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Zero-Points of FOS Wavelength Scales

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Abstract. We have investigated the internal zero-points of the HST's Faint object spectrograph (FOS) on-orbit wavelength calibration between 1990 (launch) and 1997 (de-commissioning). The analysis is based on cross-correlating about 1200 WAVECAL exposures for the high-resolution dispersers, using as templates those exposures which define the dispersion solutions currently in use by the FOS pipeline. FOS has two channels BLUE/RED using two independent Digicon detectors. For BLUE systematic shifts of the zero-points are present, which amount to a maximum offset of 7 pixels (1.75 diodes) over the entire period. The zero-points for RED modes present an apparently random distribution with a peak-to-peak range of 7 pixels. We discuss the effect of the geomagnetic environment as a possible cause for the observed behaviour and describe the ongoing work to reduce the uncertainty in the wavelength scale.

1. Introduction

The FOS was designed primarily as a faint object spectrophotometer, with less stringent requirements on highly reproducible velocity measurements. On-orbit analysis indicated that the total 1σ error budget of grating wheel (FGWA) non-repeatability, source miscentering and internal to external wavelength scale offsets should not exceed 2 pixels (≈ 0.25 resolution elements) (Keyes 1997). In addition, dispersion relations fitted to calibration lamp exposures regularly obtained for monitoring purposes did not directly show any obvious trends. Therefore, the original set of dispersion solutions was used throughout the entire operational life of FOS as the default in the pipeline calibration.

Lately, indications have been accumulating that FOS wavelength scale zero-points might be much more in error than the figure given above. In conjunction with the ST-ECF FOS Post Operational Archive project, we are reanalyzing all FOS wavelength calibration observations obtained on-orbit.

2. Analysis Method

As the usual polynomial fitting procedures may not be adequate to reliably detect zero-points shift due to masking of the polynomial coefficients, we chose

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to cross-correlate the raw, uncalibrated exposures. These cover the entire period between science verification (SV) (August 1990) and the last on-orbit wavelength calibration observation obtained in December 1996 with a single template for each FOS disperser respectively. The template raw calibration lamp exposures are those used for the SV analysis (Kriss, Blair, & Davidsen 1991) which define the default dispersion relations used by the FOS pipeline. Cross-correlation of the data sets yields a very clean peak which can be positioned to better then 0.1 pixel ($3\,\sigma$) using Gaussian profile fitting for all gratings.

3. Results

For the analysis we broke down the samples according to detector, grating and aperture, and plotted the x-shifts versus the Modified Julian Date (MJD) of exposure start. As opposed to expectations (see above), substantial shifts were found for all FOS dispersers, over both short and long time intervals, amounting to a full amplitude variation of 7 pixels peak-to-peak on both FOS channels.

3.1. FOS/BLUE specific

All the FOS blue side dispersers show a very similar and conspicuous pattern with time (cf. Fig. 1). At any given epoch the peak-to-peak scatter of the zero-point offset about the mean trend is approximately ± 1 pixel (i.e., 10 times the measurement error). The general trend amounts to an average drift of 0.75 pix/year with respect to the zero-point of the pipeline wavelength scale for each disperser. An observation in Cycle 6 therefore may be off by more than 5 pixels.

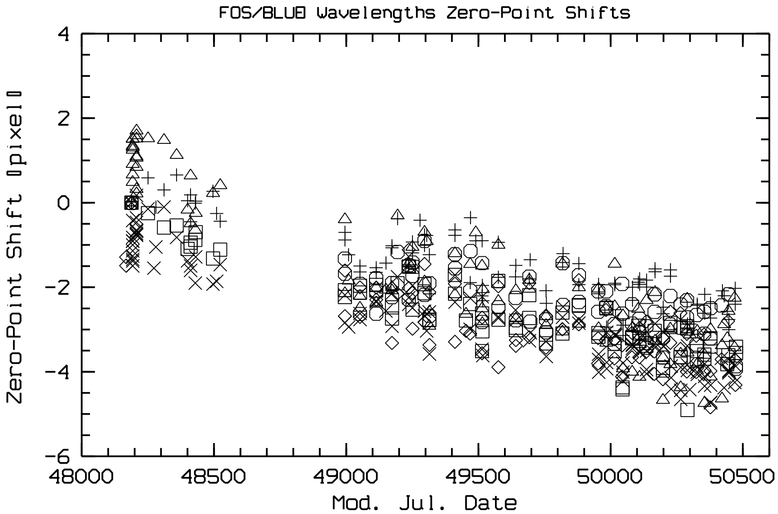

Figure 1. Uncorrected FOS/BLUE wave calibration sets.

Due to the apparent similarity in the pattern for all blue dispersers we combined all BLUE grating data into a common dataset, depicted in Fig. 1. This was done iteratively. A first straight combination, was used to define three windows in time, in which the data appear to follow different linear trends.

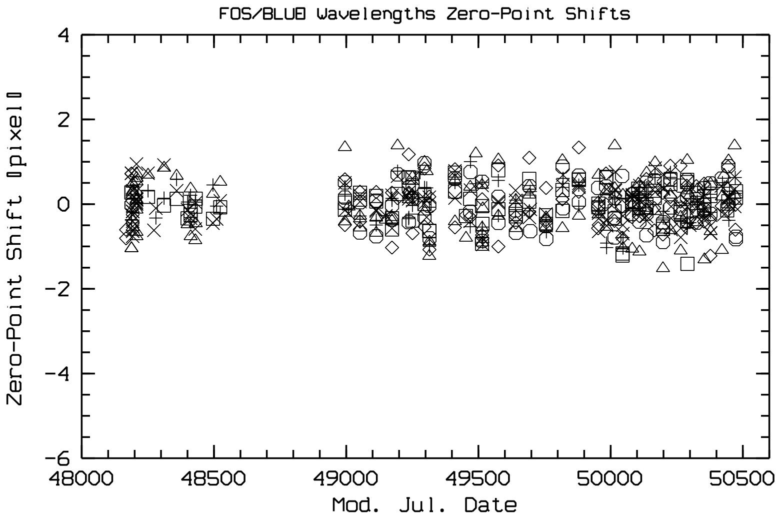

Figure 2. FOS/BLUE wave calibration sets after correction for linear trend and grating specific offset.

Interestingly enough, the boundaries of these windows coincide with the start of SV, the activation of on-board GIM (geomagnetically induced image motion) correction, the installation of COSTAR and the de-commissioning of FOS. Linear regressions were fitted to the data in these three windows, and were subsequently used to renormalize the shifts for each grating/aperture combination. The additive renormalization usually was less then 0.2 pix, for all but two gratings. The result is depicted in Fig. 2. There are no apparent slopes in the residuals (average trend – individual disperser), reassuring that this procedure is valid.

3.2. FOS/RED specific

The red side data points appear to present a scatter-diagram with no obvious trends in time and with a full peak-to-peak range of about 7 pixels (Fig. 3). Application of the same procedures used for the blue side slightly reduces the scatter but it remains large ($\approx$ 5.5 pixels) compared to the blue side.

4. Discussion

All results strongly indicate that the main physical source of the problem of shifts in the x-scale (wavelength zero-point shifts) of FOS data is unrelated to either the aperture or the FGWA. It does seem to be a detector-related process instead. We offer the following hypothesis: The long-term drift (see Fig. 1) and short-term, orbital-position related motion of the x-scale on the FOS diode arrays is very likely related to the differing magnetic shielding properties of the FOS Digicons, i.e., another incarnation of the GIM. FOS/BLUE, which had a factor 4-7 better mu-metal shield than FOS/RED, was not very susceptible to x-drifts as HST moved through its orbit. However, the shield could have

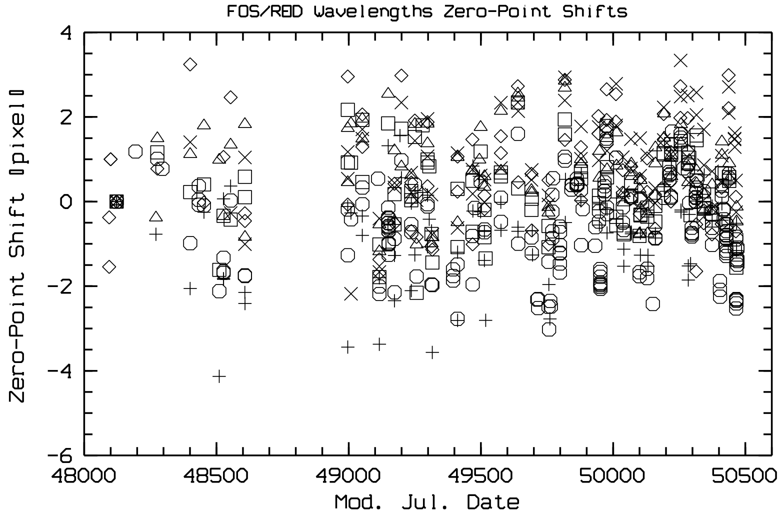

Figure 3. Uncorrected FOS/RED wave calibration sets.

acquired its own field over time, producing the long-term linear drifts. A full understanding of the zero-point shifts will require a realistic description of the ambient magnetic environment of the HST and its effect on the FOS detectors. Work to this end is well underway.

5. Quick Fix

A more detailed description of the work presented here is given in the FOS instrument science report (ISR) 149, which is available at the STScI web site:

`http://www.stsci.edu/ftp/instrument_news/FOS/pub/fos_isr149r1`

A script that corrects the zero-point shifts and reduces the scatter to the one pixel peak-to-peak uncertainty level in the Blue is available at:

`http://www.stsci.edu/ftp/instrument_news/FOS/fosbl_wcorr`

The analysis of the cause of the FOS zero-point shifts at the ST-ECF is continuing and procedures providing a full scale correction will be made available once the behaviour of the FOS wavelength scales can properly be described.

References

Keyes, T. ed. 1997, HST Data Handbook, v. II, (Baltimore: STScI)

Kriss, G. A., Blair, W. P., & Davidsen, A. F. 1991, Revised FOS Wavelength Calibration (STScI FOS ISR CAL/FOS 067) (Baltimore: STScI)