FOS APERTURE REPEATABILITY AND FILTER-GRATING WHEEL REPEATABILTY (CALIBRATION PLAN 10C AND 10D)

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ABSTRACT

Repeatability of the FOS aperture wheel was measured in the ambient calibration of March, 1983. Cross-correlation of emission line spectra indicates that the tangential motion of the aperture wheel repeated to better than $0.6\mu m$ in the focal plane except for a shift of $2.3 \pm 0.3\mu m$ in the wheel position of aperture C2 when the wheel was cycled in the following order: C2, B2, A4, B2, C2.

Repeatability of the grating wheel was measured by locating the position of the 0.1 arcsec aperture in an aperture map after the grating wheel had been moved to various positions. Shifts of up to 10 m in both X and Y detector coordinates were detected. To check for repeatability over longer time intervals, additional measurements were derived from other ambient calibrations. A shift of $-0.45 \pm .02$ diode ($23 \pm 1\mu m$) in X on the detector occurred between two H57 A4 spectra made 7hrs apart. Furthermore, aperture maps made on different dates are shifted up to 0.28 diode ($14\mu m$) in X. The shifts in spectral position that are associated with rotation of the filter grating wheel are pushing the limits of accceptability for good photometric reproducability. The detent mechanism of the filter grating wheel and the seating of the camera mirror should be checked.

I. APERTURE REPEATABILITY

A series of external Pt-Cr-Ne emission line spectra were made with different apertures in the ambient calibration of March, 1983 to determine how well the position of the aperture wheel repeated. The nine spectra, made with grating H57 and eight x-steps, were taken with the red detector over a 75 minute interval in the following order.

1	2	3	4	5	6	7	8	9
C2	C2	C2	B2	A4	B2	C2	B2	A4

To determine whether there are systematic shifts between spectra, a cross-correlation technique is used. The spectra are correlated in 100 diode bins. As there are no spectral lines in the last bin (diodes 400–500), only the results of the first four bins are considered. In each comparison, there are no systematic shifts as a function of bin number,an indication that the spectra are linearly translated but not stretched. In Table 1, the average of the first four bins is presented as a measure of the shift between spectra.

With the exception of a $.014 \pm .002$ diode shift between trials 3 and 7 with aperture C2, the spectra repeated to .004 of the diode separation or better, which is the accuracy of the measurements. The diode separation is 50μm in the x-direction. From these motions on the diode array, we can calculate the corresponding tangential motion of the aperture wheel from the geometry. The dispersion direction is angled approximately 54°to the tangent of the aperture wheel. This, combined with the $2\times$ difference in scale between the detector and the aperture wheel, determines the relation between motion on the detector (d) and motion of the aperture wheel (x):

$$x = \frac{2d}{cos(54°)} \simeq 3.4d$$

Applying this to the measured shifts, we find that the aperture wheel shifted $2.3 \pm 0.3\mu$m between trials 3 and 7 with C2, compared with 0.6μm or less for the other trials. The large shift occurred when the wheel was cycled through B2, A4 and B2 before returning to C2.

II. FILTER–GRATING WHEEL REPEATABILITY

The repeatability of the grating wheel was measured in March, 1983 by projecting an image of the 0.1 arcsec paired aperture onto the photocathode with the camera mirror. In between these aperture maps, the grating wheel was rotated to other grating positions and then returned to the camera mirror. Ten aperture maps were made in a 90 minute interval in the following order.

map1 PRI map2 H57 map3 H19 map4 H40 map5 H78
map6 H27 map7 H40 map8 H13 map9 L15 map10

Using the red detector, 68 y-steps of 11.29μm were made with a 20 diode wide section of the diode array (diodes 254–273), which was quarter-stepped and overscanned by 5 diodes. This produces a 96×68 aperture map with an effective sampling size of 12.5μm in X and 11.3μm in Y. Because the true $14 \times 14\mu$m aperture image is convolved with the $50 \times 200\mu$m FOS diode area, the aperture map produces an image approximately the same size as a diode.

The center of an aperture image is measured by first computing the average cross-section of the aperture (sum of the counts) in each dimension. A centroid of this cross-section is used to compute the center of the aperture. For example, in the X-direction, the center of the aperture is given by:

$$\overline{x} = \frac{\sum x \cdot C}{\sum C}$$

where x is the X–coordinate and C is the number of counts in each x-step. The expression for Y is the same but with y-steps substituted for x-steps. The conversion between y-steps and y-position on the detector is: y-position(μm) = y-base + 11.23μm $\times$ y-steps. The y-base used for these aperture maps is -393μm .

The positions of the upper and lower halves of the paired aperture are shown in Table 2 and Figures 1 and 2. The motion of the upper aperture corresponds to that of the lower to within .07 diode (3.5μm) in X, and 0.13 y-steps (1.5μm) in Y, suggesting that the measurement of the aperture positions is at best this accurate. Visual examination of the aperture maps clearly shows the shifts. An example is the contour plot in Figure 3 where trial 7 (dashed line) is compared with trial 8 (solid line).

In the Y-direction, an increase of 7μm occurred between trials 1 and 2, followed by a slow decline of 10μm between trials 2 and 8. The x-position repeats to better than 0.1 diode (5μm) in trials 1–7, but both apertures shift 0.2 diode (10μm) between trials 7 and 8. The wheel was moved to grating H40 between these trials, as was the case between trials 4 and 5, but no anomalous shift occurred there. The dispersion direction is oriented radially on the grating wheel, so that rotation of the wheel produces a movement in the Y direction on the detector.

III. LONG TERM REPEATABILITY

Additional spectra taken in the internal–external offset and internal wavelength calibrations show much larger changes in the x-position of spectra from day to day in the March, 1983 calibration. The external H57 A4 red spectrum obtained seven hours after the repeatability data is shifted $-0.45\pm.02$ diode ($-23\pm1\mu$m) from trial 1 of the repeatability calibration, compared with internal–external offsets ranging from .01 to .07 diode (0.5 to 3.5μm). The H57 internal wavelength spectrum obtained 40 hours earlier is shifted only $-.04\pm.02$ diode ($-2\pm1\mu$m) from trial 1. Furthermore, the A4 map for part 10B of the aperture map calibration, which was made 13 hours before the FGW repeatability maps, is shifted 0.28 diode (14μm) in X, but less than 0.5μm in Y.

The FOS notebook and the tape log indicate that the detector was used prior to these calibrations, so that it is unlikely that power-up settling times caused the shifts. In the ambient calibration, the temperature should have remained roughly constant, so that thermal shifts should not be a factor. No standard header packets were obtained with the March data, so that correlation of the shifts with temperature can not be checked. One theory to explain the observations is that the camera mirror might be loose in its fixture. Another possiblility is that we are seeing slop in the filter grating-wheel detents, which could be uncorrelated in X and Y. In the 1984 calibrations, we will obtain additional long-term repeatability spectra in order to confirm these shifts and isolate their cause.

FIGURE CAPTIONS

Figure 1. Filter grating wheel repeatabilty in X. The position of the lower aperture (dashed line) is compared with that of the upper aperture (solid line).

Figure 2. Filter grating wheel repeatabilty in Y. A constant has been added to the position of the lower aperture (dashed line) so that both apertures can be shown on the same plot.

Figure 3. Contour plot of the lower aperture. Trial 7 (dashed line) is plotted over trial 8 (solid line) to show the 0.2 diode shift between trials.

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TABLE 1. APERTURE REPEATABILITY MEASURED BY CROSS-CORRELATION OF SPECTRA

APERTURE	TRIALS	SHIFT ON DETECTOR (DIODES)	SHIFT ON APERTURE WHEEL (MICRONS)
C2	1,2	.002 +/- .001	0.4 +/- 0.2
C2	1,3	.002 +/- .003	0.3 +/- 0.5
C2	1,7	.014 +/- .002	2.3 +/- 0.3
B2	4,6	.004 +/- .002	0.6 +/- 0.3
B2	6,8	-.002 +/- .005	-0.3 +/- 0.2
A4	5,9	-.001 +/- .005	-0.2 +/- 0.8
OFFSETS BETWEEN APERTURES, FOR COMPARISON:			
C2,A4	1,9	.177 +/- .011	30.1 +/- 1.9
B2,A4	4,9	.059 +/- .006	10.0 +/- 1.0

TABLE 2. FGW REPEATABILITY: CENTROIDED POSITIONS OF 0.1 ARCSEC APERTURE IMAGES

GRATING		X-POSITION (DIODES) L	X-POSITION (DIODES) U	Y-POSITION (MICRONS) L	Y-POSITION (MICRONS) U
1	CAM PRI	267.877	267.720	−171.3	243.9
2	CAM H57	267.861	267.663	−164.3	251.5
3	CAM H19	267.905	267.747	−166.0	250.1
4	CAM H40	267.894	267.708	−166.1	248.6
5	CAM H78	267.916	267.745	−171.3	244.6
6	CAM H27	267.914	267.742	−171.0	245.2
7	CAM H40	267.928	267.772	−172.1	243.2
8	CAM H13	268.130	267.991	−173.5	243.1
9	CAM L15	268.098	267.892	−168.5	246.8
10	CAM	268.076	267.924	−171.6	243.9

L = LOWER

U = UPPER

Figure 1.

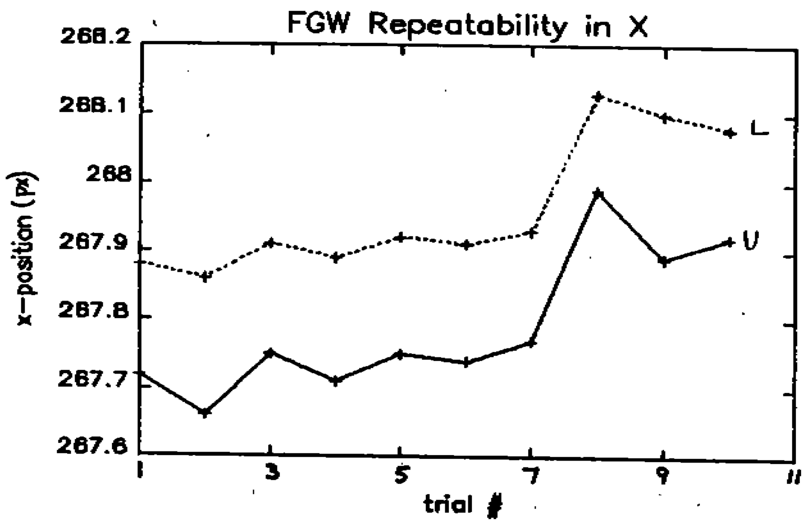

Figure 2.

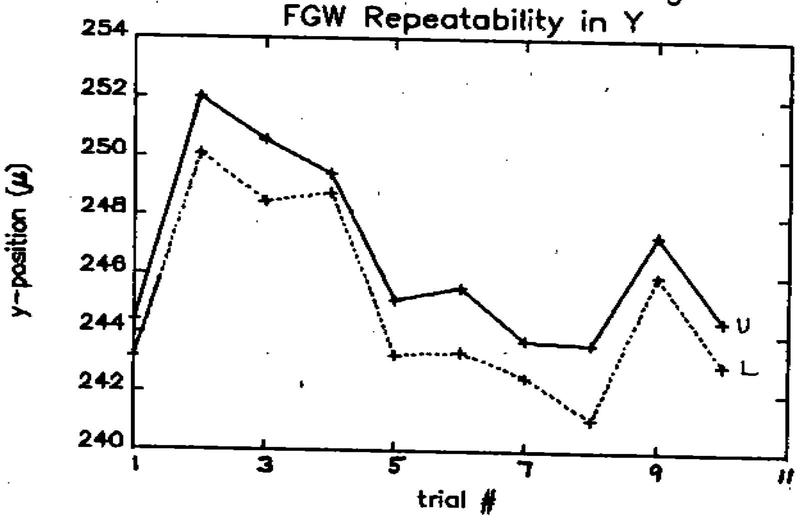

Figure 3.