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The Faint Object Spectrograph Post-COSTAR Spectropolarimetry Correction

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Abstract. While the COSTAR mirror assembly installed on the Hubble Space Telescope (HST) during the second servicing mission effectively restored HST optical capabilities, off-axis reflections from the COSTAR mirrors also introduced a measurable amount of instrument polarization. We developed a methodology to quantify and remove the induced polarization as detected by the FOS spectropolarimeter (Allen 1995), and modified the FOS calibration pipeline to accommodate post-COSTAR FOS Blue spectropolarimetry observations.

1. Introduction

Since the COSTAR mirrors have different reflectivities for light vibrating parallel and perpendicular to the line of centers between the mirrors, the polarization state of the incoming light to the FOS spectropolarimeter was altered. In addition, the parallel vibrations were shifted in phase relative to the perpendicular vibrations, so some portion of incoming linear polarization was converted to circular polarization, and vice versa.

The effects of the COSTAR mirrors were determined from observations of known unpolarized and polarized standard stars. While FOS Blue observations of an unpolarized standard, BD+28D4211, provided the relative measures of the parallel and perpendicular reflectivities, corresponding observations of a polarized standard, BD+64D106, were used to determine the phase shift. Once the induced polarization effects were determined, the proper polarization for an unknown source could then be recovered by numerically inverting the reflection process during pipeline processing.

2. Determination of the Correction

Quantifying the induced polarization was accomplished by processing observations for both the unpolarized and polarized standards through a special version of the FOS calibration pipeline (Storrs et al. 1998). In this special processing, the data were calibrated with the typical pre-COSTAR calibrations, but the final output data were forced to remain in the instrument frame, and were not rotated onto the sky frame which would be done in typical processing. While the standard version of the FOS calibration pipeline, `calfos`, is implemented as an *IRAF/STSDAS* task, the special version was used strictly to derive the post-COSTAR corrections. Consequently, the post-COSTAR corrections are bootstrapped from the pre-COSTAR calibrations. Once post-COSTAR corrections were generated by the special pipeline, it was necessary to smooth and interpolate the data to derive the final corrections. The post-COSTAR corrections comprise a new FOS calibration file, PCPHFILE. Table 1 lists the spectropolarimetric calibrated modes. There are no flux and polarimetry calibrations defined for the FOS Red detector.

Table 1. Calibrated Spectropolarimetry Modes.

Detector	Grating	Aperture (Pre-COSTAR)	Aperture (Post-COSTAR)
FOS/BLUE	G130H	4.3	—
	G190H	4.3	1.0
	G270H	4.3	1.0
	G400H	—	1.0
FOS/RED	G190H	4.3	—
	G270H	4.3	—

3. Implementation

The post-COSTAR polarization correction has been implemented for FOS Blue spectropolarimetry data in Version 3.0 and higher of both the calibration pipeline, `calfos`, as well as in the stand-alone polarimetry processing task, `calpolar`. The advantage of `calpolar` is that it provides the user with the additional flexibility to manipulate the flux calibrated data prior to polarization processing.

In order to obtain *any* calibrated spectropolarimetric data with `calfos`, the keyword MOD_CORR must be set to PERFORM in the raw data header file (D0H); this is true for both pre- and post-COSTAR epoch processing. If the spectropolarimetry data were acquired during the post-COSTAR epoch as indicated by the header keyword "KYDEPLOY = T", which stands for COSTAR deployed for FOS (T or F), *and* a post-COSTAR calibration is available as noted in Table 1, the post-COSTAR polarimetry correction obtained from the PCPHFILE reference file will be applied. If the D0H file does not contain the new PCPHFILE keyword, this keyword must be added for proper post-COSTAR spectropolarimetric processing. The D0H file can be updated to add this new keyword using the `chcalpar` task.

If no post-COSTAR polarimetry calibration file were provided for the PCPHFILE calibration file keyword (or an incorrect file were supplied), `calfos` will process all spectropolarimetric data with only the pre-COSTAR corrections. In this instance if the data were from the post-COSTAR epoch, warning messages will be issued regarding the application of only pre-COSTAR corrections.

A proper post-COSTAR calibration depends upon the data being processed using the standard pre-COSTAR corrections, with the exception that the data

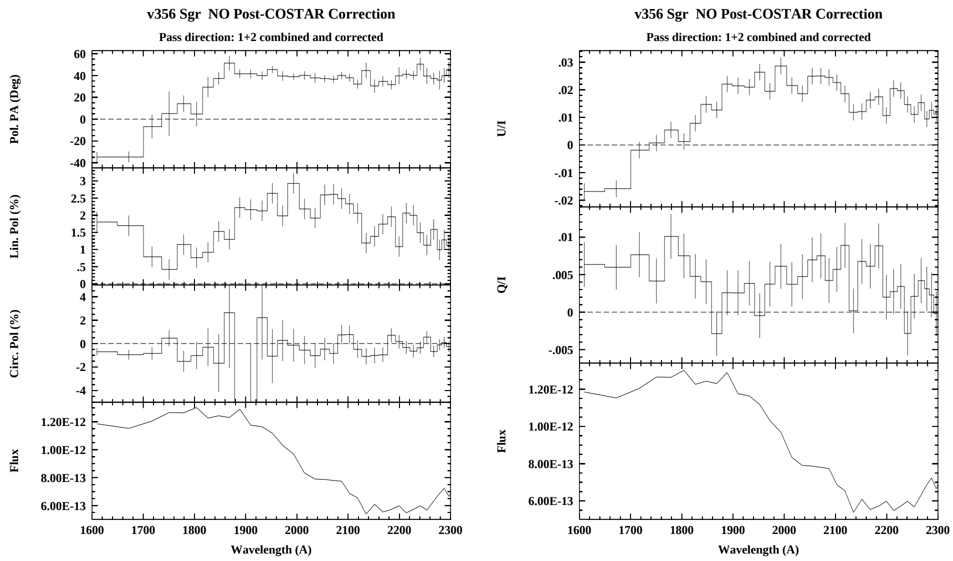

Figure 1. v356 Sgr with only the Pre-COSTAR Correction.

are left in the instrument frame rather than being rotated onto the sky frame. The Stokes parameters are then corrected to remove the additional polarization imposed by the COSTAR mirrors; the linear and circular polarization, as well as the phase angle are re-derived, and the post-COSTAR corrected final results are rotated onto the sky frame.

4. Results

The post-COSTAR corrections essentially remove the wavelength-dependent COSTAR-induced instrumental polarization in the FOS Blue observations. Figure 1 shows the polarization and Stokes vectors for the situation when no post-COSTAR correction has been applied to observations of v356 Sgr. The wavelength regime from $\sim$1900 – 2300 Å exhibits weak linear polarization on the order of 2%; this polarization is COSTAR-induced. Figure 2 shows the polarization and Stokes vectors for the situation when the post-COSTAR correction has been applied.

In self-consistency tests it was found that even after the observations which were used to determine the post-COSTAR corrections were themselves corrected for post-COSTAR induced polarization, there remained a residual of $\sim$0.08% in Stokes Q.

5. Conclusions

In the post-COSTAR epoch, the combined effects of residual geomagnetically-induced motion (GIM) and spacecraft jitter do not produce polarization greater than 1%. Additional sources of error in polarization are due to the photon

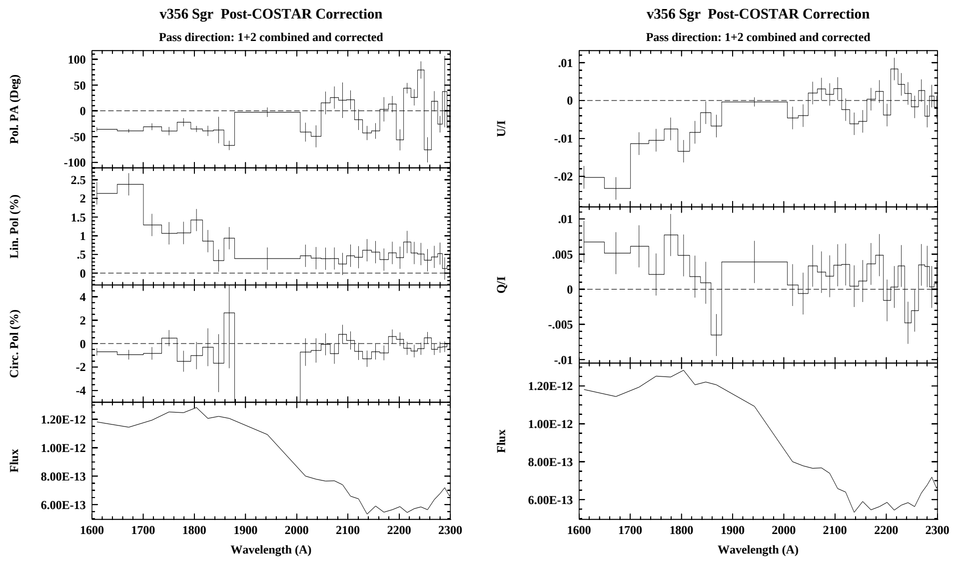

Figure 2. v356 Sgr with the Post-COSTAR Correction applied.

statistics of the observation and the error in the retardation calibration (Allen & Smith 1992). Since post-COSTAR observations made with only four polarizer positions cannot be corrected for COSTAR-induced circular polarization, these observations contain an additional 0.4% uncertainty in Q. Only observations which have been made with eight or sixteen polarizer positions can be adequately corrected for the effects of the COSTAR mirrors.

Individual pre-COSTAR spectropolarimetric data should always be checked for systematic errors due to motion perpendicular to the dispersion and the large point spread function. Light loss from one polarizer position to the next can introduce systematic effects that mimic the effect of a polarized signal. In general, since the linear polarization is biased towards positive values, observers of weakly polarized objects should correct for this bias; this can be accomplished using the `polbias` task. The `calfos` processing messages should always be monitored. If the polarimetry processing is requested, but an incorrect post-COSTAR calibration file is specified or none exists, the processing will issue warning messages and continue. In this case, only the pre-COSTAR calibrations will be applied.

References

Allen, R. G. 1995, in Calibrating Hubble Space Telescope Post-Servicing Mission, ed. A. Koratkar and C. Leitherer, (Baltimore: STScI), 60

Allen, R. G. & Smith, P. S. 1992, FOS Polarimetry Calibrations (STScI FOS IDT Report CAL/FOS-078), (Baltimore: STScI)

Storrs, A., Koratkar, A., Keyes, C., Bushouse, H., De La Peña, M., & Allen, R. 1998, FOS Spectropolarimetry (STScI ISR CAL/FOS-150), (Baltimore: STScI)