English Version
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Dr.Qiu's Talking about Astronomical Photography

Why Dark Field Is Darker Than Bias Field
and Overscan Calibration

Amateurs often encounter the same issue: dark field is even darker than the bias. In the our usual understanding, the bias field exposure time is zero or very short, while the dark field exposure time is long, we expect that exposure frame has more dark current, so the average value of the dark field should be higher than the bias field. But why is it lower? We may first suspect that it is the camera problem, or driver problem.

In fact, it is very normal and is known as overscan correction.

For CCD, this problem arises from the temperature drift of the reference voltage of the AD converter. CCD output is the analog signal, through the AD converter to convert to digital signals. The AD converter requires a voltage as a reference for conversion, which is called the reference voltage, as if we are measuring length and need a standard ruler. If the scale of the ruler changes, then the measured value will change.

Therefore, if the reference voltage changes, then the value of the conversion of the AD converter will follow and change the overall image brightness.

The reference voltage is supplied via a standard source. Usually these voltage sources will have a certain temperature drift. Taking the common high-precision reference source TL431 as an example, its temperature drift is 50ppm per degree. That is, every change in degrees Celsius will have 50 per million. At first glance this value is small. But in terms 16-bit ADC range, each degree will change several ADU. Ten degrees will result in dozens of ADU. This is very obvious.

In CCD, usually only the chip is being cooled and temperature controlled, but not the

ADC. As the ambient temperature changes, the overall image will be slightly brightened or darkened.

This is easy to explain why the dark field will be darker than the bias field. Usually we shoot multiple dark field and bias field for superposition/averaging. Since the exposure time of the bias field is extremely short and mainly the time is spent on read out, the ADC is in continuous operation and its temperature rises. This causes the reference voltage to drift. While continuous shooting the darks , the dark field exposure time is much longer. In such case, ADC does not work as hard, only during read-out, so the temperature does not rise as much.

That’s why the average of the dark field appears to be darker than the bias field.

In addition, changes in ambient temperature has similar effect. For example, when we shoot the bias, the room temperature is 25 degrees, and shooting dark field when ambient termperature is -10 degrees, thus it results in considerable drift in the ADC.

How to use OVERSCAN calibration to solve the problem

There are several ways to solve this problem. We first introduce the manual calibration method. In order to let everyone understand the principle of calibration, the following method take the MAXIMDL software as an example.

First we can shoot a series of bias, darks, lights, and flats. Note that you need to save the OVERSCAN area during shooting, you *must* uncheck "ignore OVERSCAN area"

Create the masters for averaged the bias, dark, bright, flat.

Open the master bias field. You can see there is a black side in the image on the right, this is the OVERSCAN area. Use the mouse to draw a box. This box needs to include a small part of the black edge. Record the average of the pixels in this box, eg 500 from the INFO window.

step 1

Use the PIXELMATH tool. Set the image A to the master bias field. Select “Calculation Method” to NONE. Then in OFFSET, enter the negative value of the above average, -500

Execute PIXELMATH. Complete the OVERSCAN calibration of the master bias field.

Then do the OVERSCAN calibration in the same way for the masters of flat, light and dark.

Step 2
Use the PIXELMATH tool to set the image A to the master flat and the image B to the master bias. Select SUBTRACT for “Calculation Method”, OFFSET is set to 0. The result is a precisely calibrated flat field.

With the PIXELMATH tool, set the image A as the master light and the image B to the master dark. Select SUBTRACT for Calculation Method. OFFSET is set to 0. The result is a precisely calibrated light frame.

Use the PIXELMATCH tool to set the image A to the precisely re-calibrated light field and set the image B to a precisely re-calibrated flat. Select DIVIDE for Calculation method , OFFSET is set to 0. The result is a full set of calibrated images.

The above calculation method is based on the formula

The corrected image = (L-D) / (F-B)

From this formula we can observe that the bias is primarily for on the calibrating the flat field. Dark frame is mainly used to calibrate the light frame for the dark current.

If the flat field is not correct, we usually see 4 corners are brighter than the center (over-correction), or darker (under-correction).
If the light frame calibration is not accurate, then the heat noise deduction is not accurate. (Sometimes the CCD temperature is already set at fixed value, but result varies as it is quite possible).

Automatic calibration method
Today, some software has the automatic OVERSCAN calibration like SGP. So you can

set this in the software. Please consult the experts of those software.

Note: If the average of the overscan area is higher than or very close to the effective reading, what should we do ?
This will result in subtraction of the whole image to zero , or to be reduced to near zero. In this case, a constant should be added to -500 in step A, such as 1000. The result is +500, and then perform the overscan correction. Note that this is only applied to step 1, step 2 of OFFSET or 0

CMOS case
CMOS cameras also have such problems, and the impact on CMOS is more complicated, because some of the CMOS chips come with optical dark level calibration. It will automatically do an optical dark level calibration. Optical dark level calibration and OVERSCAN area calibration are different. The difference is that the optical black level region contains thermal noise, while the OVERSCAN calibration does not. So when the exposure time is longer, CMOS dark current of the dark area increases, resulting in increased optical dark value to be subtracted, more than that of the shorter exposure. This leads to the dark field darker than the bias field situation. For CMOS calibration problems, please refer to "from the SLR camera to QHY163M" article. The English version of the article is at http://www.alessiobeltrame.com/wp-content/uploads/2017/09/QHY163M_review_EN.pdf

Chinese version in the "QHYCCD astronomical photography" can be found in groups files under related QQ group.

references
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3. Calibration http://www.astro.caltech.edu/~aam/science/thesis/total/node15.html