On-Orbit Performance of the ACS Solar Blind Channel

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ABSTRACT

The ACS solar blind channel (SBC) is a photon-counting MAMA detector capable of producing two-dimensional imaging in the UV at wavelengths 1150-1700 Angstroms, with a field of view (FOV) of 31'' × 35''. We describe the on-orbit performance of the ACS/SBC from an analysis of data obtained from the service mission observatory verification (SMOV) programs. Our summary includes assessment of the point-source image quality and point spread function (PSF) over the SBC FOV, the dark current measurements, the characteristics of the flat fields, fold analysis, throughput, and the UV sensitivity monitor to check for contamination. Where appropriate, a comparison with pre-launch calibration data will also be made.

Keywords: Hubble Space Telescope, HST Advanced Camera for Surveys, ACS, Solar Blind Channel, SBC, SMOV

1. INTRODUCTION

The Solar Blind Channel (SBC) on the Advanced Camera for Survey (ACS), installed in March 2002 on the Hubble Space Telescope (HST) during Service Mission 3B (SM3B) is a spare detector from the Space Telescope Imaging Spectrograph (STIS) program. It is a Multi-Anode Microchannel Array (MAMA) photon-counting device that uses a CsI photocathode on a curved microchannel plate (MCP). To improve the quantum efficiency, the MAMA detector has been equipped with a field electrode, or repeller wire, that repels electrons emitted away from the MCP back into the channel. Optimized for UV imaging at wavelengths 1150Å to 1700Å, the SBC has an imaging area of 1024 x 1024 pixels with a sampling of 0.030'' per pixel, yielding a total field of view of 31'' × 35''. Besides a set of long-pass filters (F115LP, F125LP, F140LP, F150LP, F165LP), and a Ly\textalpha\ (F122M) filter for direct imaging, it is also equipped with two prisms for low-resolution (R ~ 100) objective prism spectroscopy. The detector is cosmetically fairly clean, the only defects being a broken anode and three clusters of hot pixels. As with STIS MAMA detector, the ACS/SBC has bright-object limits to protect it from radiation damage. For non-variable sources, the local (per pixel) count rate cannot be over 50 counts/sec/pixel, and the global (over the whole detector) limit is < 2x10\textsuperscript{5} counts/s. The optical performance of the SBC is comparable to that of the STIS FUV-MAMA. The ACS/SBC is expected to give slightly higher quantum efficiency but lower S/N due to higher dark current than STIS FUV-MAMA. Since launch, a number of tests for performance characterization of ACS have been carried out as part of the service mission observatory verification (SMOV) program. We briefly report here the results of some of these tests for the SBC. Some discussion of the ACS imaging quality is also given in Hartig et al. (2002), and the geometric distortion in the ACS detectors is described in detail by Meurer et al. (2002).

2. SMOV RESULTS

2.1 First light

The SBC collected its first astronomical photons on 2002 May 27, with observations of the globular star cluster NGC6681. This cluster is rich in blue horizontal branch stars, which are the primary sources visible in the far ultraviolet. The NGC6681 field is being used for numerous calibration purposes including flux calibration, geometric distortion characterization, low-order flat creation, PSF characterization, and monitoring of contamination. Figure 1
combines first light data taken with three filters F125LP, F150LP, and F165LP. The images have been flat-fielded but not corrected for geometric distortion.

Figure 1: First light ACS/SBC image of the globular cluster NGC 6681.

2.2 Detector health

Figure 2. Fold Analysis for ACS/SBC.
An important SBC diagnostic is the so-called "fold analysis". Individual photon events generate charge clouds which impinge on the position-sensing anode array. The number of anode lines that collect a charge signal is the "fold number" for the event. The distribution of fold numbers measures the gain distribution for the microchannel plate (MCP). A shift to lower fold numbers would imply gain sag in the MCP, perhaps due to excessive accumulated illumination, while a shift towards larger fold number pulses could indicate leakage of gas into or production of gas within the sealed detector tube. Figure 2 shows the event distributions observed during ground testing of the tube in 1997 as well as the distribution recently observed in-flight. *Little change in the distributions has been seen over the four years of ground testing and through launch.* The small shift in the fold distribution on orbit relative to the 1997 data may be due to differences in the illumination conditions at the different epochs.

2.3 Dark currents

Figure 3 shows the first in-flight “super dark” image. The observations were taken over a ten hour span, near the maximum time between South Atlantic Anomaly passages. The dark horizontal stripe is due to a broken anode in the MAMA. The mean dark rate in this image is 1.049e-5 counts/sec/pixel = 0.0378 counts/hour/pixel. This fairly low rate is comparable to those measured during the thermal vacuum ground calibration campaign of July 2001 (Martel et al. 2001), and is largely due to a relatively cool tube temperature $T_{\text{SBC}} = 15^\circ$ to $27^\circ$ C during the observations. Ground thermal modeling indicates that a thermal balance at $T_{\text{SBC}} = 35^\circ$ to $37^\circ$ C may occur, in which case the dark rate will be about three times higher.

![Figure 3: In-flight ACS/SBC dark image.](image)

2.4 Flat field structure

Figure 4 shows the deep “P-flat” that will be used to calibrate long pass filter observations (Bohlin et al. 1999). P-flats are used to remove pixel-pixel variations, hence all low order structure has been removed from this image. The data were obtained during ground thermal vacuum calibration at Goddard Space Flight Center. Low-order flat-fields will be obtained by dithering observations of NGC6681. Ground calibrations indicate very little wavelength dependence in the flat field. Features in the flat-field include:

- Shadow of the repeller wire: dark vertical strip.
- Broken anode: masked out horizontal strip.
- Anode array pattern: horizontal – vertical checkerboard structure.
- Micro Channel Plate: hexagonal structure.
- Moire pattern: due to “beating” between anode array and MCP.
2.5 Image quality

Figure 5 illustrates the PSF structure in SBC images. The right-hand panel shows an encircled energy (EE) curve and a radial profile of a star in the first light data. The solid curves show the profiles at nominal x-scale, whereas the scale has been stretched by a factor of ten for the dashed curves. The EE curve shows that 28% of the light is contained within a circular aperture 0.12" in diameter, while 51% of the light is contained within a diameter of 0.25". The left hand panel expands a portion of the F125LP first light image. These data have been corrected for geometric distortion. There is small spur extending ~0.13" from the center of each PSF to the lower right. This is due to aberration in the system. A similar aberration is seen in UV images of the high resolution channel (HRC), but the aberration is not seen at optical wavelengths with either HRC or wide field channel (WFC; Hartig et al. 2002). We are currently investigating how much of the aberration is due to ACS optics and how much to the HST Optical Telescope Assembly.

Figure 5: ACS/SBC PSF profile (right bottom) and encircled energy curve (right top). The left panel shows the low-level elongation to the lower right in the PSF of each star due to aberration.
2.6 Throughput

The first light data indicate that the throughput is very close to pre-launch expectations. The upper left panel in Figure 6 shows the total throughput curves for SBC’s five long pass filters as well as the Ly$\alpha$ filter (F112M). Table 1 lists properties of the imaging bandpasses derived from the total throughput curves. The lower right panel compares STIS FUV MAMA count-rates with SBC measurements for six bright stars near the field center. The y axis shows the difference in count rates between the SBC and STIS observations (using the clear filter & the F25MAMA aperture, data kindly made available by T. Brown). Different symbols are used to indicate each filter. The corresponding dotted lines show the pre-launch model expectations for a Kurucz (1993) stellar atmosphere having $T = 2 \times 10^4$ K, [Fe/H] = -1.5, & log $g = 5$, appropriate for the hottest BHB stars in NGC6681 (Harris et al. 1996; Brown 2002, private communication). The SBC using either F115LP or F125LP has a higher throughput than STIS’s clear aperture. This is due to fewer reflections in the ACS/SBC optics than for STIS/FUV-MAMA.

Figure 6: Throughput of ACS/SBC.
In Figure 7 we show the average ratio of observed over expected count rates for 10 different stars in NGC 6681, whose spectra are well-known from STIS spectroscopy, as a function of wavelength for the SBC. The on-orbit data were obtained during SMOV, and measured within a 0.4” radius aperture. Data for the F122M (Lyα) filter came from the standard star HS+2027. Except for F165LP, the sensitivity of the SBC is very close to expectations. The ~ 16% increase in sensitivity in the F122M band is probably not a result of higher efficiency of the detector, but instead likely due to red leak.

<table>
<thead>
<tr>
<th>Filter</th>
<th>Unit response</th>
<th>Pivot WL</th>
<th>Rect. Width</th>
<th>Peak throughput</th>
</tr>
</thead>
<tbody>
<tr>
<td>F115LP</td>
<td>1.53</td>
<td>1431</td>
<td>406</td>
<td>0.0490</td>
</tr>
<tr>
<td>F125LP</td>
<td>1.72</td>
<td>1459</td>
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<td>F140LP</td>
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<td>F150LP</td>
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<tr>
<td>F165LP</td>
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<td>1762</td>
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<td>0.0119</td>
</tr>
<tr>
<td>F122M</td>
<td>33.44</td>
<td>1286</td>
<td>126</td>
<td>0.0081</td>
</tr>
</tbody>
</table>

Figure 7: Average observed/predicted count rate ratios of 10 different stars in NGC 6681 as a function of SBC bandpasses.

2.7 Contamination monitor

Soon after the installation of ACS on HST, a SMOV program was initiated to 1) manage ACS operations to minimize the risk of contamination of its optics by materials outgassed during servicing activity, and 2) monitor the UV sensitivity of HRC and SBC as early as possible after the service mission. The ACS UV sensitivity of the HRC CCD and SBC MAMA detectors was to be monitored approximately once a week for the first two months, and once a month thereafter. A field in the globular cluster NGC6618 was chosen. This field contains several stars well-observed with STIS for its
own UV sensitivity monitoring program. The SBC observations were made through all five longpass filters (F115LP, F125LP, F140LP, F150LP, F165LP).

The results of the UV contamination monitor show that the observed count rates are quite stable, and behave nominally for all SBC filters. There does not seem to be any degradation in throughput resulting from any contaminants deposited on the SBC optical surfaces during service mission SM3B. Figure 8 shows that the count rates measured within a 0.6” radius aperture do not change significantly during the six epochs over the first 72 days that the SBC UV fluxes were monitored for contamination. We conclude from this behavior and from the throughput comparison with STIS that the SBC optics suffered no damaging contamination from service mission activity.

![Figure 8: Count rates versus time for six different stars in NGC6681 through the F115LP filter of SBC. Similar behavior is seen for other filters. No significant changes in count rates are seen as a function of time over the first two months of monitoring.](image)

3. CONCLUSIONS

This paper outlines the on-orbit performance of the Advanced Camera for Surveys (ACS) far ultraviolet camera called the Solar Blind Channel (SBC). These on-orbit data with the SBC have been recently obtained and show that the detector is behaving nominally. Images of stars with the SBC reveal an aberration in the optics similar to that observed in the HRC at UV wavelengths.

ACKNOWLEDGMENT

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REFERENCES
