PERSONAL EXPERIENCE WITH THE ZWO ASI1600MM COOLED MONOCHROMATIC CMOS CAMERA FOR VARIABLE STAR PHOTOMETRY

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Date of purchase

Just before mid 2019

Accessories

Mini filter wheel, 5 position: R, G, B, Johnson B, Johnson V

The photometric filters are interference filters

I chose “unmounted” 31mm filters because the clearance inside the filter wheel housing is limited (but see the ZWO web site for comment on this issue)

Telescopes

80mm refractor, focal length 600mm (f/7.5)

120mm refractor, focal length 900mm (f/7.5)

Mount

German equatorial, autoguided using a guide ‘scope and guide camera, with PHD2 Guiding

Camera control and image capture software

APT - Astro Photography Tool

Image processing and aperture photometry software

AIJ - AstroimageJ. The raw output (flux) is saved to an XL spreadsheet for calculation of instrumental and (if proceeding thus) true magnitudes

Preprocessing and processing

Darks, same duration as the science images

Flats, exposed to give average counts per pixel just below half full well

Bias frames have not been always been used. ZWO claims they are not necessary

Targets

My interest is mainly in time series photometry of delta Scuti stars, short period pulsators with periods up to a few hours. On a clear night, I would typically run the image capture sequence for several hours, executing a meridian flip when necessary.

The interest is therefore in achieving the best precision for single exposures. Although it is possible to calculate rolling averages of magnitudes prior to plotting light curves, and although that smooths the curves, I prefer not to do this if possible.

If your interest is in longer period variable stars, making one magnitude determination for a particular star on one observing night, averaging multiple magnitude measurements optimizes precision, and/or allows you to study fainter stars for a given level of precision.

Exposures

The field of view is defocussed before image capture.

Science frames are exposed for up to 3 minutes, and no pause is set between consecutive images.

Image type

The camera control dialog allows either “RAW8” and “RAW16” images to be selected. If ASICAP (the manufacturer’s camera control and image capture software) is used for image capture, the RAW8 setting results in images saved in the .png format. RAW16 images are saved in the .fit format. I only ever use the RAW16 setting.

Interestingly, if RAW8 is selected when the camera control dialog is called from Astro Photography Tool, and an image taken, the file is save with a .fit extension, but AstroimageJ will not analyse it.

Gain settings

This camera allows gain settings from about 0.2 e/ADU to 5 e/ADU. The camera control dialog (in which you set the gain) can be called from your own camera control/image capture software. The gain is actually set in units of 0.1 dB, 300 dB units corresponding to 0.2 e/ADU (lowest read noise), 139 dB units corresponding to unity gain (1 e/ADU) and 0 dB units corresponding to 5 e/ADU (highest dynamic range).

The camera control dialog allows “click stop” gain settings of 0 dB units, 139 dB units or 300 dB units. When using one of these click stops, the image type defaults to RAW16. A fourth “click stop” is “manual”, which means you use the mouse to drag a slider to any gain setting you wish from 0 to 300 dB units. If you have set the image type to RAW8, then use the slider to manually set the gain, the RAW8 image type remains in place.

I find no benefit in using gain settings greater than 139 dB units. That is, I do not use amplification of the signal (and therefore the noise). For the brightest targets, it is valuable, and may even be necessary, to use gain settings between 139 and 0 dB units (that is, between 1 and 5 e/ADU).

Just a few words about amplification (gain settings between 139 and 300 dB units). In this range, the read noise is less than it is at gain settings less than 139, and much has been made of this property of the camera. However, as I understand it (and I’m only paraphrasing here what I think I understand from reading the views of others), the advantage which can be bestowed by low read noise is only present when the read noise is the dominant form of noise, and this only occurs in low illumination environments, with low signal sky backgrounds. My environment is not like that – I image in a suburb about 9 km from a city, with high sky background signal, and shot noise (due to the random nature of the rate of arrival of photons at the sensor) dominating over read noise. Therefore, I cannot take advantage of the low read noise range of the gain settings of this camera.

SUMMARY OF THE RESULTS OF USING THE CAMERA

Linearity

Testing was done with flat frames at various exposure times, up to saturation (full well) of the sensor. When binned 1x1 or 2x2, the full well is 65,504 counts per pixel and the response has a good linear fit (as seen with linear regression and plotting residuals) until quite close to that, around 64,000. (Note: counts with these values are seen with AstroimageJ).

It is clear from these results that binning 2x2 (and higher, presumably) is done by software, which simply averages the ADUs over each 4 binned pixels in an image binned 2x2. The results are: a .fit file of 8MB (instead of 32MB in an unbinned image); a cleaner background; fainter stars much more readily visible against the background; and a smoother line profile of a star image. I now use 2x2 binning routinely because of these benefits. I’ve yet to determine if binning improves photometric precision. Preliminary results do not show that it does.

A word about those counts of more than 60,000. This is a 12 bit camera. Therefore the native full well depth at unity gain is about 4096 counts (ADU) per pixel. The camera software however has apparently been set, in RAW16 image mode, to multiply the native counts by 16, hence the high count number seen in image statistics.

Photometric precision

At unity gain, with defocussed images, and photometry of 8th to 10th magnitude stars with an 80mm or 120mm refractor, time series photometric precision is very good.

With brighter stars, the gain needs to be adjusted to be less than 139 dB units (>1 e/ADU) to allow long enough exposures to optimize the precision.

With stars fainter than 10th magnitude, and the 120mm refractor, precision falls off. But even 11th magnitude stars show good precision when the magnitudes from 10 consecutive images are averaged.

These telescopes (80mm and 120mm refractors) have quite small apertures. Even an 8 inch Schmidt-Cassegrain would go one magnitude fainter than my 120mm refractor, so AAVSO observers with (say) 11 to 14 inch instruments could obviously go deeper.

The bottom line is that the best precision is achieved when:

Variable and comparison stars are of a similar magnitude

The stars are bright (8th magnitude in V or brighter) with 80mm or 120mm refractors

The degree of defocus, exposure, and gain setting are tuned to that the peak count per pixel for the brightest star is close to the top of the range of the linear response of the sensor.

Photometric accuracy

This has not been tested properly, due to smoke from fires, and near-constant summer cloud at night for several weeks. It is the next project.