QHY268M Camera Evaluation

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Introduction

Following the replacement of photographic film many years ago with digital sensors, CCD's have been the go-to technology for both amateur and professional astro imagers. The alternative CMOS based devices although used very successfully for terrestrial cameras have always been viewed as somewhat inferior for astronomical applications. However, recent developments in manufacturing technologies have resulted in a new generation of CMOS sensors having characteristics that, at least on paper, match or exceed that of CCD's. One such sensor is the Sony IMX571, a back illuminated APS-size chip with 3.75µm pixels and native 16-bit A/D. QHY has incorporated this sensor in the 268 series cooled astro cameras and is available in both colour and monochrome versions. Unusually, this camera is provided with multiple readout modes giving a choice of read noise and gain characteristics. This document reports a range of tests on the 268M monochrome version and compares the results with my trusty QHY9M camera equipped with a KAF8300 CCD sensor.

Methodology

The electronic gain (eG), read noise (N_R), full well (FW) and dynamic range (D_R) of the cameras were determined using the method developed by Jim Janesick[1]. This requires two bias frames and two flat frames where the flats are recorded at about half well capacity. Pixel maths are then used to measure the mean ADU values (µ) of the flats and biases. Next, difference frames (Δ) are generated and the standard deviation (σ) and variance (σ^2) noted. When producing the difference frames it was found necessary to add a pedestal to one of the frames in order to avoid truncated histograms.

The camera parameters can then be calculated according to the following formulae:

$\Delta \mathit{flat}$ = flat1 – flat2

$\Delta \mathit{bias}$ = bias1 – bias2

$$eG = \frac{\{\mu(\text{flat1}) + \mu(\text{flat2})\} - \{\mu(\text{bias1}) + \mu(\text{bias2})\}}{\sigma^2(\Delta \mathit{flat}) - \sigma^2(\Delta \mathit{bias})} \quad (e^-/\text{ADU})$$

$$N_R = \frac{eG \times \sigma(\Delta \mathit{bias})}{\sqrt{2}} \quad (e^-)$$

$$FW = 65535 \times eG \quad (e^-)$$

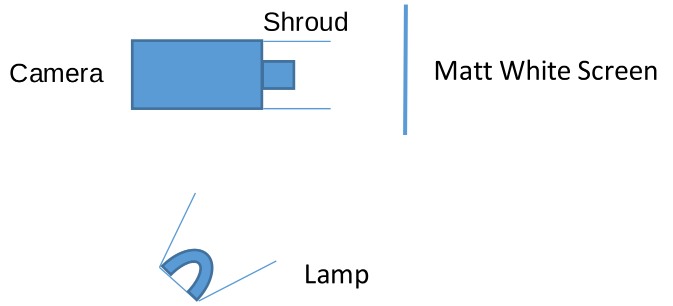
$$D_R = \frac{FW}{N_R} \quad \text{(Grey levels)}, \qquad \frac{\text{Log}(FW/N_R)}{0.301} \quad \text{(Stops)}$$

The linearity of the cameras was determined by taking a series of increasing exposures until saturation and recording the mean ADU values at each exposure.

Frames were captured using Nebulosity v4 software then transferred to Maxim DL for the pixel math operations. For these tests the cameras were set to 1x1 binning.

1. Photon Transfer James R Janesick SPIE 2007 ISBN 9780819467225

Experimentally, owing to the sensitivities of the cameras a neutral density filter was placed over the sensors and the cameras aimed at a white card illuminated by a tungsten filament bulb. By varying the distance of the light source suitable exposure times at each gain setting could be obtained.



At each gain setting an offset was used to ensure that the minimum ADU values always exceeded zero (~100). In addition, when measuring each frame usually only the central portion was used in order to avoid any edge effects – 1400x1000 pixels for the QHY9M and 2065x1449 for the QHY268.

Results and Discussion

The QHY268 has three read out modes designated #0 Photographic, #1 High Gain, #2 Extended Full Well and #3 Extended Full Well 2CMSIT. Perusing the data provided on the QHY website, the best characteristics for wide band imaging appeared to be provided by modes 0, 1 and 3 (Table 1) and these were selected for initial testing. Also tabulated are the corresponding published values for the QHY9M.

Table 1 Published Data

	QHY268				QHY9M
Mode	0	1	1	3	1
Gain Setting	30	0	60	0	0
R_N (e$^-$)	2.65	3.5	1.5	5.7	8
FW (Ke$^-$)	31.5	61	25	90	25.5
D_R (Stops)	13.7	14.1	14	14	~11.5
QE_{max} (%)	90				55

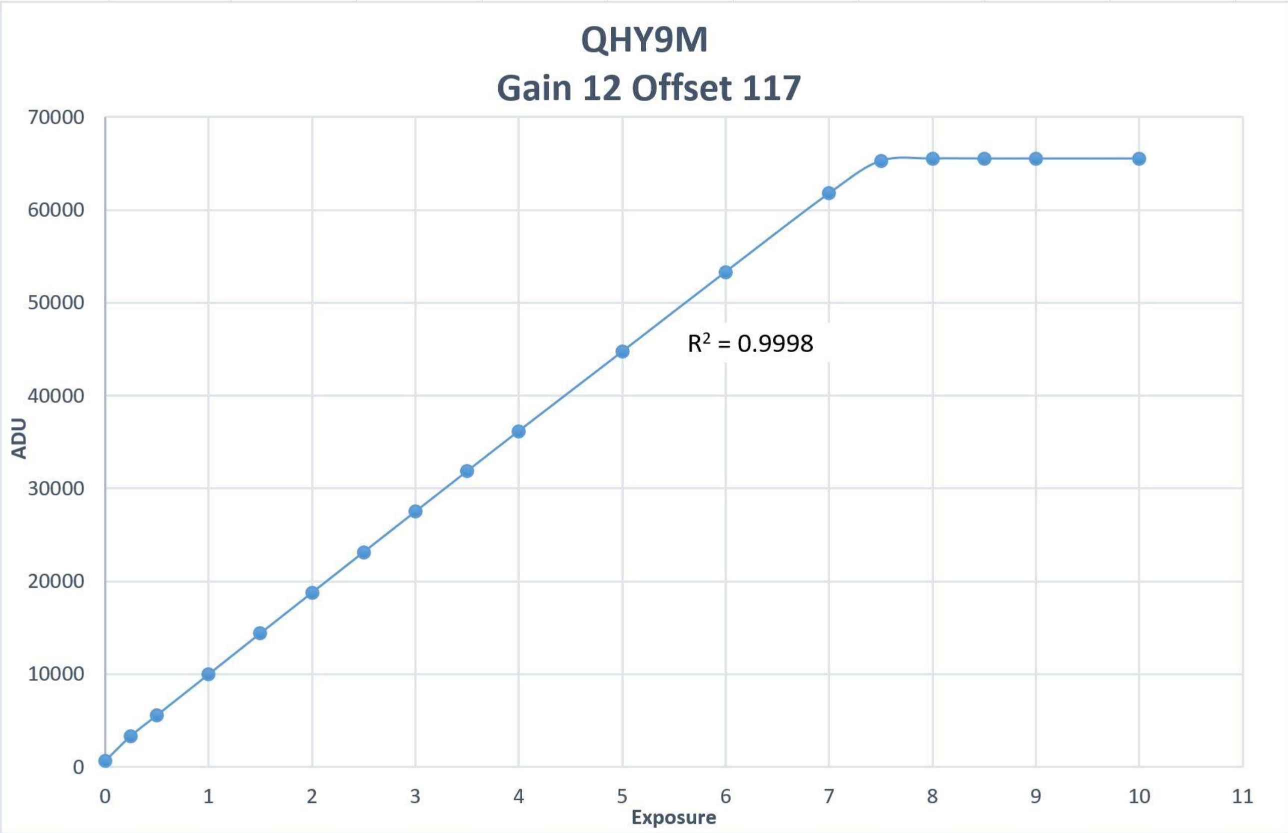
The results for the QHY9M at -25^{o}C set point are given in Table 2 and broadly confirm the published data although the full well value is somewhat larger.

Table 2 QHY9M Measured Results (Offset 117)

Gain Setting	**eG** (e$^-$/ADU)	**R_N** (e$^-$)	**FW** (e$^-$)	**D_R** (Levels)	**D_R** (Stops)
12	0.51	10.55	33600	3185	11.63

As regards linearity, Plot 1 shows the excellent behaviour typical of CCD sensors.

Plot 1 QHY9M Linearity



The results for the QHY268 are summarised in Table 3. A set point of -5°C was used (~65% power). Under observing conditions it may be possible to operate at -10°C or lower without unduly taxing the thermoelectric cooler. Overall stability of the set point was excellent.

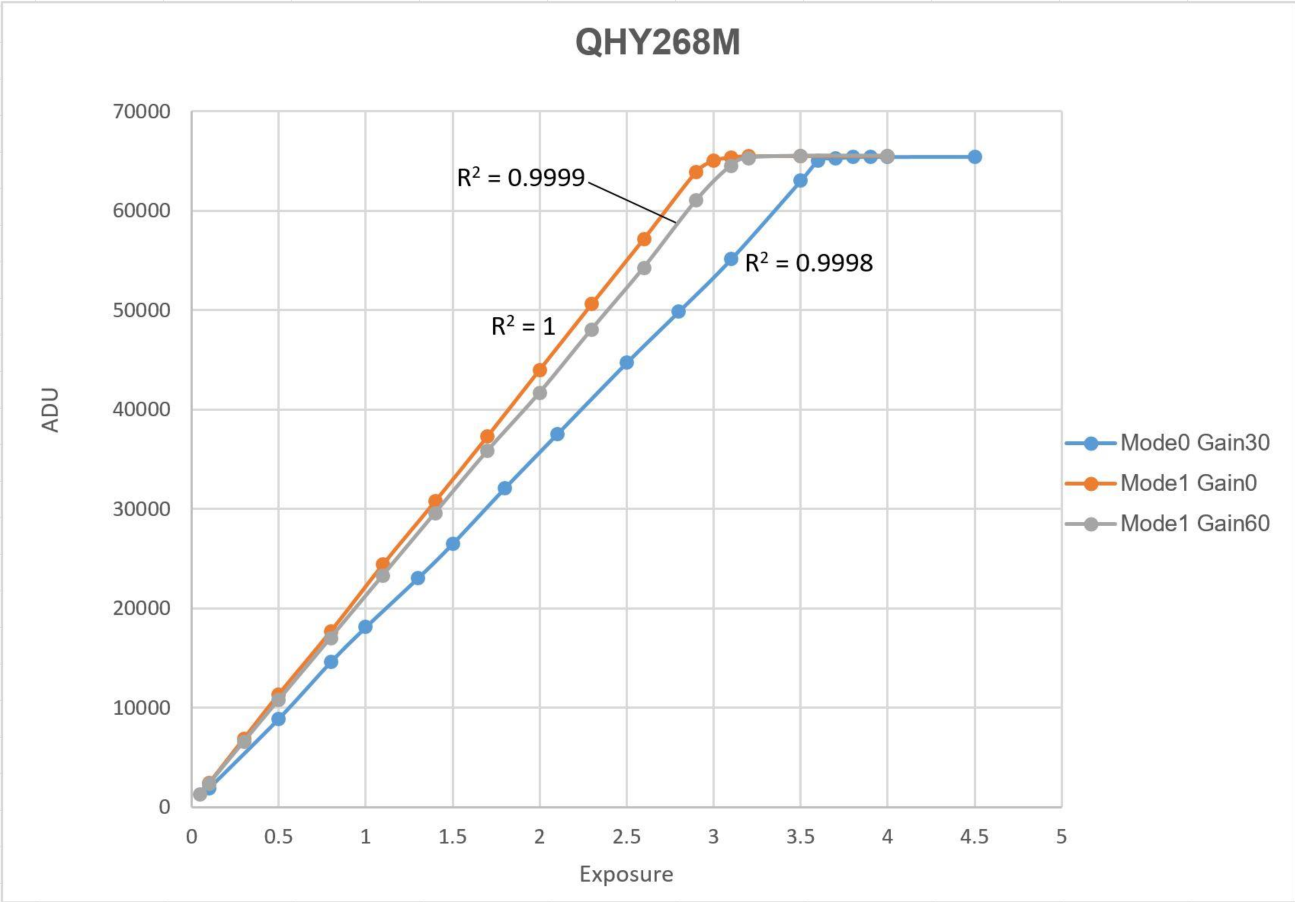
Table 3 QHY268M Measured Results

Mode	**Gain Setting**	**Offset**	**eG** (e^-/ADU)	R_N (e^-)	**FW** (e^-)	D_R (Levels)	D_R (Stops)
0	30	13	0.37	2.63	24652	9354	13.19
1	0	12	0.78	3.45	51100	14786	13.85
1	60	13	0.3	1.53	19890	12944	13.66
3*	0	10	1.29	5.78	85060	14711	13.84
3	25	10	0.98	5.5	64000	11660	13.51

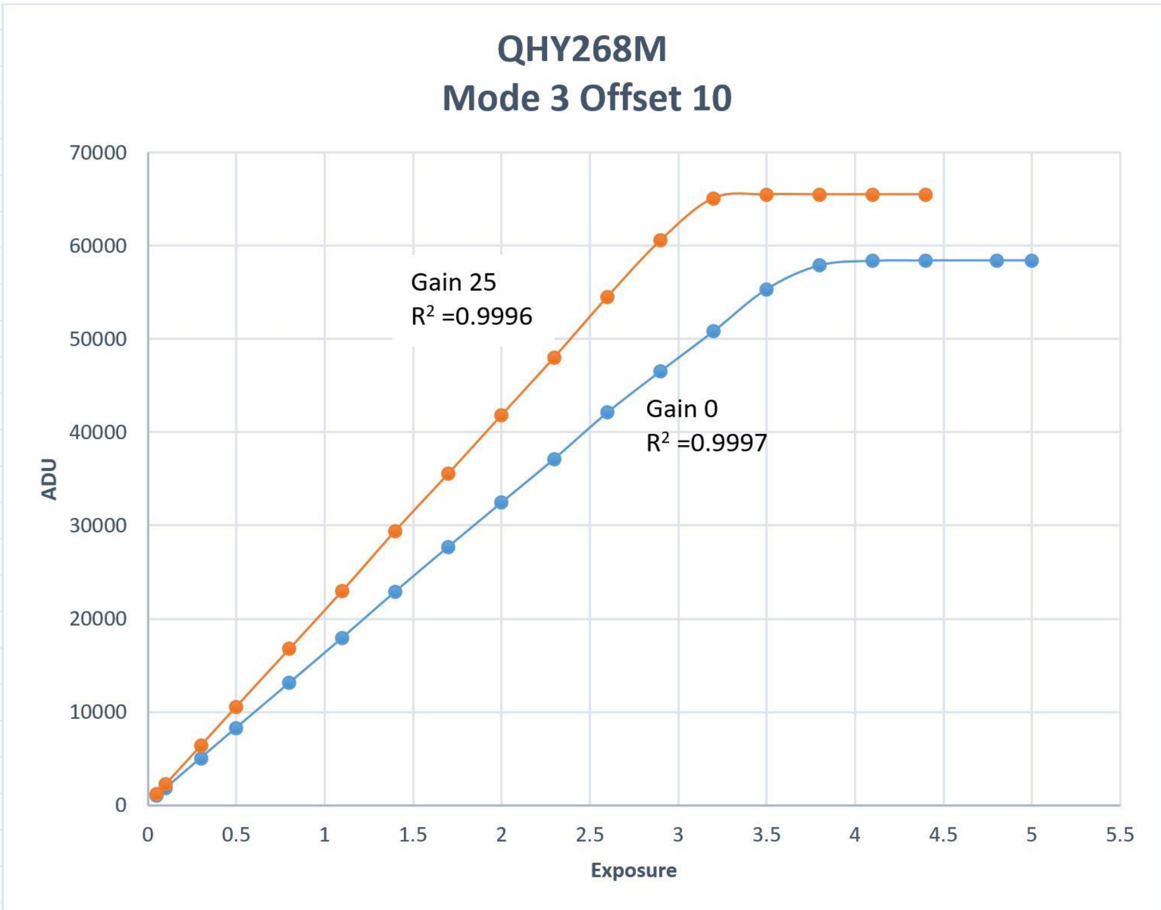
* This setting saturated at 58400 ADU, see Plot 3

Straight away it can be seen that the results are very similar to the published values and comfortably exceed that of the QHY9M. In particular, the much lower read noise (even in Mode 3) and higher dynamic range bodes well for its use in wide band imaging. The linearity plots are also excellent with R^2 values essentially unity. In the case of Mode 3 Gain 0, saturation was reached before 65535 ADU and the Gain needed to be increased to 25 in order to make full use of the 16 bit span albeit at some loss of full well capacity.

Plot 2 QHY268M Linearity Modes #0, #1

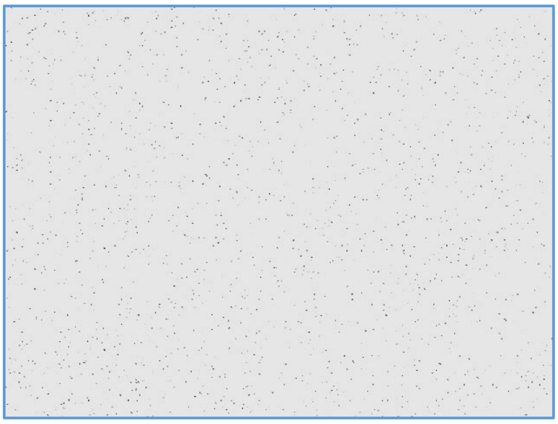


Plot 3 QHY268M Linearity Mode #3



For completeness, 5 min dark frames for both cameras were taken and used to construct Bad Pixel Maps. The images are inverted for clarity and show typical distributions the effects of which should be easily removed from the light frames during processing. Incidentally, there was no indication of amp glow on any of the images.

QHY9M 4/3" Sensor 8.6MP



QHY268M APS Sensor 26MP

Given the flexibility of choice in operating characteristics, I would opt for Mode 1 Gain 0 for general wide band imaging as it exhibits the desirable combinations of low noise, decent full well capacity and a good dynamic range together with excellent linearity.

In summary, these brief tests of the QHY268M more than confirm the paper specifications and that this camera is worthy of serious consideration for astro imagers thinking of switching to CMOS technology.

Acknowledgement

I would like thank Prof David Rees for the loan of the camera