## Position Repeatability of Spectra Obtained with the FOS

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### Abstract

This paper deals with data taken before the on-board GIM correction was applied, and concerns observations taken in the atypical manner of many independent exposures. In this case, a GIM factor of 1.8 diodes Gauss$^{-1}$ should be applied to Red side observations.

## I. Introduction

FOS science proposals do not usually include requests for wavelength calibration exposures corresponding to the science exposures. Instead a standard wavelength calibration exposure is used to provide the correspondence between detector readout position (pixel number) and wavelength. The applicability of the standard calibration depends on the consistency with which the FOS hardware can place, and hold, spectra on the detector's diode array , exposure after exposure.

If we accept that wavelength errors are negligible for the standard calibration, then any difference we might find between the observed and expected wavelength of a given feature in a spectrum depends only on the hardware repeatability . Known factors affecting this repeatability are:

1) geomagnetically induced image motion or GIM (cf. Baity et al. 1993) This problem, identified early in Orbital Verification, was traced to poor quality magnetic shielding. Algorithms for its removal have been incorporated into the PODPS reduction software (see Keyes, this volume).

2) target centering error (1 to 2 quarter steps – Caganoff et al. 1992)

3) aperture wheel non–repeatability (small – Harms and Dressel 1992)

4) filter -grating wheel non-repeatability (Hartig 1989).

Other factors, such as temperature effects, may be important but have not been addressed.

A number of sky spectra were obtained with several low dispersion configurations as part of Science Verification. The output from several of the configurations contain well defined zero order spectra and atmospheric emission lines whose positions can be reliably compared from exposure to exposure. Since discrete targets are not

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involved, the results are independent of target centering. The sky spectra form a consistent data set that can be used to study problems due to hardware repeatability.

## II. Observations

Between February 1991 and March 1992, exposures of seventy sky fields were made using the G160L grating and the FOS Blue Digicon. During the same period exposures of 68 sky fields were obtained with the Red Digicon using the G160L and G650L gratings as well as the prism. The FOS target aperture, a 4.3 arcsec square, was used for all exposures. Fields which inadvertently contained point sources were identified using the zero order spectra present in the G160L and G650L exposures. These exposures and the prism sky spectra, which normally contain no discrete emission features, are not included in the following discussion.

## III. Discussion

In practice, any observation run may be broken into several exposures to satisfy scheduling requirements. Each exposure, presented to the user in separate files, is usually broken up into several sub-exposures or readouts.

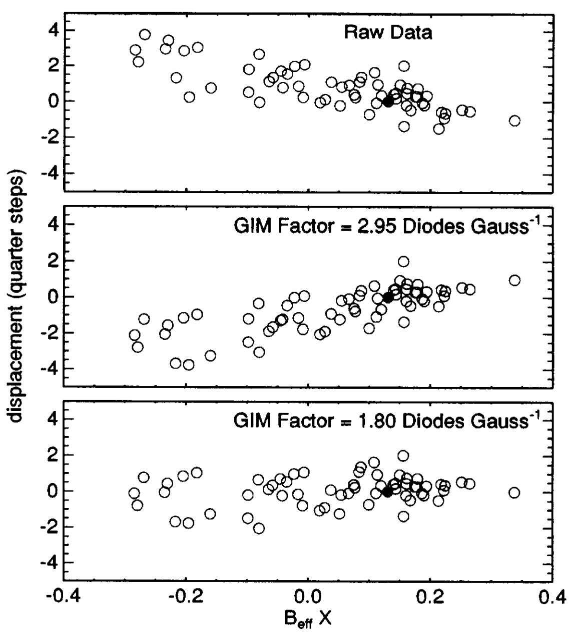


Fig. 1: Displacements for zero order of G160L Red detector data

As a first approximation to the variation due to non-repeatability, the raw data, corrected for bad channels but not for any geomagnetically induced motion, were used for each configuration. The zero order spectra were correlated with a standard chosen from the appropriate data set. For each configuration, only the first readout from each run was used since the hardware remained fixed for subsequent readouts. Figure 1 shows the position variation, in quarter steps relative to the chosen standard (filled circle), plotted against the component of the Earth's magnetic field oriented along the detector array , $B_{eff}X$, for the G160L data taken with the Red detector . The correlation between displacement and magnetic field is apparent. A similar correlation occurs with the G650L data although the scatter is a bit larger due, perhaps, to the lower signal in the zero order spectra. The G160L data taken with the Blue detector show little correlation.

The dependence on the magnetic field, and hence the overall scatter , should be reduced by using data corrected for the geomagnetic image motion. The data were reduced in the standard manner but a dummy unit-value inverse sensitivity curve was used to avoid the loss of the zero order spectra. The standard reduction uses GIM factors of 2.95 diodes Gauss$^{-1}$ for the Red detector and 0.7 diodes Gauss$^{-1}$ for the Blue detector . Unexpectedly , the new results were worse for the Blue detector and different but not improved for the Red detector (see Figure 1).

**Table I: Result of Zero Order Sky Spectrum Correlation**

| | $\sigma$ (qs*) | Peak-to-Peak (qs*) | Linear Fit Slope (qs* Gauss$^{-1}$) |
|---|---|---|---|
| **G160L Blue – 64 Spectra** | | | |
| Raw Data | 0.47 | 2.1 | 0.67 |
| GIM = 0.7 diodes Gauss$^{-1}$ | 0.72 | 3.5 | 3.28 |
| GIM = 0.4 diodes Gauss$^{-1}$ | 0.47 | 2.1 | 0.90 |
| **G160L Red – 62 Spectra** | | | |
| Raw Data | 1.19 | 5.3 | -5.81 |
| GIM = 2.95 diodes Gauss$^{-1}$ | 1.22 | 5.8 | 6.01 |
| GIM = 1.80 diodes Gauss$^{-1}$ | 0.83 | 4.1 | 1.33 |
| **G650L Red – 62 Spectra** | | | |
| Raw Data | 1.69 | 8.1 | -6.23 |
| GIM = 2.95 diodes Gauss$^{-1}$ | 1.64 | 7.2 | 5.50 |
| GIM = 1.80 diodes Gauss$^{-1}$ | 1.40 | 5.9 | 1.02 |

* qs stands for quarter steps $\sim 12.5\mu$ (4 quarter steps diode$^{-1}$)

Since these tests were run prior to implementation of the on-board GIM correction, each exposure was preceded by a degauss operation. The data set for each configuration was formed using only the first sub-exposure from each observation. These sub-exposures are completely independent and each was preceded immediately by a degauss operation. Previous work (Hartig et al 1991), confirmed by laboratory tests (Beaver and Foster 1992), indicated smaller GIM factors were required to register data immediately preceded by a degauss. For the Red side, the smaller factor is around 1.8 diodes Gauss$^{-1}$ compared to 2.95 diodes Gauss$^{-1}$ within an exposure. Similar tests have not been run on the Blue side but the Blue side is expected to be better by a factor of 4 or so, implying a reduced GIM factor around 0.4. The results on the Red side improved when the smaller GIM factor was used as can be seen in Figure 1.

The peak to peak scatter and internal scatter about the mean for the various configurations and conditions are presented in Table I. We believe that most of this scatter is due to filter-grating wheel non-repeatability. Keep in mind that these numbers refer to the position repeatability between independent exposures. Consecutive exposures made in a single run with the same instrument configuration are not independent since the filter–grating wheel is not moved.

## IV. Conclusions

The GIM corrections were originally implemented to register sub-exposures within exposures, which they do. However, the manner of implementation has not corrected the lack of registration between exposures. Two GIM factors are required. The best factors determined in this analysis are smaller than those found previously or expected indicating the need for additional work. This is particularly true for the Blue detector since the factors are small and the best result was obtained with no GIM correction. Small position errors in the flat fields and the wavelength and intensity calibrations may be present due to the use of the wrong GIM factors.

For random observations the maximum differences in the zero points of the wavelength scales due to hardware non-repeatability are 2, 4, and 6 quarter steps for the G160L Blue, Red and G650L Red configurations respectively. (Note that the standard calibration observations are also subject to position non-repeatabilities.) The standard deviations are 0.5, 0.8 and 1.4 quarter steps respectively. The values for the G650L are less certain due to the poorer quality of the zero order spectra.

The G160L configuration on the Blue side corresponds to the same hardware configuration as the G270H on the Red side so we might expect that the uncertainties, with proper corrections, would be comparable. The uncertainties in the G130H can be assessed on the Blue side using the geocoronal Lyα line. Other acceptable features, such as strong interstellar lines, might be useable with some of the other configurations, especially the high dispersion ones.

For more information see Lyons et al. 1993.

## Acknowledgment

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