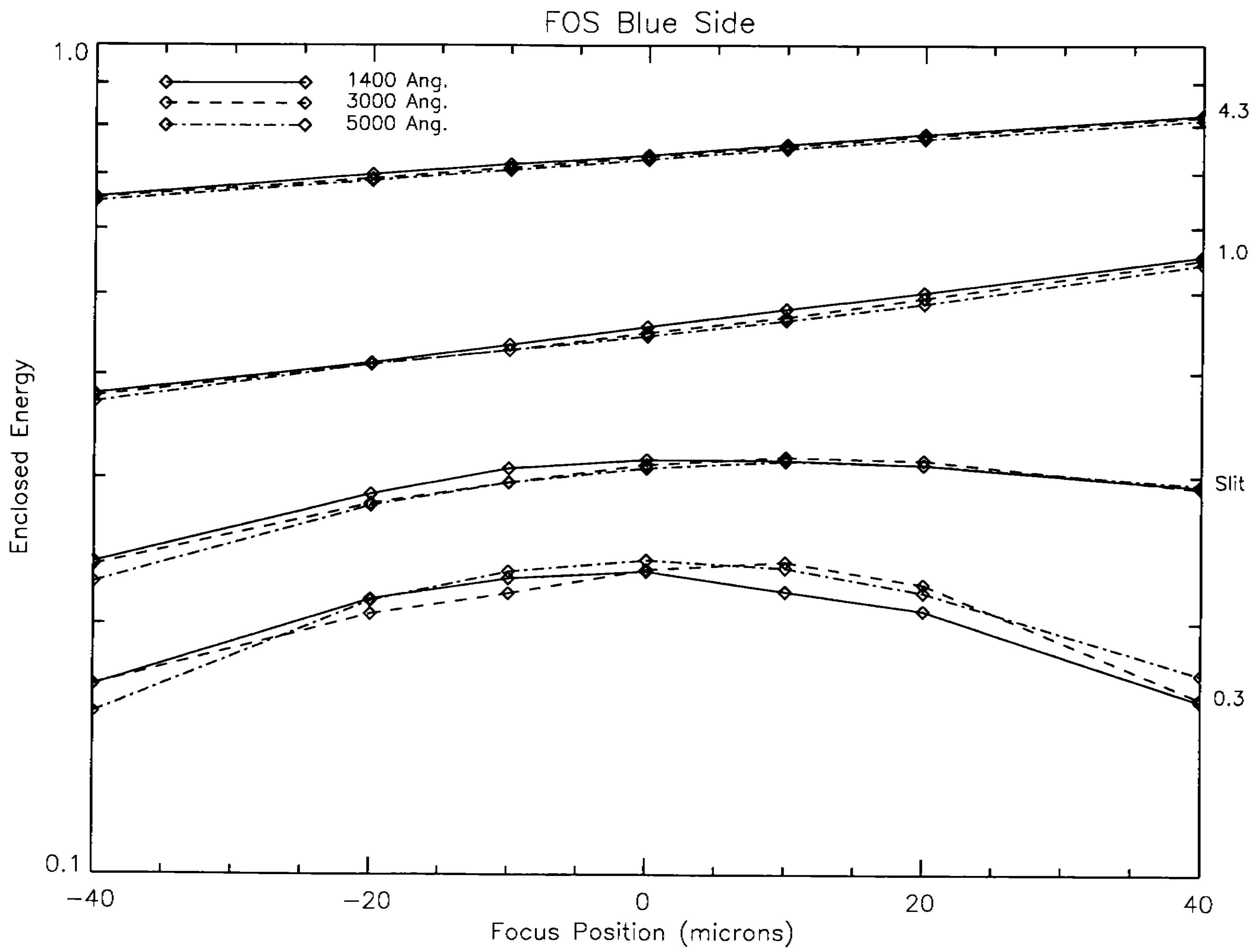
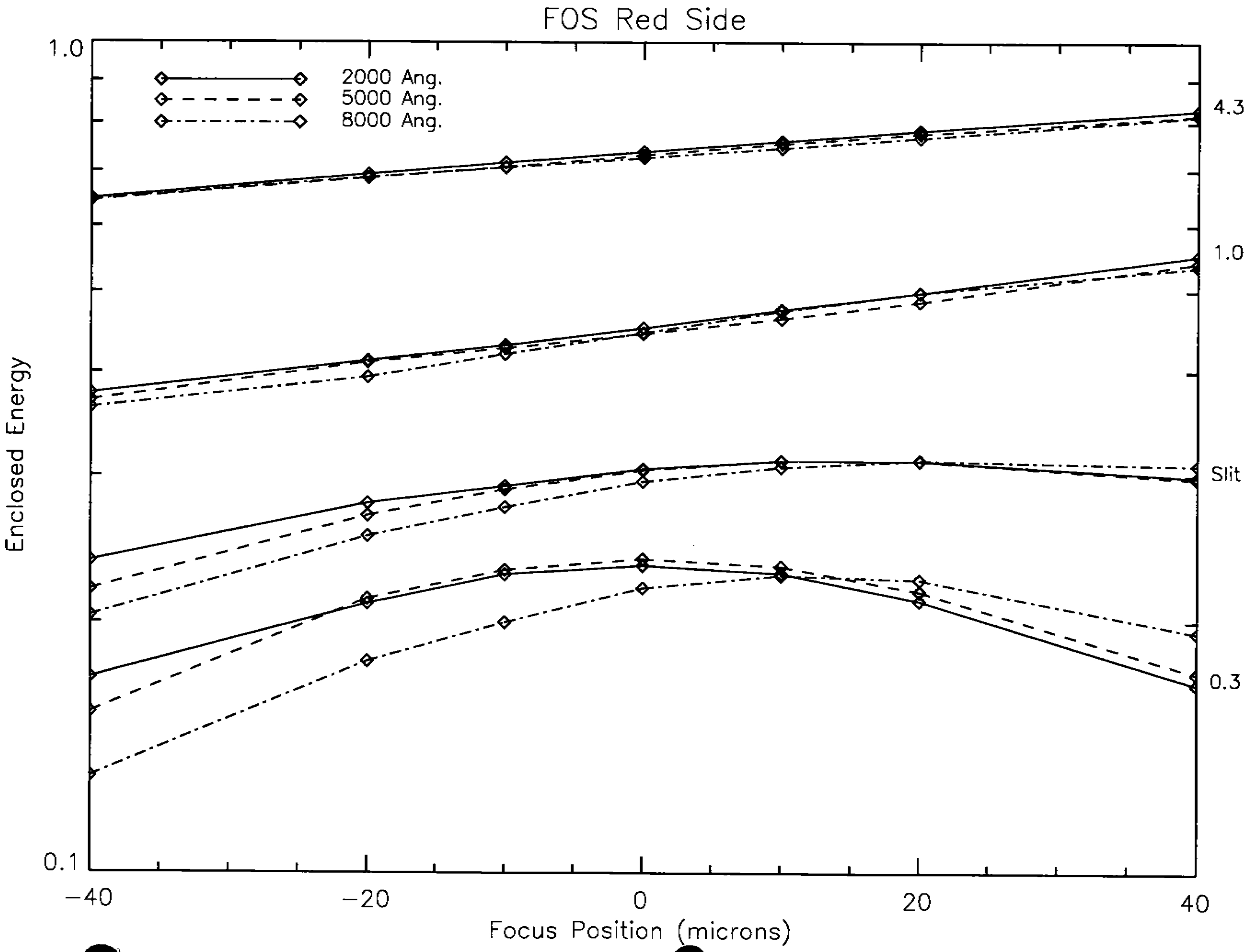

FOS Blue Side
1400 Ang.
3000 Ang.
5000 Ang.
4.3
1.0
Slit
0.3
1.0
0.1
Enclosed Energy
−40
−20
0
20
40
Focus Position (microns)

Fig. 3



FOS Red Side
2000 Ang.
5000 Ang.
8000 Ang.
4.3
1.0
Slit
0.3
1.0
0.1
Enclosed Energy
−40
−20
0
20
40
Focus Position (microns)

TABLE 1

Aperture Throughput Relative to Nominal Focus

Detector	BLUE			RED		
Wavelength	1400	3000	5000	2000	5000	8000
FOCUS						
4.3 arcsec square aperture						
-40	0.890	0.890	0.890	0.877	0.880	0.888
-20	0.948	0.940	0.942	0.939	0.937	0.947
-10	0.975	0.970	0.971	0.970	0.967	0.973
0	1.000	1.000	1.000	1.000	1.000	1.000
10	1.030	1.029	1.030	1.030	1.032	1.028
20	1.061	1.059	1.058	1.062	1.062	1.058
40	1.117	1.116	1.115	1.124	1.118	1.124
0.25 x 2.0 arcsec Slit						
-40	0.753	0.757	0.730	0.776	0.720	0.690
-20	0.909	0.898	0.902	0.910	0.882	0.860
-10	0.976	0.952	0.961	0.954	0.948	0.931
0	1.000	1.000	1.000	1.000	1.000	1.000
10	0.997	1.020	1.019	1.023	1.027	1.040
20	0.985	1.011	1.009	1.023	1.026	1.060
40	0.926	0.935	0.954	0.978	0.976	1.046
1.0 arcsec circular aperture						
-40	0.831	0.839	0.833	0.836	0.832	0.813
-20	0.905	0.916	0.926	0.914	0.925	0.885
-10	0.951	0.954	0.962	0.953	0.961	0.943
0	1.000	1.000	1.000	1.000	1.000	1.000
10	1.050	1.044	1.044	1.052	1.043	1.062
20	1.099	1.101	1.093	1.103	1.093	1.118
40	1.216	1.225	1.220	1.224	1.220	1.202
0.5 arcsec circular aperture						
-40	0.683	0.719	0.757	0.705	0.755	0.720
-20	0.866	0.880	0.896	0.877	0.896	0.902
-10	0.934	0.955	0.949	0.961	0.949	0.953
0	1.000	1.000	1.000	1.000	1.000	1.000
10	1.002	1.023	1.049	1.005	1.049	1.012
20	0.962	1.031	1.084	0.984	1.085	1.019
40	0.869	0.951	1.037	0.903	1.036	1.045
0.3 arcsec circular aperture						
-40	0.730	0.728	0.657	0.733	0.654	0.593
-20	0.926	0.885	0.894	0.900	0.896	0.816
-10	0.981	0.937	0.969	0.976	0.970	0.908
0	1.000	1.000	1.000	1.000	1.000	1.000
10	0.945	1.021	0.978	0.979	0.980	1.036
20	0.896	0.960	0.914	0.907	0.914	1.024
40	0.697	0.699	0.728	0.719	0.728	0.883

TABLE 2

Relative Aperture Throughput at Nominal Focus

Detector Wavelength	BLUE 1400	BLUE 3000	BLUE 5000	RED 2000	RED 5000	RED 8000
Aperture						
4.3 arcsec square	1.000	1.000	1.000	1.000	1.000	1.000
0.25 x 2.0 slit	0.427	0.423	0.422	0.414	0.416	0.407
1.0 arcsec circular	0.618	0.610	0.609	0.612	0.607	0.614
0.5 arcsec circular	0.483	0.462	0.438	0.475	0.436	0.437
0.3 arcsec circular	0.314	0.316	0.327	0.317	0.326	0.303