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Bias, Auto-Bias And getting the most from Your Trifid Camera.

The imaging chip of the Trifid Camera is read out, one well at a time, by a 16-bit Analog to Digital Converter (ADC). Because it has 16-bits of precision, the ADC can output values from 0 to 65,535, which represent the number of electrons that each well contains.

Trifid has an ADC gain control, which allows you to adjust the conversion ratio between electrons and ADC counts. Generally, a gain of two will give you one electron per ADC count. But what is image bias and what does the ADC bias control do?

When the imaging chip is read out, three things are combined in the resulting ADC count for each well: the image we are interested in, noise and an offset common to all wells called image bias. As an example of image bias, if a particular image had ADC counts ranging from 2,100 to 5,200, then the bias would be 2,100, because at least that many counts is present in all cells. The image bias can be subtracted off during image processing, because usually it adds nothing to the image. In the Trifid Camera we also give you the ability to add or subtract image bias using the ADC bias control.

It should be clear from this that any image bias will use up some of the ADC's 65,000 counts. Now since the Trifid Camera allows us to adjust the bias level before the ADC does a conversion, we should subtract off all of the image bias, right? Unfortunately, things are not that simple if you want to maximize the performance of your camera. You can actually improve the sensitivity of your camera with wise use of the ADC bias control, which is one reason we have given you that control instead of making ADC bias a fixed value.

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To explain how to best use the ADC bias control, we need to back up and first understand the signal coming out of imaging chip.

As the imaging chip is read out, there are two levels for each well that the ADC looks at. The first is a reset level; the second is the signal level that represents the number of electrons in the well. By sampling both levels and comparing them, the ADC can make very precise measurements at a high rate of speed, even though the absolute signal levels may be floating up and down over some noise. (This operation is called correlated double sampling, if you are interested.)

Now if there is a certain difference present in the measurement of all wells, then we have an image bias, which seems like something we would like to eliminate. But note that the ADC cannot express negative values. If the difference between the signal level and the reset level was negative, then all the ADC can output is zero, which is its way of letting us know that the signal is less than the minimum level it can express. Within the values that are inexpressible, we can lose the very signal—the very image—we are trying to capture.

Included below are some example images to demonstrate this point. To create these images we flashed a dim green LED through a test target in a dark box for a very short period of time while the shutter of a KAF-3200ME Trifid Camera stayed open for five seconds. For these tests the imaging chip was at room temperature. As normal part of our testing we use this same setup, flash the LED for two seconds and the ADC counts in the exposed areas are 10,000 or less.

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We made two runs with the camera. In one run the ADC output bias adjusted to zero, so that a dark frame image showed no counts in any of the pixels. In the second run the bias of a dark frame was set to 2,000 ADC counts, so that the minimum count seen in the pixels was 2,000.

Note that the ADC bias control indicates how much bias to add to or subtract from the image before it is converted by the ADC. When we say that the image bias was zero, we do not mean that the control was set to zero, but rather that the control was set to a negative level such that the resulting image had no bias. The same thing was done for the images with a 2,000 bias in the output image.

What you see are the raw images without software bias subtraction, but the images have been stretched, so small differences in ADC counts are going to show up as dramatic differences in light level and it will look like there is a lot of noise in the images. We will discuss the noise some more after you look over the photos. (I did not realize until later that my thumbprint is also visible—sorry about that. Daniel)

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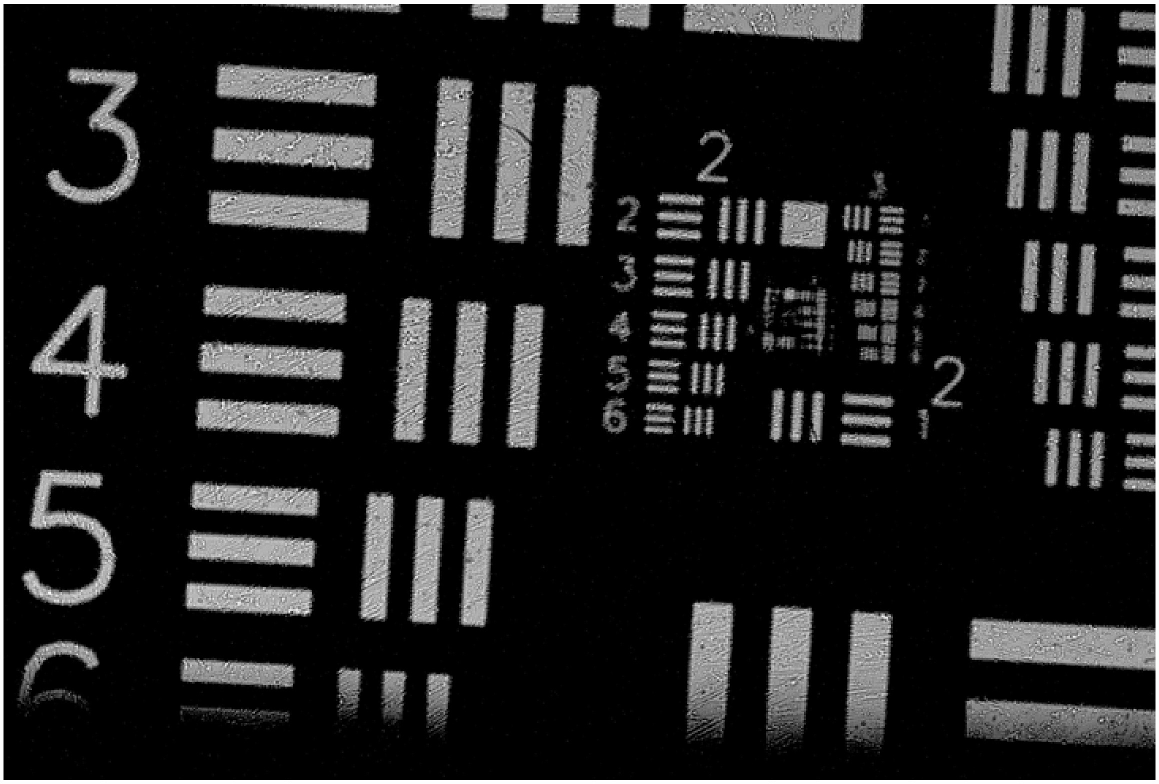
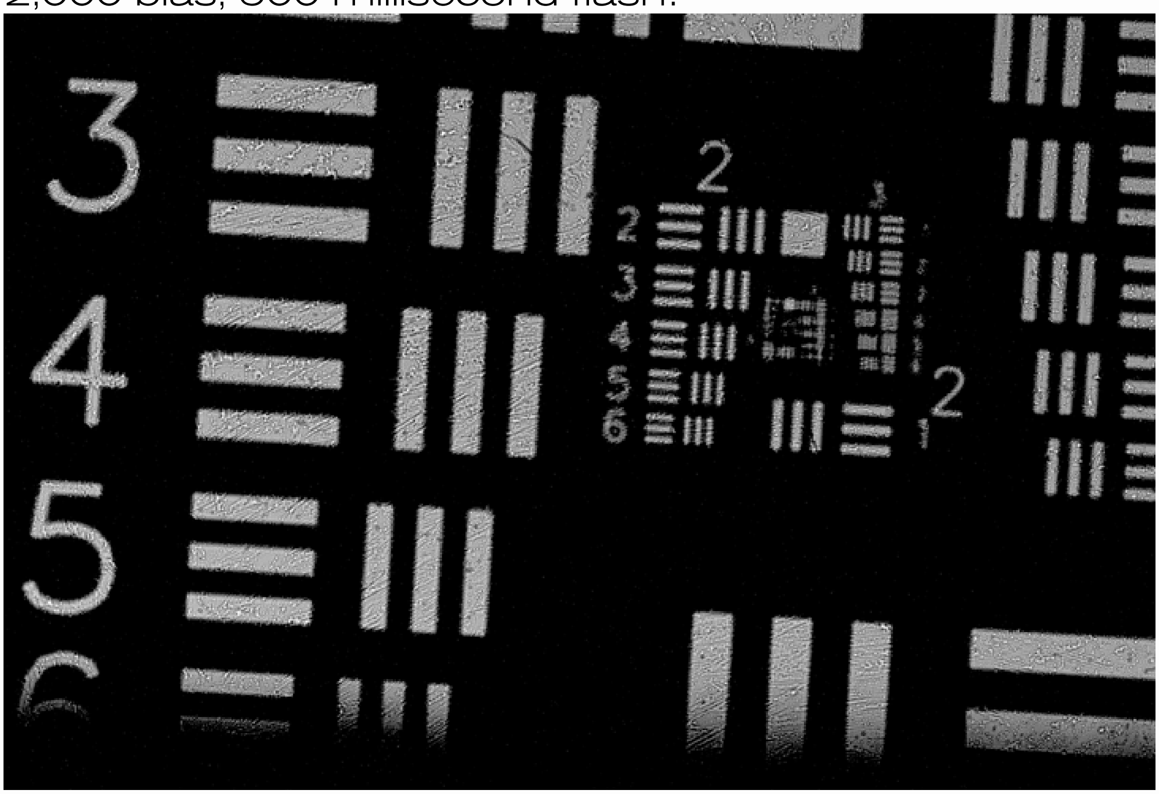
Zero bias, 500 millisecond flash:



2,000 bias, 500 millisecond flash:



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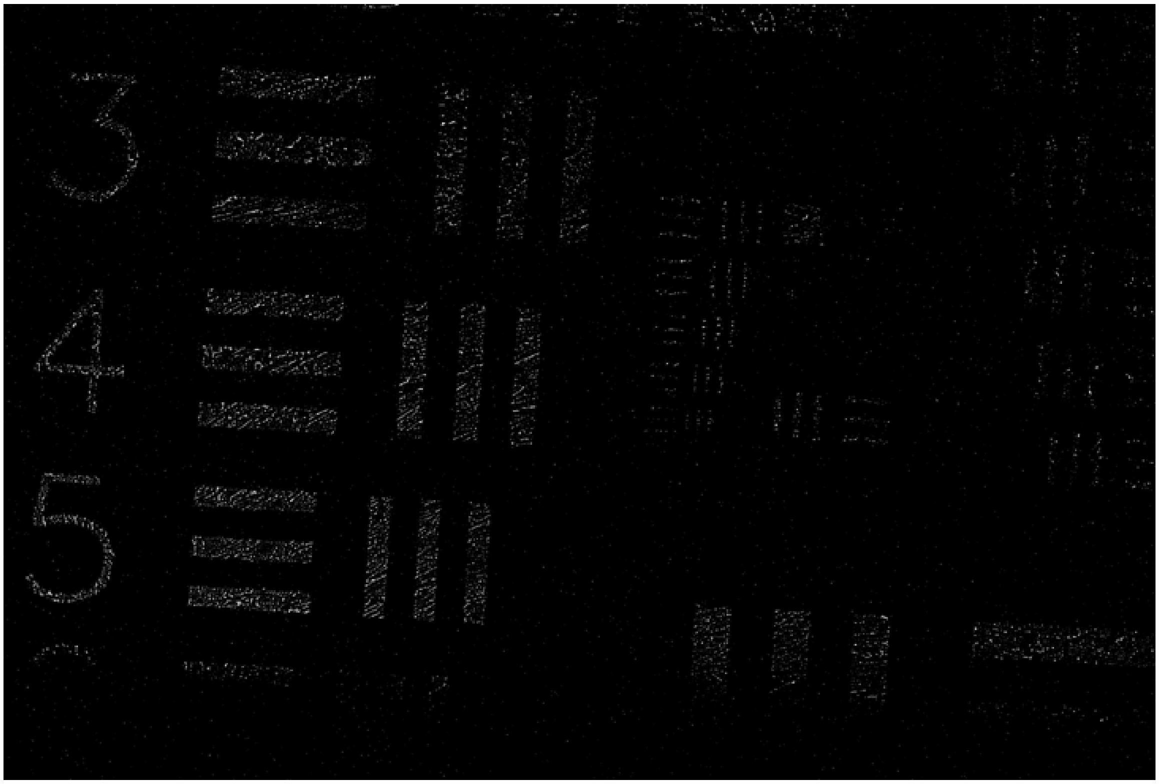
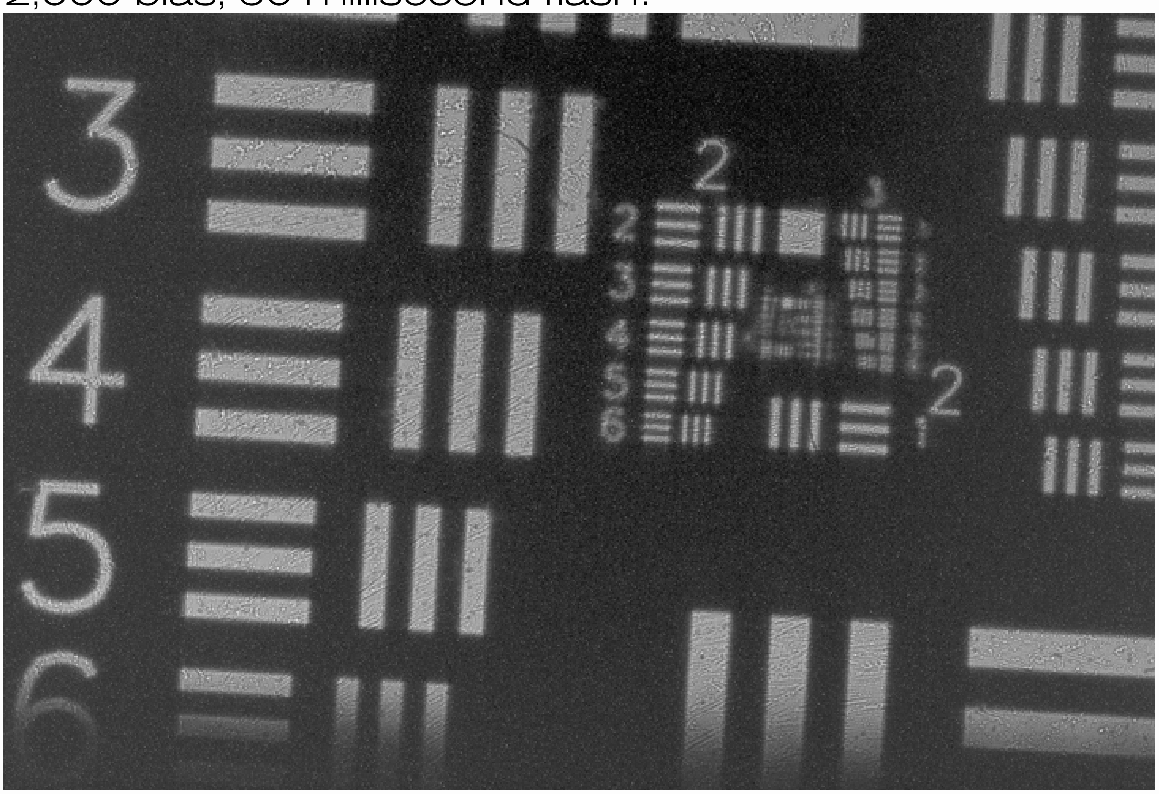
Zero bias, 50 millisecond flash:



2,000 bias, 50 millisecond flash:



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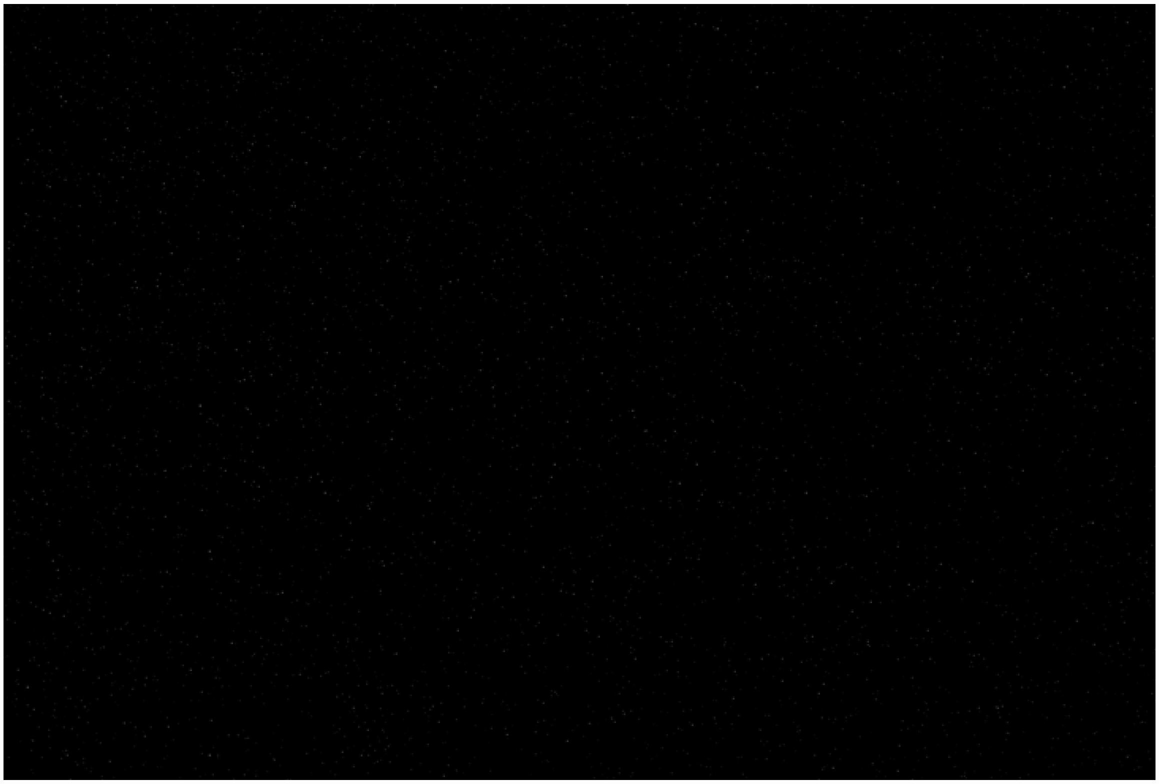
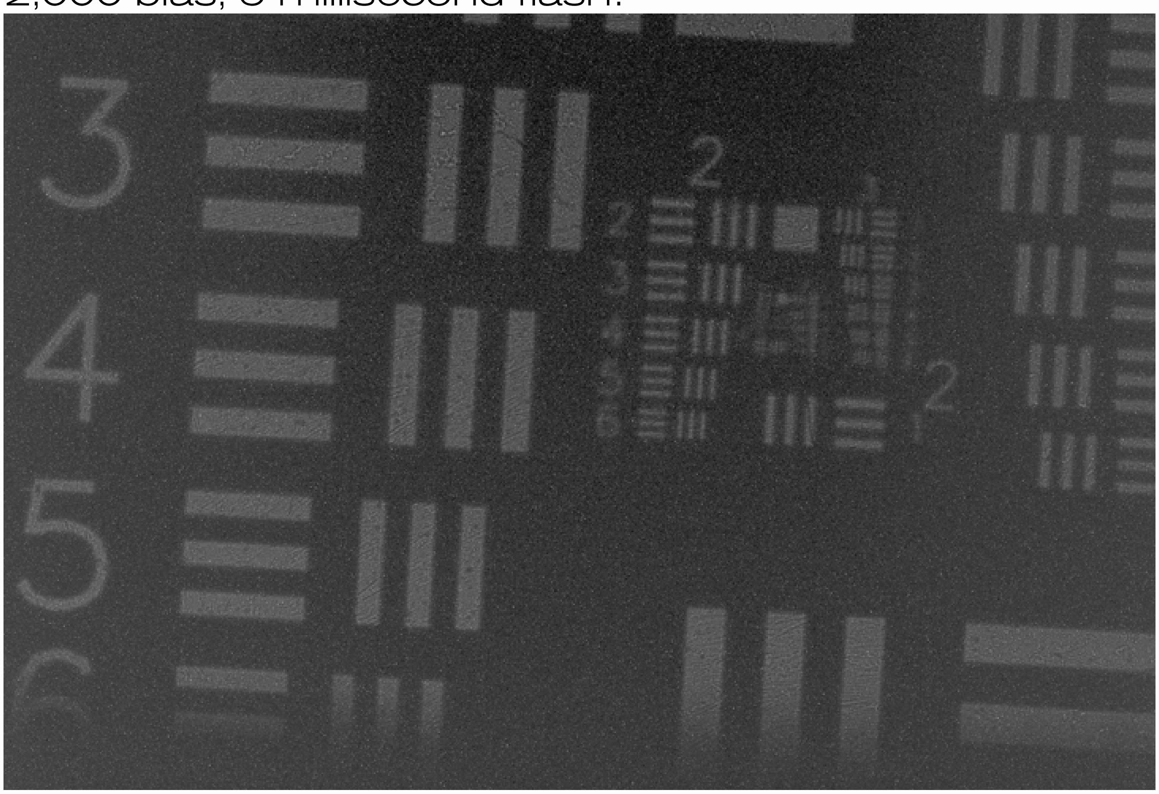
Zero bias, 5 millisecond flash:



2,000 bias, 5 millisecond flash:



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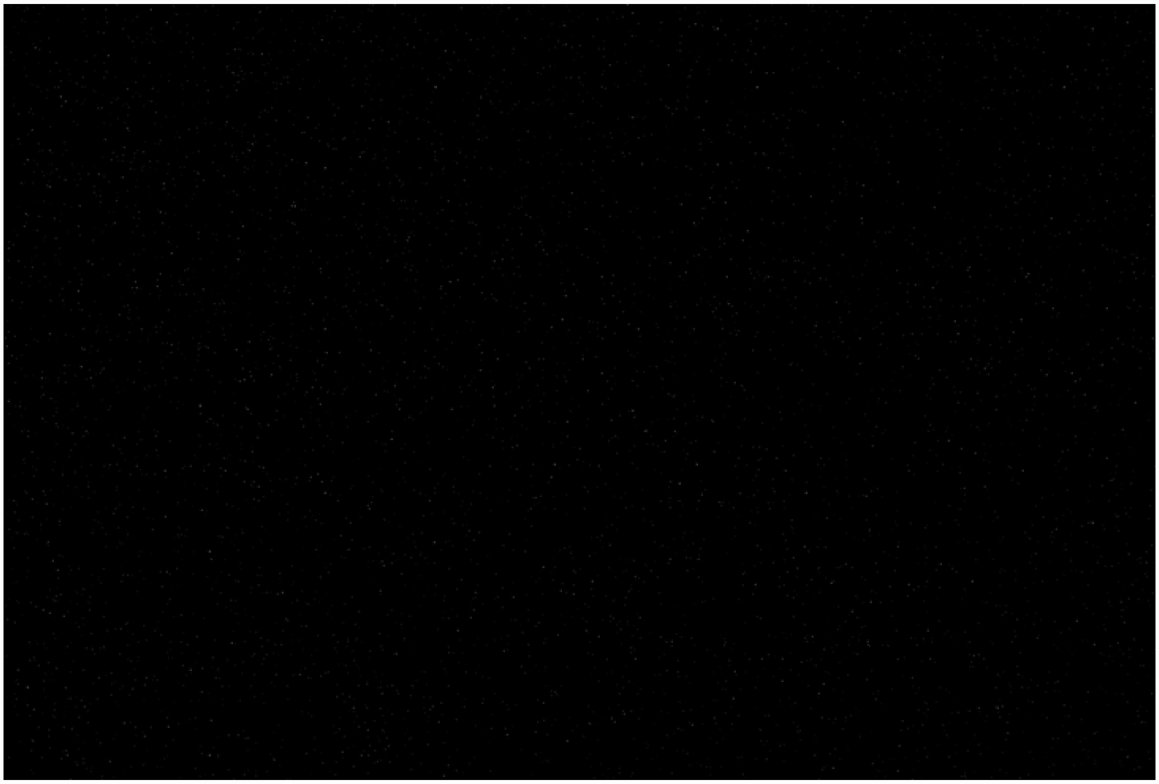
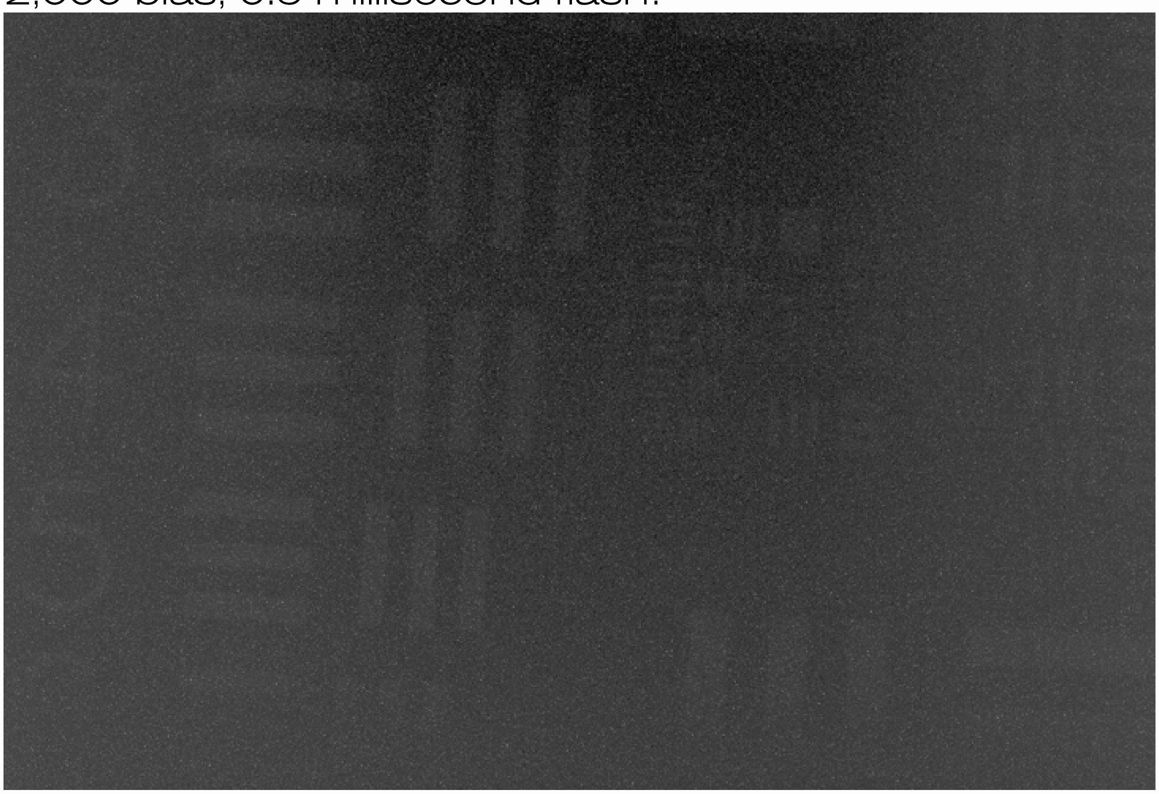
Zero bias, 0.5 millisecond flash:



2,000 bias, 0.5 millisecond flash:



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In the first set of images, which used a 500 millisecond flash, there is little difference. Though the light level is already low, both images display good contrast and little noise.

In the second set of images with a 50 millisecond flash, we can see some distinct differences. While the pattern is recognizable in both images, the zero bias image is low in noise, but also low in signal. The 2,000 bias image is higher in noise, but we can also make out a lot more detail.

With a 5 millisecond flash, the difference is now night and day. The zero bias image no longer displays any recognizable pattern, but the pattern is distinct in the noise of the 2,000 ADC image.

The last images with a 0.5 millisecond flash just show how much further the imaging chip can be pushed, given a higher ADC bias.

Now some will argue that you can do well with a much lower ADC bias than 2,000, so long as it is positive, but there is such a thing as giving yourself breathing room.

The signal coming out of imaging chip is only two volts in amplitude at most, so 2,000 counts out of 65,000 is just 61 millivolts. This is small when you consider we trim these voltages with a 15 volt regulated supply. What you lose with a larger bias is the upper region of the image. If you have ADC counts all the way from 0 to 65,000 in the original signal, adding 2,000 to the bias will mean that all of the brightest values from 63 to 65 thousand will come out as 65,000. But to our way of thinking, what you gain is much more than what you lose. Either way, we give you the control, so you can set the bias level as you see fit.

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If what you want is low noise, high contrast images and you don't care about the very dim signal you lose, then by all means, set the output image bias to zero.

Be default, when the Trifid Control Panel GUI first turns on the imaging chip power supplies, the Control Panel will measure the bias and set the ADC bias so that the resulting image will have a 2,000 bias count before the software bias removal is performed. You are then free to adjust the ADC bias level to suit your needs. If you turn the auto-bias off, software removal of the bias in the image is also turned off.

Now, what about all of this noise you add when you turn up the bias in the resulting image? It is true that the signal to noise ratio in the final images is not very good, but at least there is some signal to process. Unfortunately, when we increase the signal the visibility of the noise increases also. The noise was always present in the raw image, but now you can see it.

Please note that these test images are not very typical of how of how the camera is normally used: everything in the frame is very dim and there is not the equivalent of a star anywhere. And even more, digital astrophotography does not consist of a taking single raw image. Instead, you are going to make a calibrated image, which means that you will take bias frames, you will take dark frames, you will take flat frames and you will combine them with your raw images to create amazing photographs of things we have never seen before.

The whole point of doing image processing is to improve the signal to noise ratio of the object you are interested in. If you leave some bias in the output image you give yourself the signal to work with in the first place.

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When you see noise show up in your bias frames and dark frames, do not despair: your camera is not broken. It is instead showing you just how hard it is working to capture faint objects.

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