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Mitigating Elevated Dark Rates in SBC Imaging

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Abstract

We present a new aperture that can be used to mitigate elevated dark rates in SBC imaging modes. The reference pixel of this new aperture is located at (175,185) on the detector. At this location the dark rate remains constant at all temperatures. This aperture is limited to observations of small targets, but visits can span an extended number of continuous orbits. We also present results on the heating and cooling rates of the detector. The length of time that the SBC is enabled affects how long it takes to cool back down to its initial temperature. It takes ∼2 hours for the detector to reach a temperature at which the dark rate becomes elevated. Once that threshold is reached, it takes ∼6 hours after the detector is turned off for the temperature to go back down to acceptable levels.

Introduction

The Solar Blind Channel (SBC) of the Advanced Camera for Surveys (ACS) is a photon-counting Multi-Anode Microchannel Array (MAMA). This type of detector does not experience dark current like CCDs do. In CCDs, the dark current structure is relatively constant. That is to say that most pixels have a constant dark rate from frame to frame. This is why dark frame subtraction to remove hot and warm pixels is effective for CCD images. The stability of the ACS Wide Field Channel (WFC) CCD makes it possible to combine darks from a period that spans up to four weeks (Ryon, 2018). On the other hand, the dark current in MAMA detectors appears in random pixels from frame to frame, meaning that a dark frame cannot be subtracted from a science frame without imprinting a random pattern on the image. The amount of dark current, like CCDs, does still depend on the temperature of the detector. For the SBC, Avila (2017) showed that dark current remains at a very low rate until the detector reaches $\sim 25°$C. That temperature is reached approximately 2 hours after the detector has been turned on. Above that temperature threshold, most of the dark current is generated in a large region of the detector (about 750×750 pixels), located slightly above and to the right of the center of the detector (Figure 1).

Based on this information we created a new SBC aperture that users can employ if they need to plan observations that keep the detector on for more than 2 orbits. We also investigate how long the detector should remain off after a long period of usage so that the detector has an opportunity to reach a temperature where the dark current is not an issue.

Data

We used the ACS quick look database (`https://github.com/spacetelescope/acsql`) to extract the header keywords MDECODT1 and MDECODT2 from the header of every SBC file up to May 2017. These keywords provide the temperature of the electronics box, just on top of the detector, at the beginning (MDECODT1) and end (MDECODT2) of each frame. We make use of the same images used in the analysis by Avila (2017). The data set consists of dark frames taken continuously for 5.5 hours using 1000s exposures. This observing strategy samples the dark rate as a function of detector temperarute. See Avila (2017) for a full listing of the images used.

We also make use of ACS RIU (Remote Interface Unit) engineering telemetry that is not included in the header. This type of engineering telemetry data is continuously sampled at least once a minute unlike the data found in image headers, which is only taken at the beginning and end of an exposure. The HST operational ground system CCS (Control Center System) collects and archives this telemetry data. This data set shows a ∼5 degree offset from the header keyword data used above. The CCS data set is cooler, but the temperature profile of the two data sets is the same (see Figure 1 of Avila (2017) for comparison).

Halo Avoidance

The overall elevated dark rate in the SBC is driven by a particular region of the detector where most events occur at elevated temperatures (Avila, 2017). Figure 1 shows a sample dark frame where the temperature is $> 25°$C. The region with elevated dark rate is visible above and to the right of center and takes up a large portion of the detector. The lower left region appears unaffected.

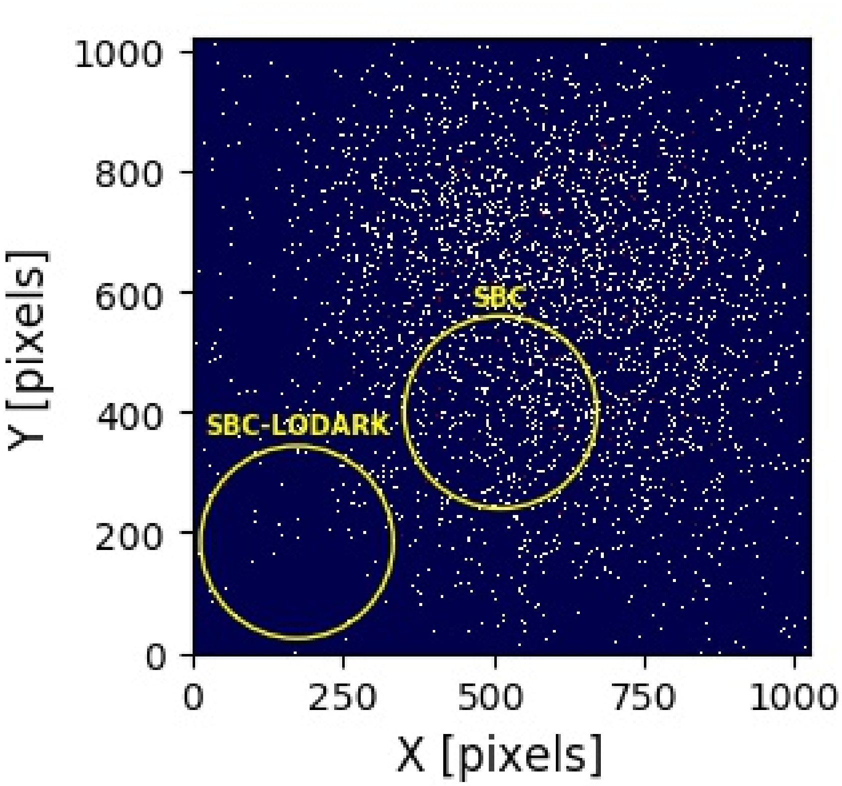

Figure 1: Example of a frame (`jd0401mrq_raw.fits`) with elevated dark rate. The higher number of counts seen in the upper-right two-thirds of the image are the elevated dark rates. The two yellow circles indicate the apertures used to measure the dark rates in various images. The average temperature of the detector during this exposure was 29.29°C.

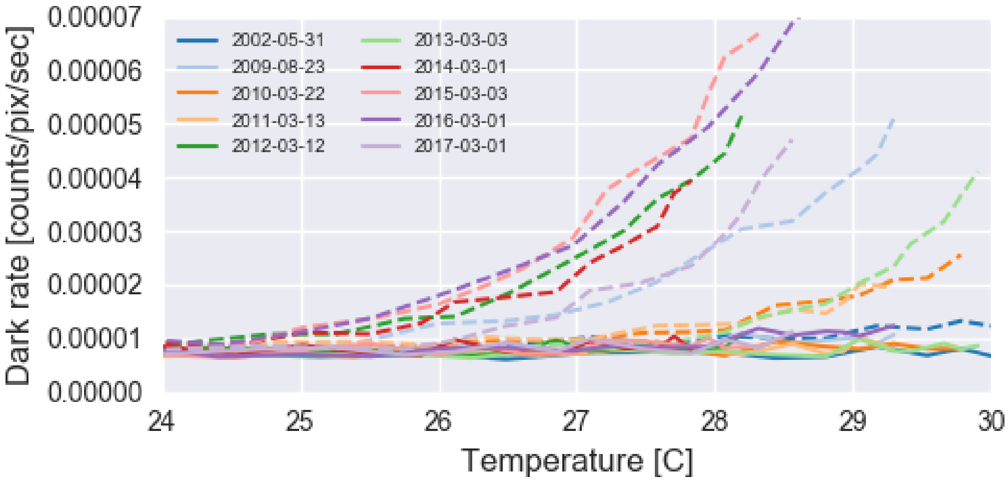

Figure 2: Dark rates measured in the two regions from Figure 1 across several images. Dashed lines correspond to the current default aperture position (labeled SBC in the previous figure), solid lines correspond to the new proposed aperture position (labeled SBC-LODARK in the previous figure).

We used the same set of dark frames used by Avila (2017) to measure how the dark rate changes as a function of temperature inside the two yellow apertures shown in Figure 1. The aperture close to the center of the detector, located at pixel (512,400), corresponds to the reference aperture (SBC) used in APT (Astronomer's Proposal Tool). The location of the lower left aperture (labeled SBC-LODARK in Figure 1) was chosen so that it was as close as possible to the corner but also avoiding the first few bad rows and columns. This aperture is centered at (175,185). The apertures are both 160 pixels ($\sim 5''$) radius in size. The results of these measurements are shown in Figure 2. The solid lines correspond to the SBC-LODARK aperture, and the dashed lines correspond to the SBC aperture. It is clear that the dark rate in the SBC-LODARK aperture remains constant even above the $\sim 25^\circ$C threshold.

Any user that needs to observe for longer than ~ 2 orbits, which is when the temperature of the detector goes above the limit, and has a small target that would fit inside the SBC-LODARK aperture, can place the target at that location. We have therefore defined SBC-LODARK as a new aperture located at (175,185) on the detector. This option will be available to users beginning with ***APT v26.2***.

There is a small cluster of four permanently damaged pixels at (56,282), lying inside the proposed aperture, that always have elevated counts. Users should be careful to always throw away these pixels during their photometric analysis. Those pixels are clearly marked as bad in the data quality arrays of all science frames.

SBC Cooling

The ACS RIU engineering telemetry shows that the detector usually stays around 14°C when not in use. This will vary by ±1°C depending on the HST attitude, since the detector is coupled directly to the aft bulkhead radiator. When the SBC is turned on, it draws ~23 watts of power. Engineering data shows that the temperature will quickly rise for the first couple of orbits (Figure 3) and begin to level off once it reaches $\sim 23^\circ$C, reaching its maximum of 25°C after 5 orbits.

The length of time that the SBC is enabled affects how long it takes to cool back down to its normal "off mode" temperature of 14°C. The declining curves in Figure 3 show how the detector cools after being switched off after different usage times. When coming from the maximum temperature of $\sim 25^\circ$C, it takes ~5 orbits (~8 hours) for this to occur.

The SBC does not operate during observatory passages over the South Atlantic Anomaly (SAA) and there are ~ 8 orbits available between SAA passages that can be used for observing. Theoretically, a few orbits could be executed at the beginning of the window, shut down the detector to let it cool, and then schedule a few more observing orbits at the end of the window. Figure 4 shows the available windows for a period in January 2018. In this case, observations could be scheduled for orbits marked 64 and 65, turn off the detector for ~ 6 hours, allowing it to cool to acceptable levels again, and finally observe during orbits 69 and 70. In practice, such a strategy would be difficult to implement because it introduces scheduling constraints and increases the number of on/off cycles. The only way to ensure that the detector is turned off to let it cool is to schedule visits that straddle an SAA passage. In any case, observers should consult with their Program Coordinators for any scheduling needs.

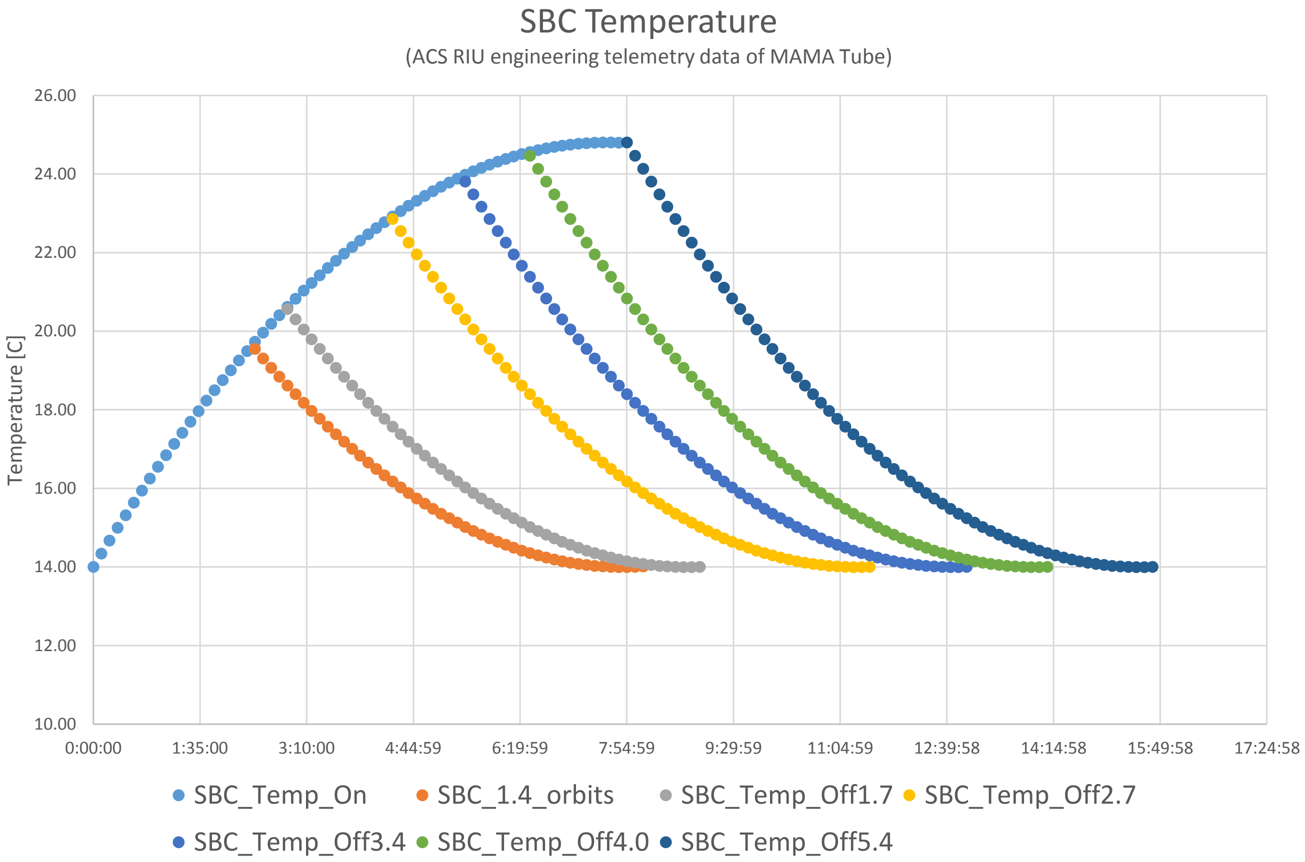

Figure 3: Temperature profile as measured using engineering data. Time (in hours) is plotted along the abscissa

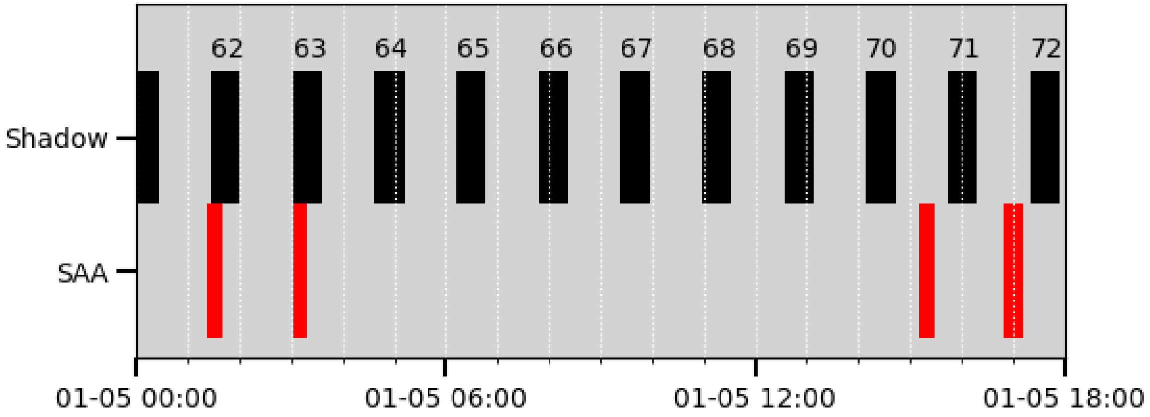

Figure 4: Visibility windows for a short period in January 2018. Black bars represent times when the telescope is in shadow. Red bars show when the telescope is in SAA.

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