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FOS PRE-COSTAR BLUE SIDE: TARGET ACQUISITION ACCURACY

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Abstract

Pointing accuracy of the FOS is examined after a sample of 12 planetary nebulae in the Magellanic Clouds are acquired using on-board binary search or peak-up acquisition modes. Accuracies are determined from FOS images of the 4″.3 aperture after completion of the normal acquisition modes. The accuracies are measured with respect to the image center. The location of the aperture center is unknown and does not necessarily coincide with the image center. From 10 cases, the binary search acquisition mode is repeatable to $1\sigma = 0''.08$, but with a mean systematic offset from the image center of 0″.09. The uncertainty in the mean is 0″.03. The offset is predominantly in the X-dimension, and is also present in data presented by Caganoff, Tsvetanov, & Armus in CAL/FOS-081. The maximum uncertainty in the peak-up acquisition mode is 0″.30 in each axis for the aperture and search pattern used here, and the results from the two objects acquired with a peak-up indicate no systematic effect greater than this uncertainty.

1 Introduction

The HST frame of reference is defined by the guide stars contained within the Guide Star Catalog. In general, the relative positions of the guide stars are accurate to within 0″.4 over the HST 30′ field of view (Taff et al. 1990).

The binary search and peak-up acquisition modes of the FOS are designed to center the desired objects in the science apertures. The standard apertures range in size from the 4″.3 square aperture down to the 0″.3-diameter circular aperture. The pointing accuracy with respect to the aperture center becomes more important as the aperture size decreases (Evans 1993; Bohlin 1994).

Caganoff, Tsvetanov, & Armus (1992) conducted a series of tests for the different acquistion modes of the FOS but their results are subject to small sample statistics. Based on two blue-side cases reported in Caganoff, Tsvetanov, & Armus, the binary search acquisition mode is repeatable to $1\sigma = 0''.08$, but with a systematic offset of 0″.11.

The peak-up acquisition mode accuracy depends on the size of the aperture and the sampling pattern. For a peak-up using the 0″.3 aperture with 0″.2 steps, Caganoff, Tsvetanov, & Armus find a repeatability of $1\sigma = 0''.04$ for the blue-side, but with a systematic offset of 0″.18.

2 Observations

2.1 Method of Acquistion

A sample of 11 planetary nebulae in the Magellanic Clouds are observed with the FOS under GO proposal 3441. An additional planetary nebula in the Large Magellanic Cloud is observed under GO proposal 4040. All observations are obtained with the blue-side detector of the FOS.

The object dimensions are determined from PC images taken in the F502N filter under GO proposal 2266. Those objects with diameters less than the FOS diode width of $\sim 0''.357$ are acquired using binary search mode. The two remaining objects in the sample are acquired using peak-up mode.

The peak-up acquisition mode is carried out in a single stage, using a 5×5 grid with $0''.5$ steps of the $1''.0$-diameter aperture. The subsequent uncertainty in an object's position is $0''.25$ in both the X and Y dimensions for a symmetric pre-COSTAR PSF. The pre-COSTAR PSF is not symmetric and therefore the uncertainty in an object's position can be as large as $\sim 0''.30$ (Evans 1993).

2.2 Acquisition Image

Following the acquisition of each object, an FOS image is taken with the $4''.3$ aperture. Descriptions of this acquistion mode can be found in the FOS Data Products Guide (Golombek et al. 1993, page 44). The FOS images are examined in their blurred form as recorded by the telescope. As most of the targets are faint and extended, deconvolution of the blurred images tends to lower the S/N to one.

The blue side plate scale is derived from database values (cf. Koratkar 1993). The scale in the X-dimension is $0''.08925$/pixel, where four pixels are equivalent to the width of one FOS diode. The scale in the Y-dimension is $0''.08958$/pixel, which is equivalent to 16 Y-base units. The X-Y dimensions of the image are 96×64 pixels, or $8''.6 \times 5''.7$. Therefore, the scanned region of the photocathode is *larger* than the size of the $4''.3$ aperture. Many of the pixels towards the image edges do not have full illumination of the diodes.

3 Results

The position of each object is measured using the IRAF-STSDAS task `aperlocy`. Positions from three centering algorithms are calculated in units of diodes in the X-dimension and Y-base units in the Y-dimension. The planetary nebula targets are all acquired using the MIRROR disperser. All the targets appear more point-like than their narrow-band [O III] images, because the blue-side detector is sensitive to UV flux from the central stars. The (X,Y) centroid returned by `aperlocy` defines the object center in the acquisition image.

The binary search acquisition mode relies on finding the centroid of a target in the X-dimension, and on stepping the diode array in the Y-dimension until the target lies on the edge of the array. The centroid and maximum of a target can differ by $\sim 0''.05$, even for point sources, because of slight asymmetries in the HST-FOS PSF (Evans 1993).

A peak-up acquisition returns to the region of the sky at which the greatest flux is recorded through an aperture following a predefined scan pattern. The uncertainty in the target acquisition is determined mainly by the aperture size and the step size between dwells in the scan pattern.

By definition, the image center is located at the X and Y midpoints of the 96×64-pixel image. In terms of the pixel coordinate convention used within IRAF, the center of the first pixel is located at (1.0,1.0). Therefore, the image center is located at (48.5,32.5). The image center position can be converted to diodes and Y-base units using the following relations:

$$\text{IMAGE\_CENTER(X)} = \text{FCHNL} + (48.5 - 1)/\text{NXSTEPS} \quad (1)$$

$$\text{IMAGE\_CENTER(Y)} = \text{YBASE} + (32.5 - 1)\text{YSPACE} \quad (2)$$

The header keywords for the blue side have the following values: FCHNL = 230 diodes, NXSTEPS = 4, YBASE = −1544 Y-bases, and YSPACE = 16 Y-bases. The YBASE keyword refers to the starting Y-base value at the bottom of the image and not to the Y-base position of the center of the aperture.

The values of the header keywords are those values which are uplinked to the spacecraft to execute an aquisition image exposure. The actual position on the photocathode may not be the same from one observation to the next. The filter-grating-wheel non-repeatability is of the order of 10μm, or $0''.07$ (Hartig 1989). In addition, there are long term shifts with respect to time in the Y-base position of the aperture center location observed on the blue-side photocathode (Koratkar et al. 1994).

Using the expressions defined above, the image center is located at (241.875 diodes, −1040 Y-bases) with respect to the IRAF coordinate frame. The aperture and image centers are not necessarily identical. The offsets of the object (X,Y) positions from the image center, $\sqrt{(\delta X)^2 + (\delta Y)^2}$, are listed in Table 1 for each object. Despite the uncertainties in the *absolute* target and aperture center positions, the *relative* offset between the target and image center positions can be measured.

Table 2 shows the mean offsets and (X,Y) positions calculated from the information presented in Table 1. Mean offsets are also calculated from blue-side data presented in Table 1 of Caganoff, Tsvetanov, & Armus. For the peak-up mode results, data are taken from the second peak-up stage conducted by Caganoff, Tsvetanov, & Armus, which used the $0''.3$ aperture with $0''.2$ steps. The intrinsic uncertainty in each dimension is $0''.1$. Combined with the uncertainty associated with the asymmetry in the PSF, the total uncertainty in the peak-up acquisition is $\sim 0''.15$. In principle, the third peak-up stage with the $0''.3$ aperture and $0''.05$ steps is more accurate but, as with the second peak-up stage, the pointing accuracy is limited by spacecraft jitter and geomagnetically induced image motion. See Caganoff, Tsvetanov, & Armus for a discussion. The quoted errors in Table 2 represent a 1-σ scatter in the derived means.

The mean (X,Y) position of an object after a binary search acquisition from this study and Caganoff, Tsvetanov, & Armus agree to within the quoted errors. Both studies find a systematic offset from the image center of the order of $0''.1$, predominantly in the X-dimension and in the same direction. No sytematic offset is seen in the Y-dimension.

The mean (X,Y) position following a peak-up acquisition does not coincide with that from a binary search acquisition. The maximum uncertainty in the Caganoff, Tsvetanov, & Armus peak-up method is $0''.15$, whereas in this study the maximum uncertainty is $0''.30$. The (X,Y) peak-up positions in Table 2 give an offset from the image center in the same direction in the X-dimension as that recorded by Caganoff, Tsvetanov, & Armus, but the offset is smaller than the uncertainty in the peak-up method. In contrast, the Caganoff, Tsvetanov, & Armus data are more accurate and show a difference of $0''.28$ in the X-dimension between the mean binary search and peak-up target positions. This result is however based on only two observations and requires more observations to reduce the statistical errors.

4 Conclusions

The mean (X,Y) position of the object after a binary search acquisition is offset from the FOS acquisition image center by 0.″09, predominantly in the X-dimension. The binary search acquisition mode is repeatable to $0''.08$. From 10 observations, the uncertainty in the mean systematic offset is $0''.08/\sqrt{10} = 0''.03$. The measured repeatability and systematic offset are in agreement with those obtained by Caganoff, Tsvetanov, & Armus (1992) from only two blue-side binary search acquistions. The image center does not necessarily coincide with the aperture center so no conclusions can be reached concerning the binary search acquisition accuracy with respect to the $4''.3$-aperture center.

The two peak-up mode acquisitions with the $1''$ aperture do not appear to position the object to the same point as the binary search mode acquisitions in the $4''.3$ aperture. However, the peak-up acquisitions have an intrinsic uncertainty of $0''.25$ in each axis, which is greater than the discrepancy observed between the two acquisition methods. More images following peak-up acquisitions, with maximum positional uncertainties of $\sim 0''.1$, are necessary to accurately measure any offset between the final mean binary acquisition position and the final mean peak-up position in FOS acquisitions.

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TABLE 1

POSITIONS MEASURED FROM ACQUISITION IMAGES

Rootname	Object	X_{Object} (Diodes)	Y_{Object} (Y-bases)	δX ($''$)	δY ($''$)	Offset ($''$)
Y1C10102T	SMC-SMP 1	241.60	−1033	−0.10	0.04	0.11
Y1C10202T	SMC-SMP 3	241.59	−1056	−0.10	−0.09	0.13
Y1C10302T	SMC-SMP 6	241.59	−1020	−0.10	0.11	0.15
Y1C10402T	SMC-SMP 28	241.67	−1022	−0.07	0.10	0.12
Y1C10502T	LMC-SMP 2	241.70	−1031	−0.06	0.05	0.08
Y1C10602T	LMC-SMP 8	241.90	−1040	0.01	0.00	0.01
Y1C10802T[a]	LMC-SMP 35	242.24	−1046	0.13	−0.04	0.14
Y1C10902T	LMC-SMP 40	241.77	−1041	−0.04	−0.01	0.04
Y1C10A02T	LMC-SMP 47	241.47	−1023	−0.14	0.09	0.17
Y1C10B02T	LMC-SMP 76	241.56	−1028	−0.11	0.07	0.13
Y17V0102T	LMC-SMP 85	241.63	−1050	−0.09	−0.06	0.10
Y1C10C02T[a]	LMC-SMP 87	242.12	−1019	0.09	0.12	0.15

[a] Peak-up mode.

TABLE 2

COMPARISON WITH EARLIER RESULTS

Mode	$\overline{X}$ (Diodes)	$\overline{Y}$ (Y-bases)	$\overline{\delta X}$ ($''$)	$\overline{\delta Y}$ ($''$)	$\overline{\text{Offset}}$ ($''$)
Caganoff, Tsvetanov, & Armus; Blue-side Result Only					
ACQ/BIN	241.57 ± 0.03	-1035 ± 15	-0.11 ± 0.01	0.03 ± 0.08	0.11 ± 0.08
ACQ/PUP	242.34 ± 0.11	-1049 ± 4	0.17 ± 0.04	-0.05 ± 0.02	0.18 ± 0.04
This Study					
ACQ/BIN	241.65 ± 0.12	-1034 ± 12	-0.08 ± 0.04	0.03 ± 0.07	0.09 ± 0.08
ACQ/PUP	242.18 ± 0.08	-1033 ± 20	0.11 ± 0.03	0.04 ± 0.11	0.12 ± 0.11