

Results From FGS Cycle 5 Calibration Programs #6180 and #6181

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ABSTRACT

Results from Cycle 5 FGS calibration programs #6180 and #6181, "Red/Blue Transfer Function Calibration" for the Clear (F583W), PUPIL, and Neutral Density (F5ND) filters are discussed. To date, these programs have obtained TRANSfer Mode observations at the center of the field of view of FGS #3 for 5 targets of color index B-V ranging from -0.1 to +1.9 mag. The reference files so obtained serve to calibrate, for Cycle 5, the behavior of the Transfer Function or S-curve as a function of the filter and color index for targets of immoderate color index.

1. Introduction

The interferometric fringe visibility pattern, known as the Transfer Function or S-curve, obtained with the Fine Guidance Sensors (FGSs) during a TRANSfer Mode observation changes not only with the filter used and the position in the field of view, but also with the color index of the target (Taff, Adv. Space Res. Vol. 11, No. 2, pp. 97-102, 1991). Appropriate reference data is thus required in order to reduce TRANSfer Mode observations (for example, Transfer scans of multiple stars). The FGS calibration plan for Cycle 5 includes for the first time, in programs #6180 and #6181, the calibration of the dependence of the Transfer Function on the color index of the target.

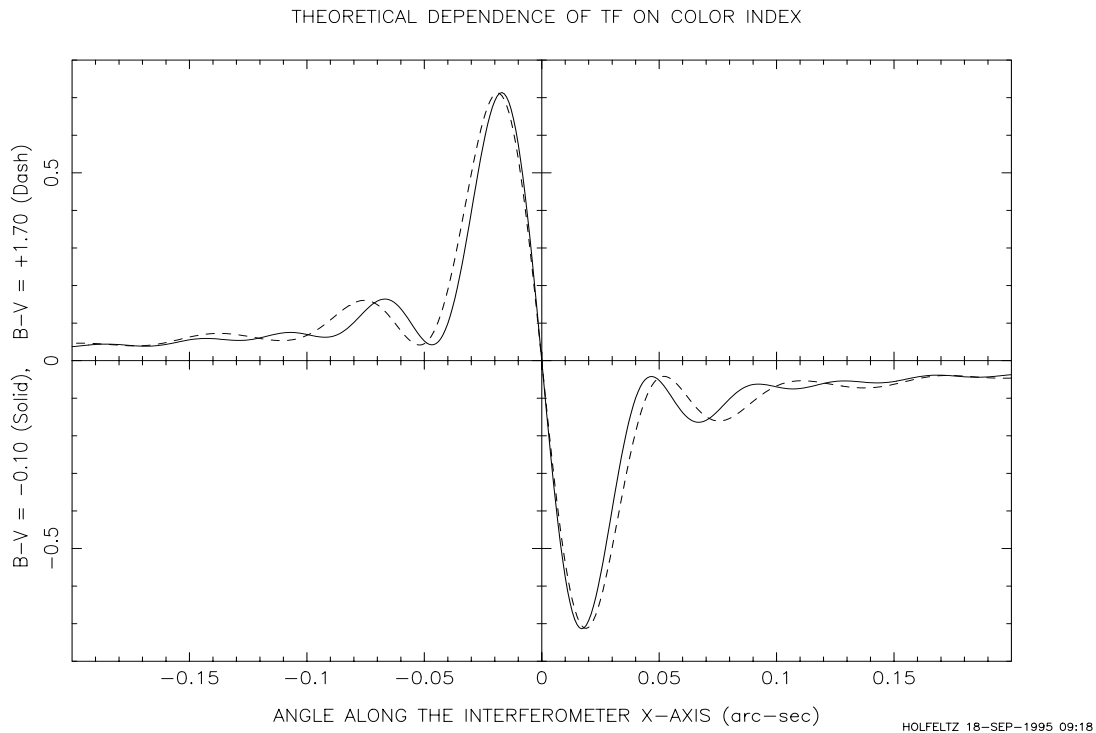
The ideal (pre-launch) theoretical Transfer Function for a monochromatic point source can be expressed as

$$S(z) = \frac{\sin^2(z)}{z} \quad \text{where} \quad z = \frac{2\pi R\theta}{\lambda}$$

where R is the effective radius of the primary mirror, λ is the effective wavelength of the target's radiation, and θ is the angle between the interferometer's axis and the target. In

effect, the FGS has poorer “resolution” for redder targets as compared to bluer targets. This results in broader primary lobes and more widely spaced secondary lobes. Figure 1 shows two theoretical Transfer Functions for targets of color index $B-V = -0.10$ and $+1.70$ mag.¹

Figure 1: Theoretical Transfer Functions for $B-V = -0.10$ and $B-V = +1.70$ mag



Calibrating the “Color Index Effect”

FGS Cycle 5 calibration program #6180, “Red/Blue Transfer Function Calibration”, was to obtain reference Transfer Functions of three targets of color indices $B-V = +0.18$, $+1.5$, and $+1.92$, through the Clear(F583W) and PUPIL filters at the center of the field of view of FGS #3. Similarly, program #6181, “Red/Blue Neutral Density Transfer Function Calibration”, acquired reference Transfer Functions of three targets of color index -0.1 , $+1.28$, and $+1.7$ at the center of FGS #3 through the Neutral Density (F5ND) filter. Table 1 lists the calibration targets, their V magnitudes, (B-V) color indices and the corresponding program number.

1. The theoretical predictions are based on software originally written by L. G. Taff using the effective temperatures given as a function of color index in *Astrophysical Quantities* (C. W. Allen, 1976, William Clowes & Sons, Limited, London, pg. 206).

Table 1. Targets Observed in Calibration Programs #6180 and #6181.

Target	V mag	(B-V)	Program #
^a LAT-COL-1A	9.7	+1.92	6180
^a LAT-COL-1B	9.6	+0.18	6180
^b SAO 185689	9.3	+1.50	6180
^c HD 59149	6.7	+1.28	6181
^c HD 28484	7.9	+1.70	6181
^d HD 28149	5.5	-0.10	6181

We wish to express our thanks to the following people who were of immeasurable help in researching and choosing the targets:

^a Paul Hemenway, Fritz Benedict and the Space Telescope Astrometry Team

^b Michal Simon

^c Otto Franz

^d Doug Gies

2. Observations and Data Reductions

The Observations

Program #6180 was to obtain fifteen scans of each of three targets with both the Clear (F583W) and PUPIL filters. Due to a proposal error, one target (LAT-COL-1B) was not found. HOPR #288 (an HST Observation Problem Report) was filed requesting one orbit to repeat the observations. An addendum to this report will be issued documenting the outcome of the HOPR and any data obtained as a result. Program #6181 obtained thirty scans of each of three targets through the Neutral Density (F5ND) filter. Table 2 summarizes the observations.

Table 2. Summary of Observations

Filename	Filter	Target	Date
Program #6180			
F2VU0101M	PUPIL	LAT-COL-1A	6 Sept. 1995
F2VU0102M	F583W	LAT-COL-1A	6 Sept. 1995
F2VU0201M	PUPIL	LAT-COL-1B	a

^a Pending outcome of HOPR #288

Filename	Filter	Target	Date
F2VU0202M	F583W	LAT-COL-1B	^a
F2VU0301M	PUPIL	SAO 185689	6 Sept. 1995
F2VU0302M	F583W	SAO 185689	6 Sept. 1995
Program #6181			
F2VM0101M	F5ND	HD 59149	15 Sept. 1995
F2VM0201M	F5ND	HD 28484	16 Sept. 1995
F2VM0301M	F5ND	HD 28149	17 Sept. 1995

^a Pending outcome of HOPR #288

Data Smoothing and Merging

All scans in a given data set which were judged to be uncorrupted by jitter were co-added or merged together and averaged in 1 milli-arc second bins. The resulting scan was fit with a continuous piece-wise polynomial. These polynomial fits to the data are the reference Transfer Functions to be used in the reduction of TRANSfer Mode science data (for example, the analysis of Transfer Scans of double stars). Table 3 gives information regarding the merging of the Transfer Scans; column 1 lists the filename, column 2 lists the number of scans obtained in the observation, columns 3 and 6 give the number of uncorrupted scans which were merged together for the x and y axes, respectively. Columns 4 and 5 give the average and maximum signal-to-noise ratio of the merged scans for the x axis. The maximum signal-to-noise ratio is defined as the peak-to-peak amplitude of the Transfer Function divided by the standard deviation about the mean of the Transfer Function far from the null ($\theta > 300$ milli-arc seconds). The average signal-to-noise ratio is defined as the average of the absolute value of the amplitude of the signal within ± 300 milli-arc seconds of the null divided by the standard deviation about the mean of the Transfer Function far ($\theta > 300$ milli-arc seconds) from the null. Columns 7 and 8 give the average and maximum signal-to-noise ratios for the y axis.

Table 3. Input to and Results of Merging of Transfer Functions

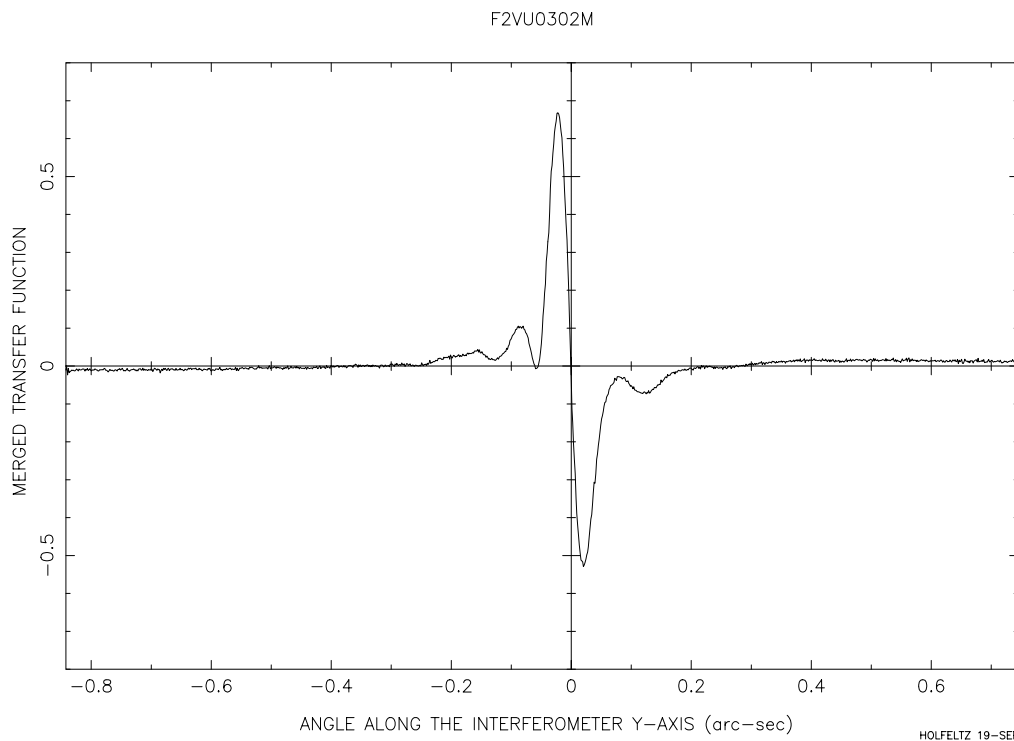
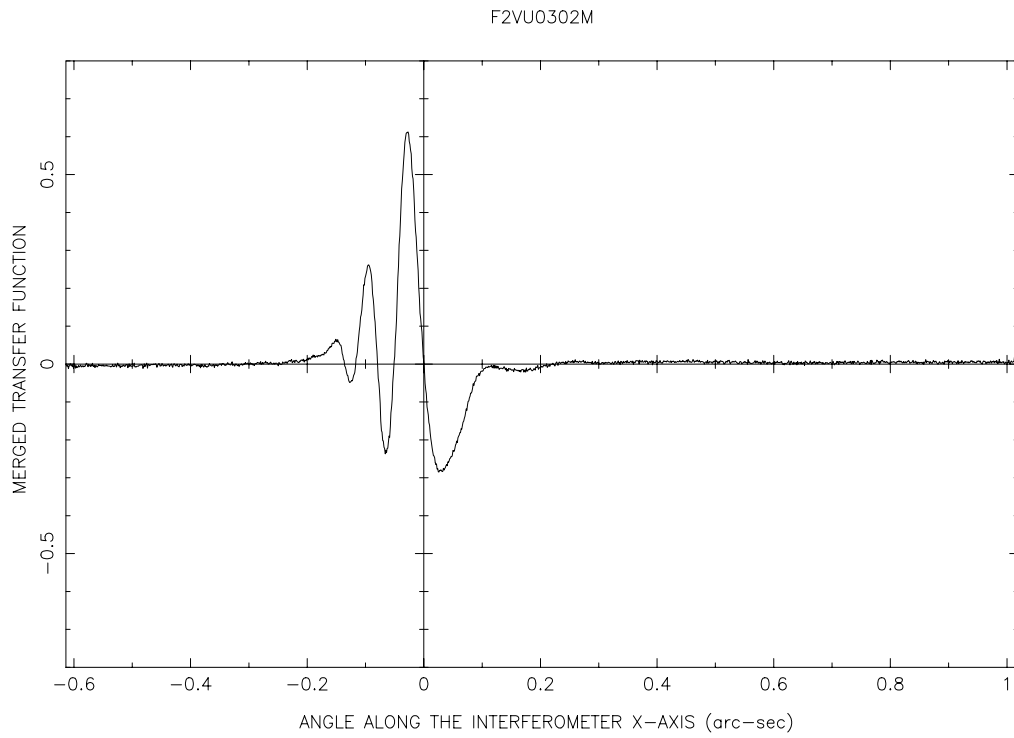
Filename	# Scans Observed	X-Axis			Y-Axis		
		# Scans Merged ^a	Avg S/N	Max S/N	# Scans Merged ^a	Avg S/N	Max S/N
F2VU0101M	15	15	9	182	14	6	103
F2VU0102M	15	15	9	168	15	5	107
F2VU0301M	15	15	11	216	15	6	108
F2VU0302M	15	15	10	196	14	5	114
F2VM0101M	30	30	13	157	30	8	114
F2VM0201M	30	29	10	118	29	8	107
F2VM0301M	30	29	13	175	28	8	117

^a Only those scans which were judged to be uncorrupted by jitter were merged.

The Transfer Functions

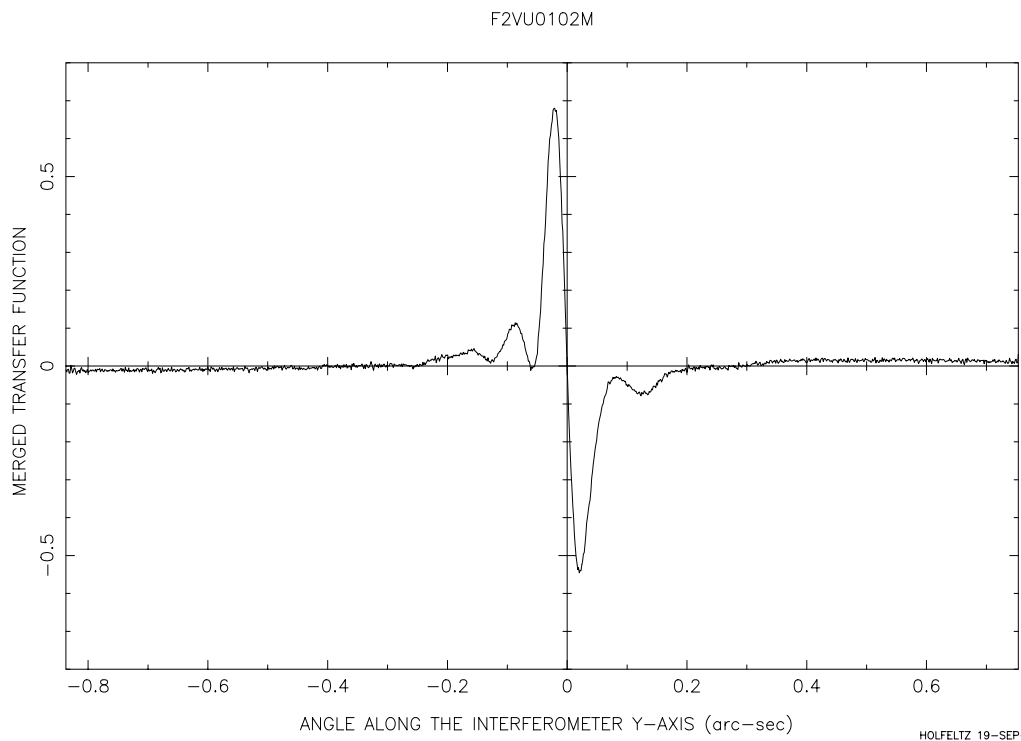
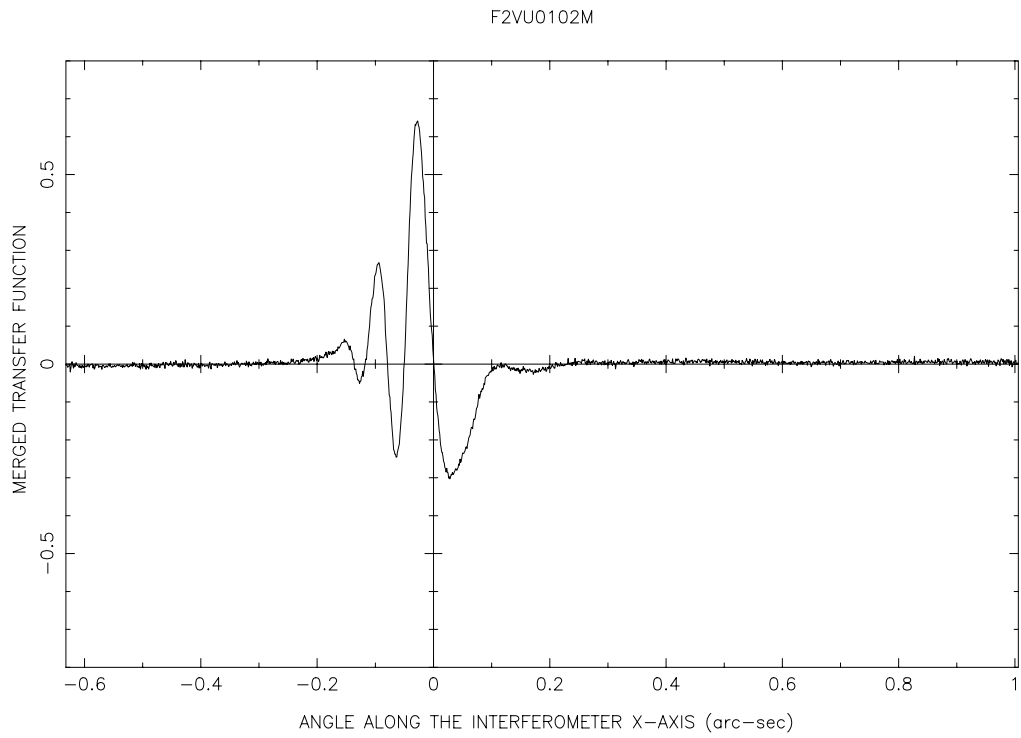
The reference Transfer Functions obtained as a result of merging or co-adding all of the individual scans (prior to being fit by a polynomial) for each of the two targets observed to date (B-V = +1.5, and +1.92 mag.) through the Clear (F583W) and PUPIL filters, and the three targets observed with the Neutral Density (F5ND) filter (B-V = -0.1, +1.28 and +1.7 mag) are shown in Figure 2 through Figure 8, respectively.

Figure 2: Clear Filter (F583W) Calibration Transfer Function for B-V = +1.5



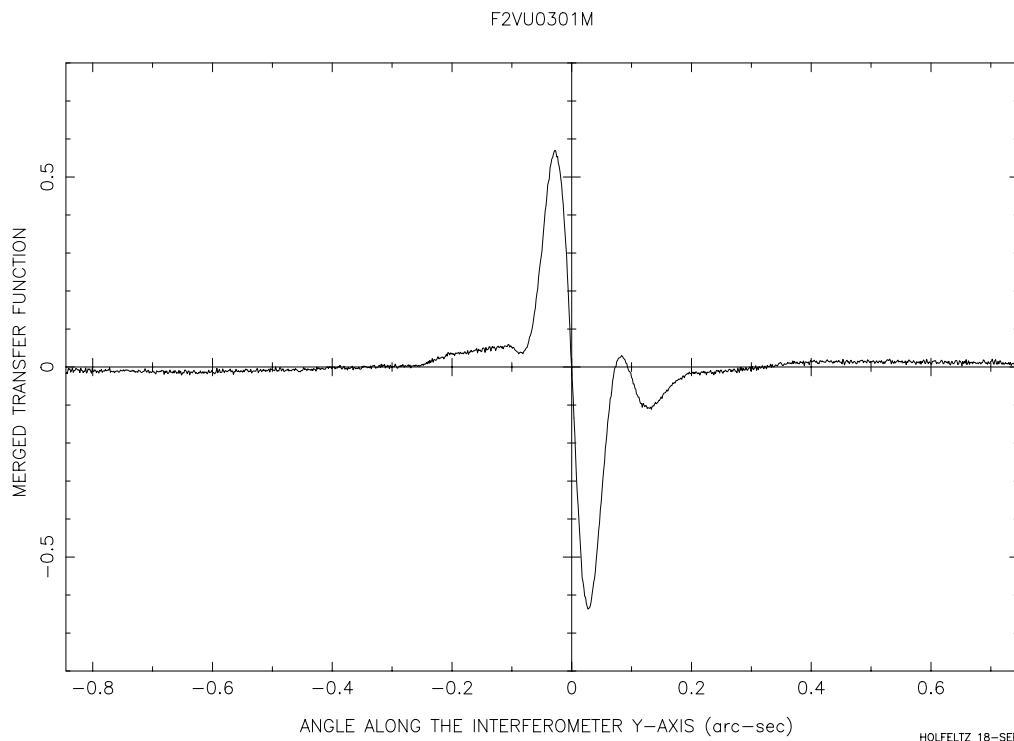
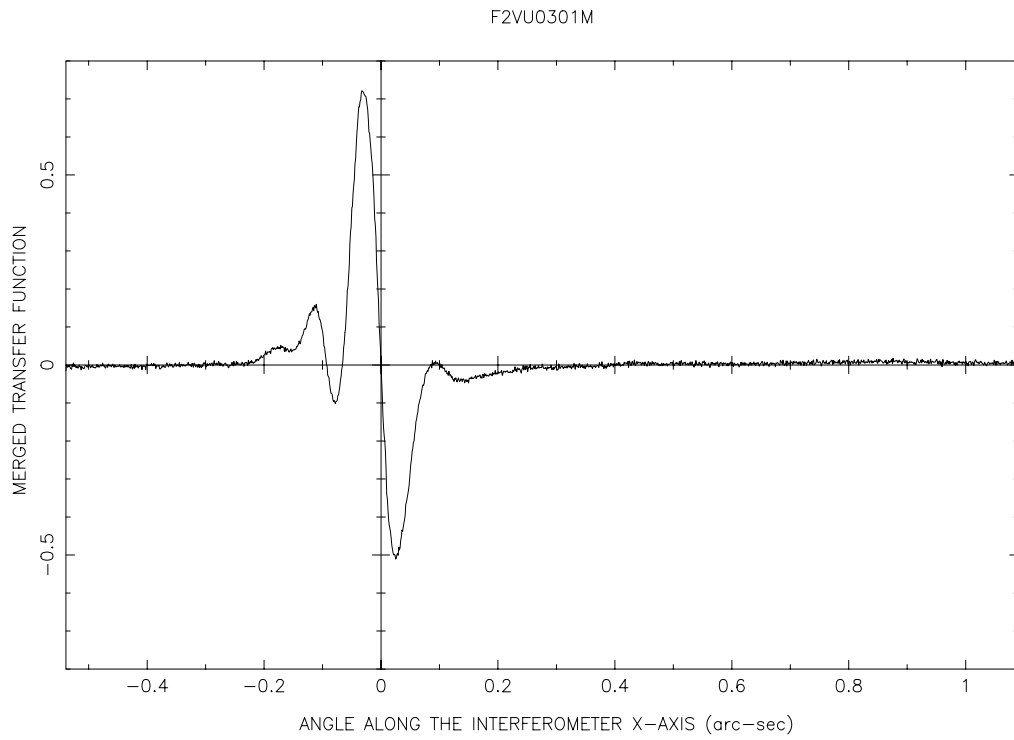
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Figure 3: Clear Filter (F583W) Calibration Transfer Function for B-V = +1.92



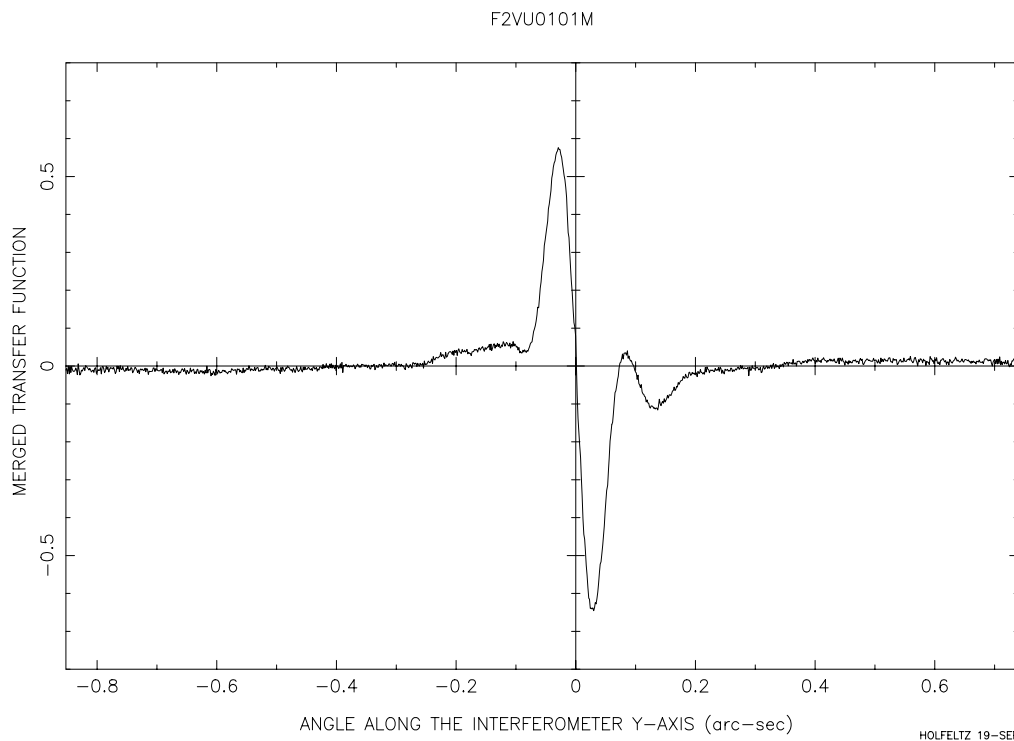
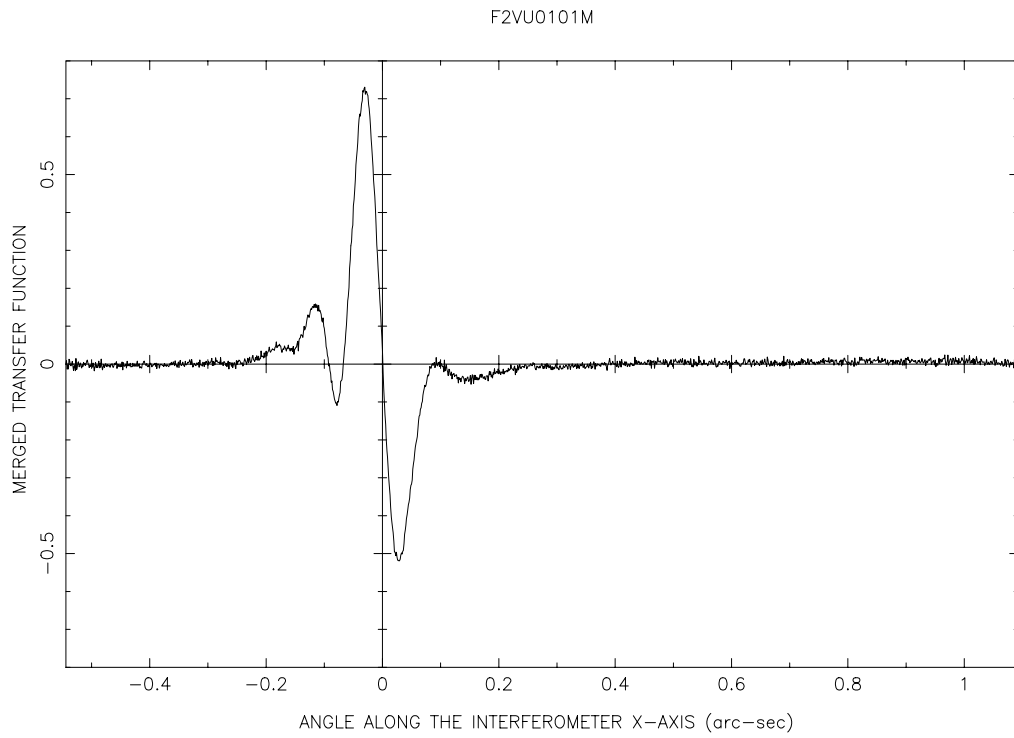
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Figure 4: PUPIL Filter Calibration Transfer Function for B-V = +1.5



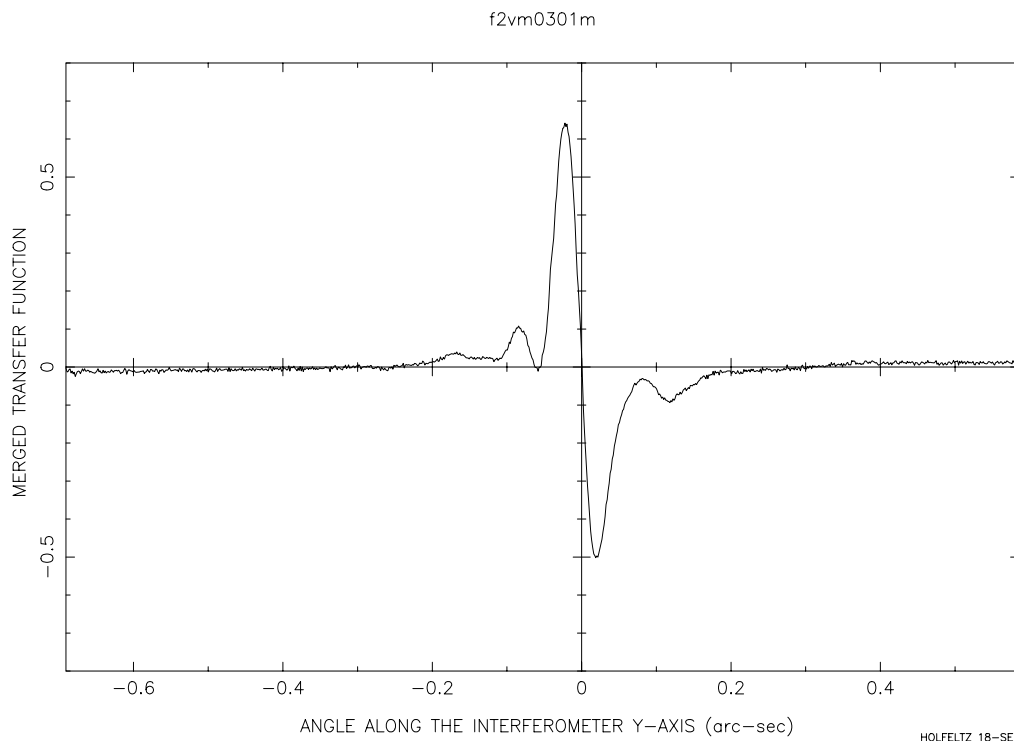
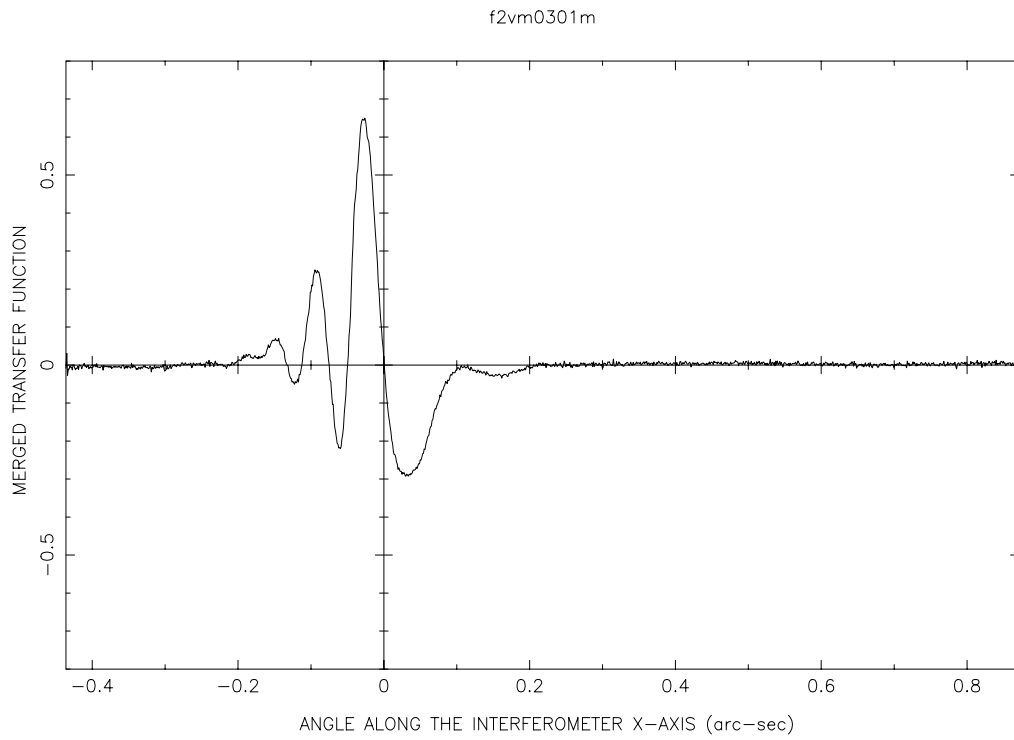
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Figure 5: PUPIL Filter Calibration Transfer Function for B-V = +1.92



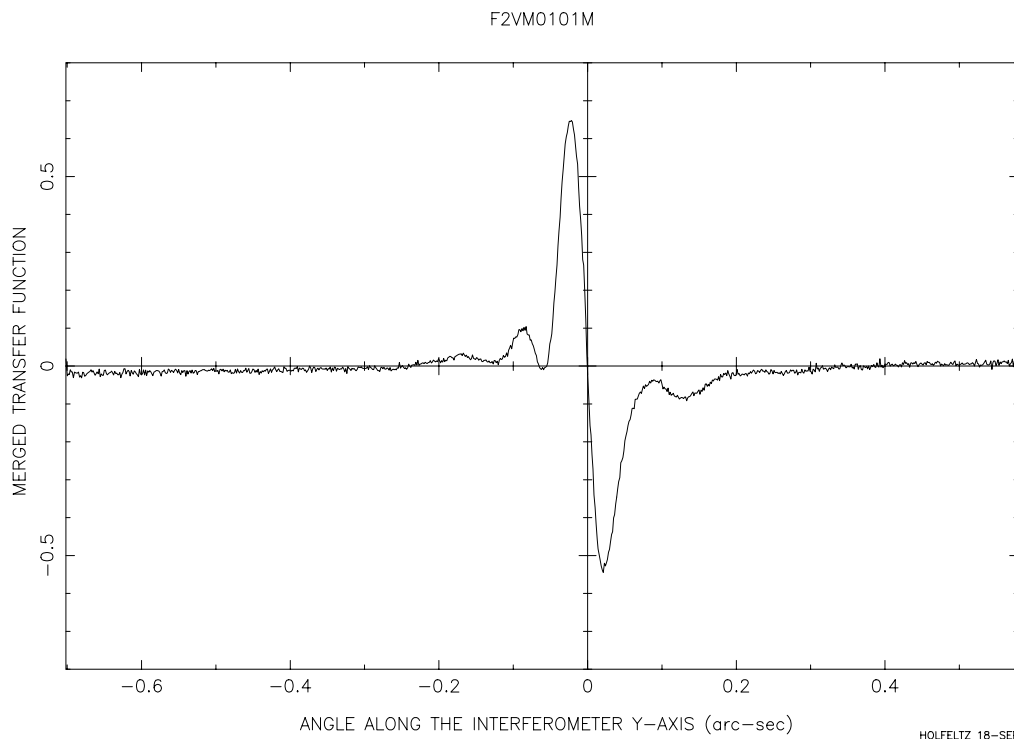
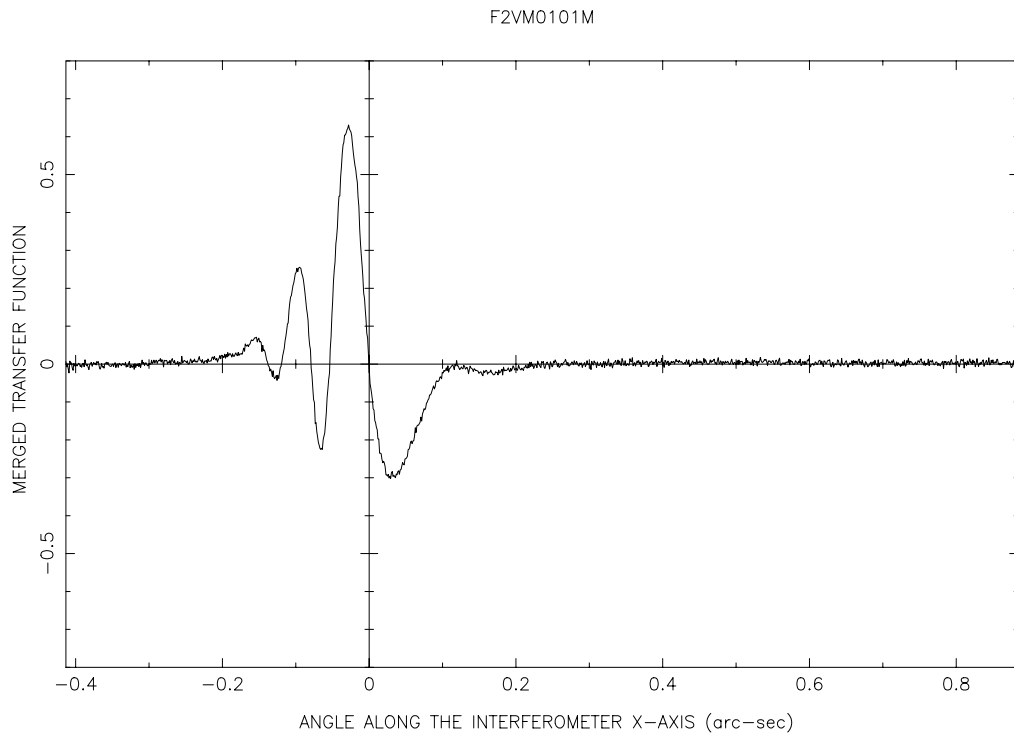
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Figure 6: Neutral Density Filter (F5ND) Calibration Transfer Function for B-V = -0.1



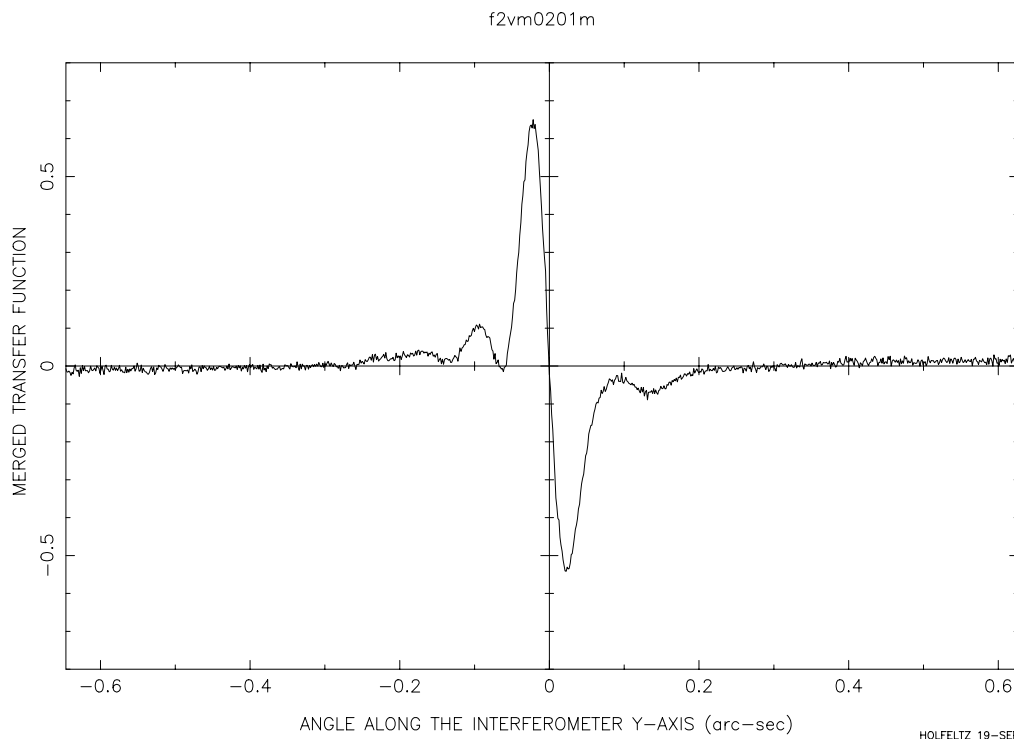
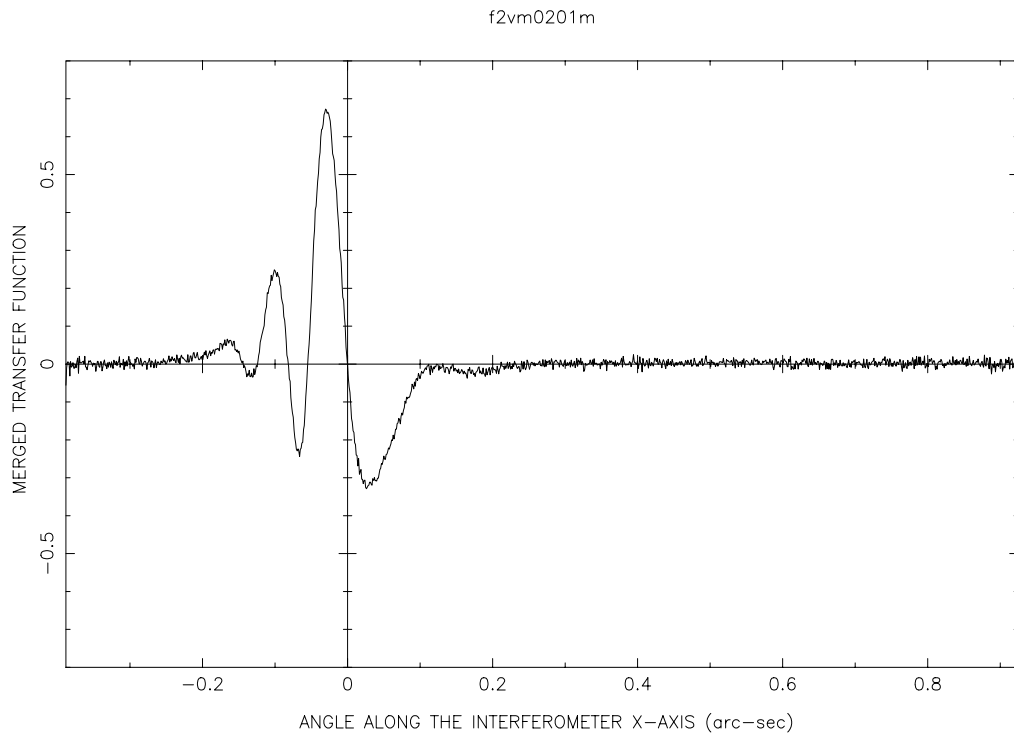
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Figure 7: Neutral Density Filter (F5ND) Calibration Transfer Function for B-V = +1.28



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Figure 8: Neutral Density Filter (F5ND) Calibration Transfer Function for B-V = +1.7



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The Results

Significant parameters of the reference S-curves are summarized in Table 4 through Table 6; see Figure 9 for definitions of these parameters. Filenames are given in the first column, the B-V color index is listed in column 2, the axis (x or y) in column 3. Columns 4 through 6 give, respectively, the absolute value of the peak of the primary and secondary lobes and the full width at half maximum of the primary lobe. Data for the positive lobes are given first in each table followed by the same information for the negative lobes (see Figure 9).

Figure 9: Definition of parameters given in Table 4 through Table 6.

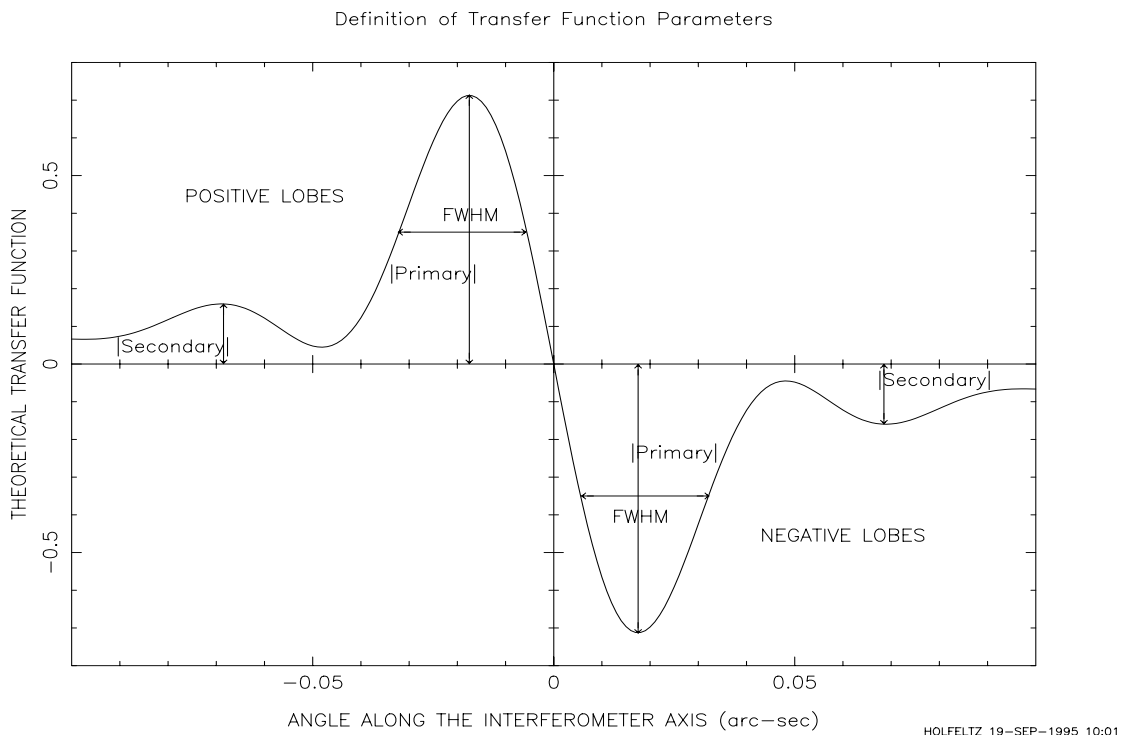


Table 4. Parameters for Clear Filter (F583W) Red & Blue Calibration Transfer Functions

Filename	B-V	Axis	^a Primary	^a Secondary	^b FWHM
Positive Lobes					
F2VU0102M	+1.92	X	0.65	0.23	0.030
		Y	0.70	0.10	0.029
F2VU0302M	+1.50	X	0.56	0.27	0.035
		Y	0.72	0.12	0.029
Negative Lobes					
F2VU0102M	+1.92	X	0.30	0.02	0.060
		Y	0.56	0.07	0.034
F2VU0302M	+1.50	X	0.28	0.02	0.062
		Y	0.56	0.07	0.033
^a ±0.03					
^b Full width at half maximum for the primary lobe, ±0.001 arcsec					

Table 5. Parameters for PUPIL Filter Red & Blue Calibration Transfer Functions

Filename	B-V	Axis	^a Primary	^a Secondary	^b FWHM
Positive Lobes					
F2VU0101M	+1.92	X	0.73	0.15	0.041
		Y	0.58	0.06	0.044
F2VU0301M	+1.50	X	0.72	0.15	0.041
		Y	0.56	0.06	0.044
Negative Lobes					
F2VU0101M	+1.92	X	0.51	0.04	0.045
		Y	0.65	0.11	0.042
F2VU0301M	+1.50	X	0.50	0.04	0.044
		Y	0.64	0.11	0.042
^a ±0.01					
^b Full width at half maximum for the primary lobe, ±0.001 arcsec					

Table 6. Parameters for Neutral Density Filter (F5ND) Red and Blue Calibration Transfer Functions

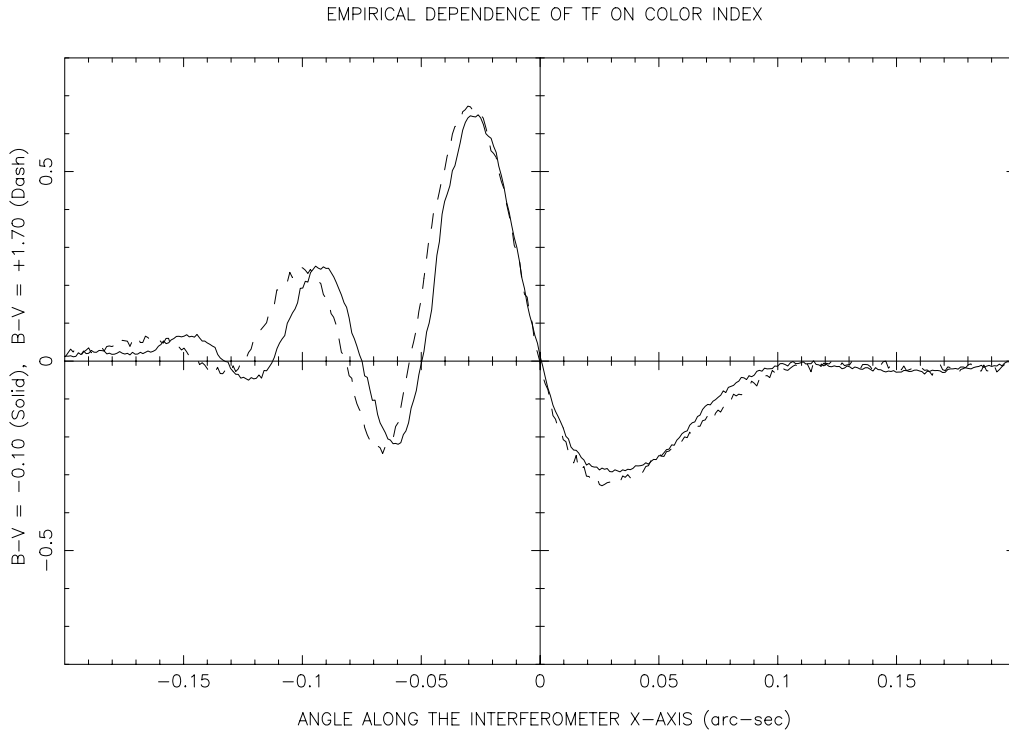
Filename	B-V	Axis	^a Primary	^a Secondary	^b FWHM
Positive Lobes					
F2VM0101M	+1.28	X	0.64	0.26	0.033
		Y	0.65	0.10	0.032
F2VM0201M	+1.70	X	0.67	0.23	0.034
		Y	0.64	0.11	0.033
F2VM0301M	-0.10	X	0.64	0.25	0.032
		Y	0.64	0.11	0.031
Negative Lobes					
F2VM0101M	+1.28	X	0.30	0.02	0.062
		Y	0.55	0.08	0.038
F2VM0201M	+1.70	X	0.32	0.03	0.062
		Y	0.55	0.07	0.039
F2VM0301M	-0.10	X	0.29	0.03	0.060
		Y	0.52	0.09	0.033
^a ± 0.01 ^b Full width at half maximum for the primary lobe, ± 0.001 arcsec					

3. Conclusion

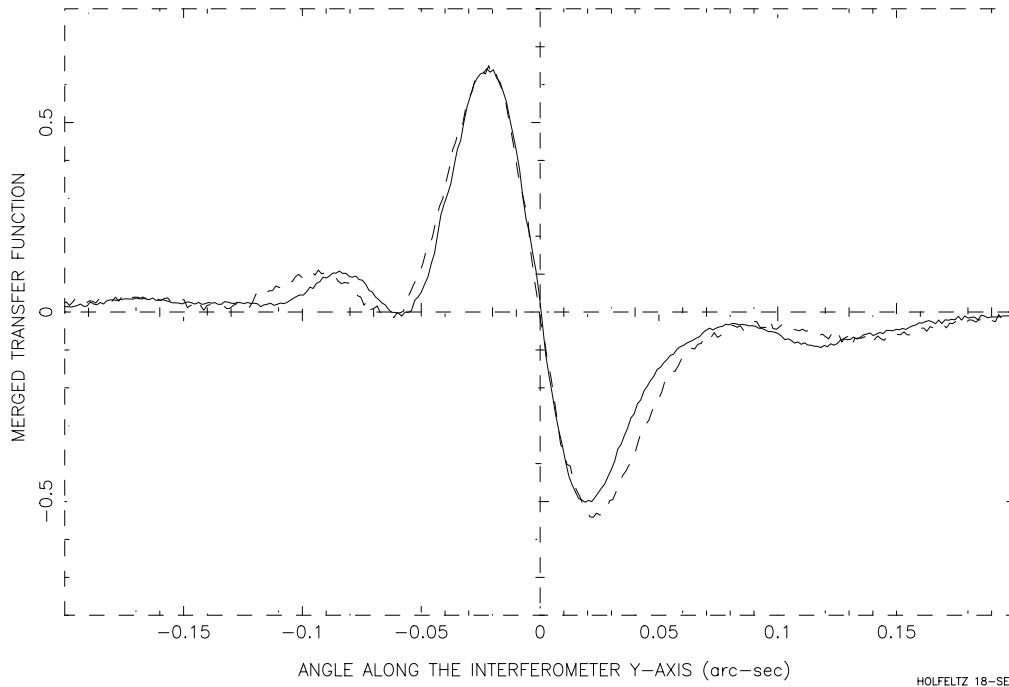
Empirical Dependence of Transfer Function on Color Index

The empirical Transfer Functions for B-V = -0.1 and B-V = +1.7 mag are shown in Figure 10. Note the broadening of the primary lobes and the outward shifting of the secondary lobes for Transfer Function of the redder target. Compare to Figure 1 which shows the theoretical Transfer Functions for B-V = -0.1 and +1.7 mag.

Figure 10: Empirical Transfer Functions for $B-V = -0.10$ and $B-V = +1.7$ mag



f2vm0301m



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Choosing and Using Calibration Data

Theory predicts the dependence of the Transfer Function on the color index of the target; observations confirm the theoretical predictions. This so-called “color index effect” is a second-order effect but it is non-negligible. The reduction of data using a reference Transfer Function of incorrect color index could result in the failure to detect a secondary component or the spurious “detection” of a non-existent secondary. Observers *must* take the color index of the target into account when choosing the reference Transfer Function to be used in the reduction of the data. The smoothed, merged Transfer Functions (`*.fit`) and the polynomial fits to the merged data (`*.poly`) are available for use on the (VAX/VMS) science cluster at Space Telescope Science Institute on `disk$boston_data:[holfeltz.go.refdat]`. A list of all available reference Transfer Functions (`ref.lis`) is available in the same directory.