ATIK 314e CCD Camera Performance Review
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ABSTRACT: The instrument reviewed is an ATIK 314e monochrome CCD; thermo-electrically cooled camera that is a very capable and inexpensive high resolution camera geared toward shorter focal length OTA's. This review focuses on my results in measuring the performance of this camera as described by Craig Stark in his paper, "Signal to Noise: Understanding it, Measuring it, and Improving it Part 3 - Measuring your Camera" [1]. I also demonstrate the images that are possible using this camera.

A Modest Start

Having a famous sounding last name naturally impressed me at an early age and learning about Edwin Hubble helped turned my interest toward astronomy; that, along with the Apollo program, got me really thinking about space and the Moon. I received my first telescope (a Tasco 60mm Refractor with an alt-az mount) when I was 14. I had used binoculars prior to that but I was in heaven (literally) with this new scope. I used that scope for a couple of years and managed to buy another 60mm Refractor on a small manual GEM mount that enabled me to track the Moon very well. At that time all I cared about was looking at the Moon and the planets (I still remember to this day my very first view of Saturn). I managed some rudimentary photos using eyepiece projection into my Polaroid instant camera. I was truly amazed at being able to pick out Tycho and the Alphonsus/Arzachel region. I remember referring to the latter as the 'keyhole' craters in my observing notes because of the way it looked in those crude Polaroid photos. I have always had a special fondness for the Moon and still do today.

I got away from observing after High School and even though I took a basic astronomy course in college, didn't use a telescope until 1986 when I bought my first SCT: a Meade 2120 LX5 from Company Seven. Boy, I was really blown away by its size and heavy mount. Also the hand controller was very nice. I used that instrument regularly as a purely visual tool for several years before I moved on to other hobbies (flying for one).

Ten years passed where I didn't use the Meade once. A couple of years ago, I started thinking about how computers had improved the instrumentation used in small aircraft and looked into what had been going on with amateur astronomy and what was available. I immediately zeroed in on the EQ6 mount and the large (5-6 inch) APO Refractors that are available today at a reasonable price. I had always liked using a refractor and thought that a large refractor might just do it for me. I was looking at Sky and Telescope one day and saw an ad for the ATIK 314 series cameras. I had just recently learned about pixel size and how it relates to seeing and focal length and all that stuff, so since I was looking at the Orion 120mm EON / Sky-Watcher Equinox 120mm APO's I knew that the ATIK 314e with the 4.65 micron pixels would be a very good fit for the 900mm Fl of those scopes. This was especially so, since I was really

interested in getting high resolution pictures of the Moon. That plus the price was in my budget, sold it for me.

To make a long story short, I invested my money in a Sky-Watcher EQ6 Pro mount, Sky-Watcher Equinox 120mm F/7.5 APO, the ATIK 314e TEC Camera, an Orion SSAG guide camera, Orion Flip Mirror, Orion off-axis guider, and various other sundry items including software and some good eyepieces. The main thing that sold me on the EQ6 Pro mount was the fact that EQMOD was available and was open-source. This made it a very attractive platform on which to build my observing and astrophotography program around 50 miles south of Washington, D.C., in Locust Grove, Virginia.

My main goal with this new system was to obtain high resolution photos of the moon and secondarily, be able to image and track asteroids. I spent several months prior to purchasing my equipment learning about what was involved with performing astrometry and photometry with amateur scopes and found a lot of wonderful resources on the internet. I found AIP4Win and the accompanying book "The Handbook of Astronomical Image Processing" by Berry and Burnell [2], to be a gold mine for understanding what was involved with processing my images. Several years ago, I purchased "Astronomical Photometry" by Henden and Kaitchuck [3], and found that to be a very good source of information also. Since then I have been fine tuning my equipment and procedures, learning more each time I take the scope out.

Initial Testing of the ATIK 314e

When I initially received my camera, I immediately inspected it and found it to be very nice and smaller than I expected based on the ads I had seen. I purchased the camera from Adirondack Astronomy in NY and received it fairly quickly as I recall. I also purchased an Astrodon Schuler V-band photometric filter that has since been discontinued and replaced by a better version. Since I had read about the camera online, I was hoping also to find details on the performance of the camera, but it seems that everyone was enamored with the 314L with the slightly larger (6.45 micron) pixels. The 314e seems to be a bit of an orphan in this regard. I didn't find anything bad about the 314e… in fact I couldn't find all that much about it at all. I had played with it a little installing the ArtemisCapture software (no problem there) and figuring out how to configure it to mount on my scope. I performed some initial testing as per Berry and Burnell [2] Chapter 8 section 2.2., (AIP4Win) indoors at approx 70°F. I found the following for my camera (SN 1018264712) on 26 March 2009:

Gain g :		**0.1955 e^-/ADU**
$\sigma_{Readout}$:	**6.681**	**e^-_{rms}**
$Dark_{e^-}$:		**0.9474 e^-/pixel/sec**
Full Well Depth:		**12812 e^-**

I used the following equations from Berry and Burnell Chapter 8:

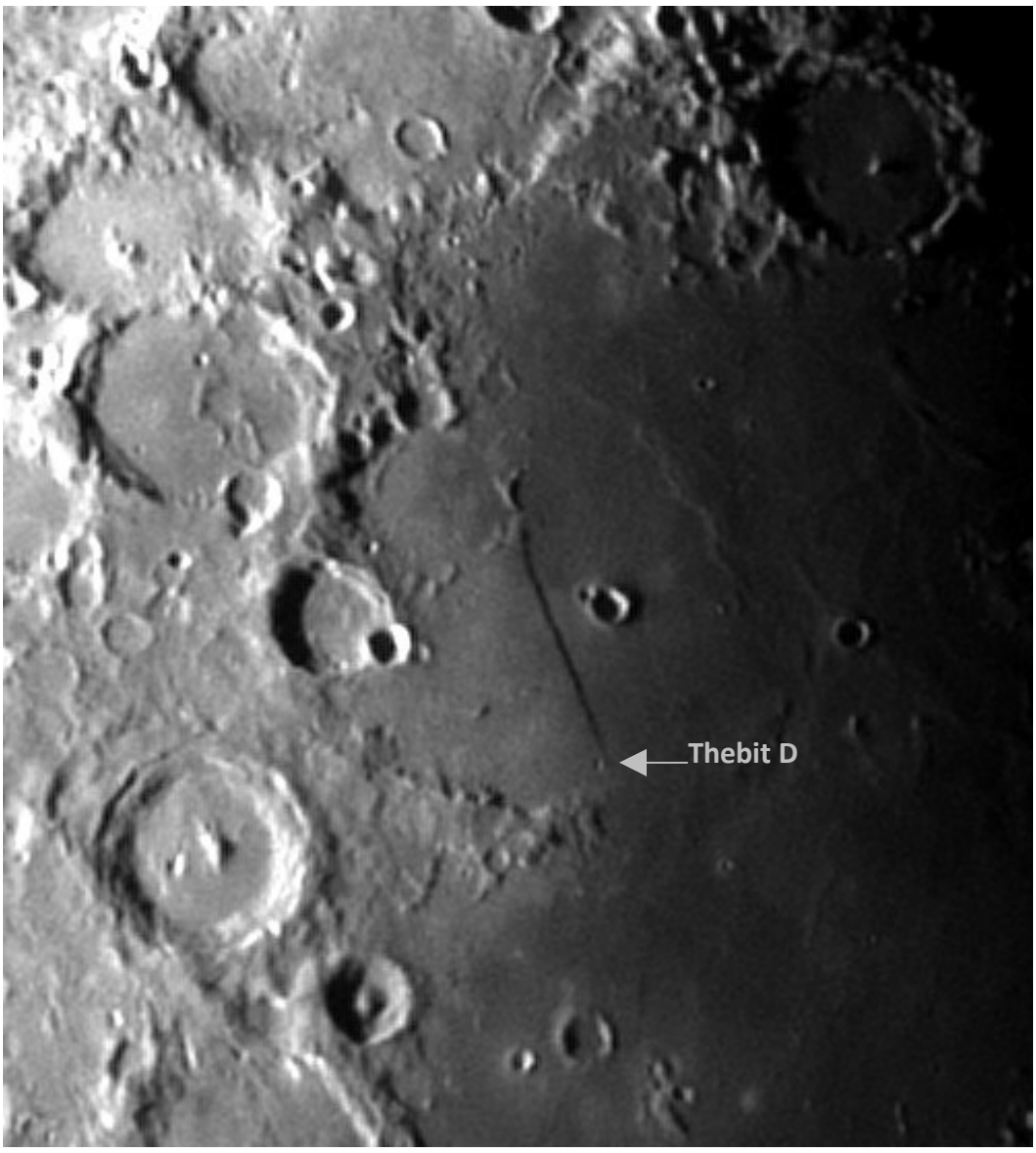
$$g = \frac{(\overline{F1}-\overline{F2})-(\overline{B1}+\overline{B2})}{(\sigma^2{}_{F1-F2})-(\sigma^2{}_{B1-B2})} \qquad Dark_{e-} = \frac{gD_{ADU}}{60.00} \qquad \sigma_{Readout} = \frac{g\sigma_{B1-B2}}{\sqrt{2}}$$

The gain was somewhat unexpected but I really didn't know what it meant at that time. I guess I was expecting to see a gain of around 1, since that is what I had read about as a typical value.

Images Obtained

I have used the camera over the past several months obtaining photos of the Moon and a couple of asteroids. I have finally configured my scope with the Orion off-axis guider and Orion SSAG guide camera in as satisfactory manner to where using PHD (Craig Stark, Stark Labs) is a pleasure. Here are a couple of prime focus (non-stacked) images of the Moon using the ATIK 314e:

Rupes Recta:



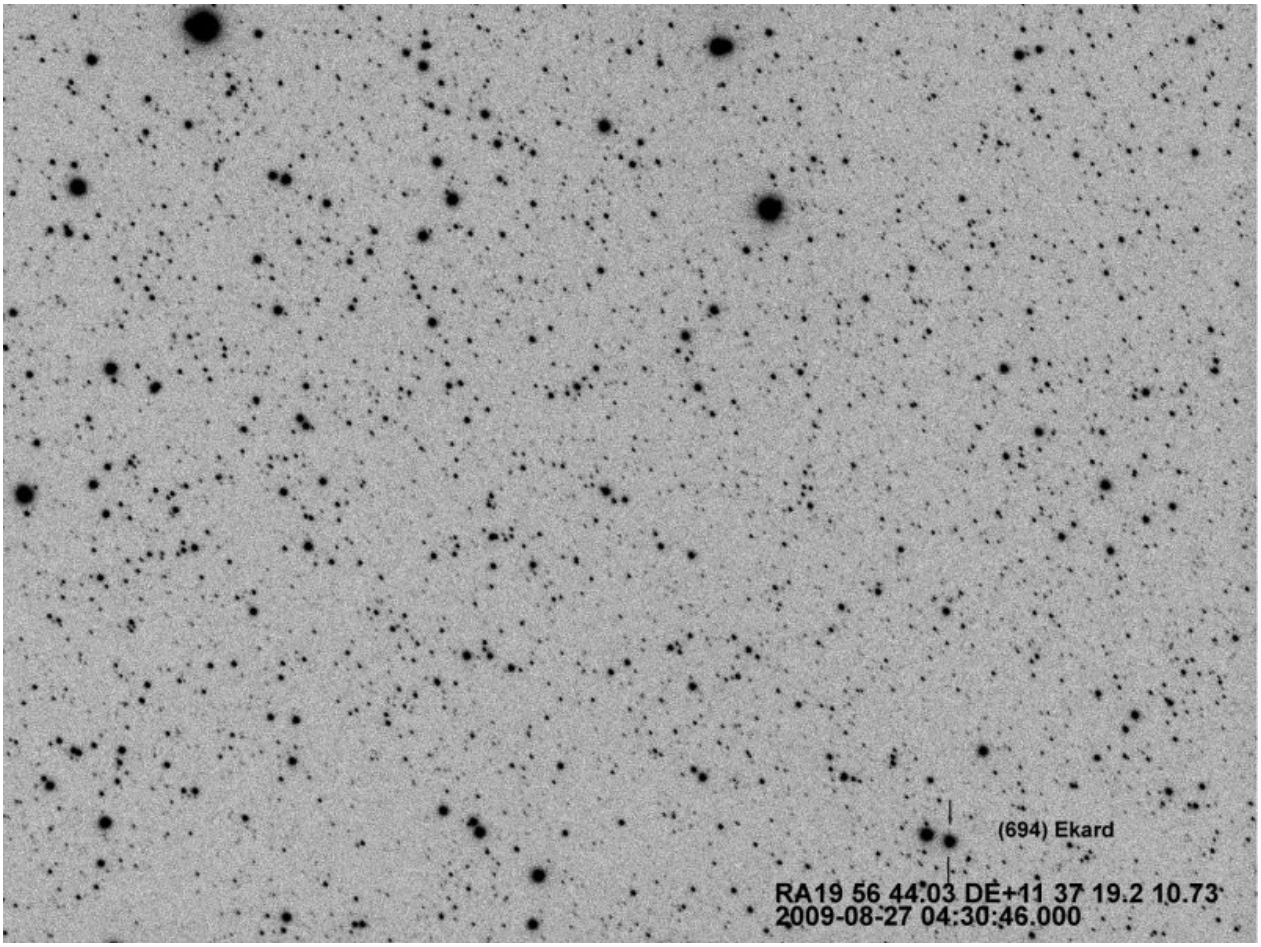
This image above of Rupes Recta is a crop from a frame obtained on 03 April 2009. This is a 0.007sec exposure with the Sky-Watcher 120mm Equinox mounted on a Sky-Watcher EQ6 Pro mount. You can see that Thebit D is clearly resolved at the end of the Straight Wall. This crater is only 3 miles in diameter. If you look closely, features as small as 1.0 to 1.5 miles can be discerned in this image.

Tycho:

Here is another crop from a frame obtained on 03 April 2009. This image was a 0.007sec exposure also.

These images were my first light images of the Moon with this camera. I was impressed with what I was able to accomplish with such little experience with this camera. I was pleased to see the detail in the slumping walls of the crater. I think the camera gives a very film like image if you do not get carried away with the sharpening.

694 Ekard:



In August, I was able to image asteroid 694 Ekard. This 60 second exposure was taken on 27 Aug 2009 04:30:46.000 UTC. This was the first time I got over an hour's worth of exposures with my mount tracking the whole time. Although some of the images showed some trailing due to periodic error in the mount during the 60 second exposure, this image is typical of what was obtained (the asteroid is in the lower right hand corner marked by the vertical bars). More recently, I was able to image 450 Brigitta and perform satisfactory astrometry on the images. In other images, using AIP4Win [2] and the UCAC2 and SA2.0 databases, I have obtained astrometry measurements with residuals of about ±0.2-0.4 arcsec. This is at a scale of about 1.04"/pixel. My seeing on good nights have been around 2 arcsec, and is normally around 2.5-3.0 arcsec.

After reviewing Craig Stark's excellent series on Signal to Noise Ratio, I decided to again measure the performance of my camera. The camera has seen about 10 months of use and I was curious whether the performance had changed in any way. I have been very impressed with the images I have been able to produce with it and I am hoping to get many years of service from this imager, and measuring the basic parameters might give me some indication of degradation.

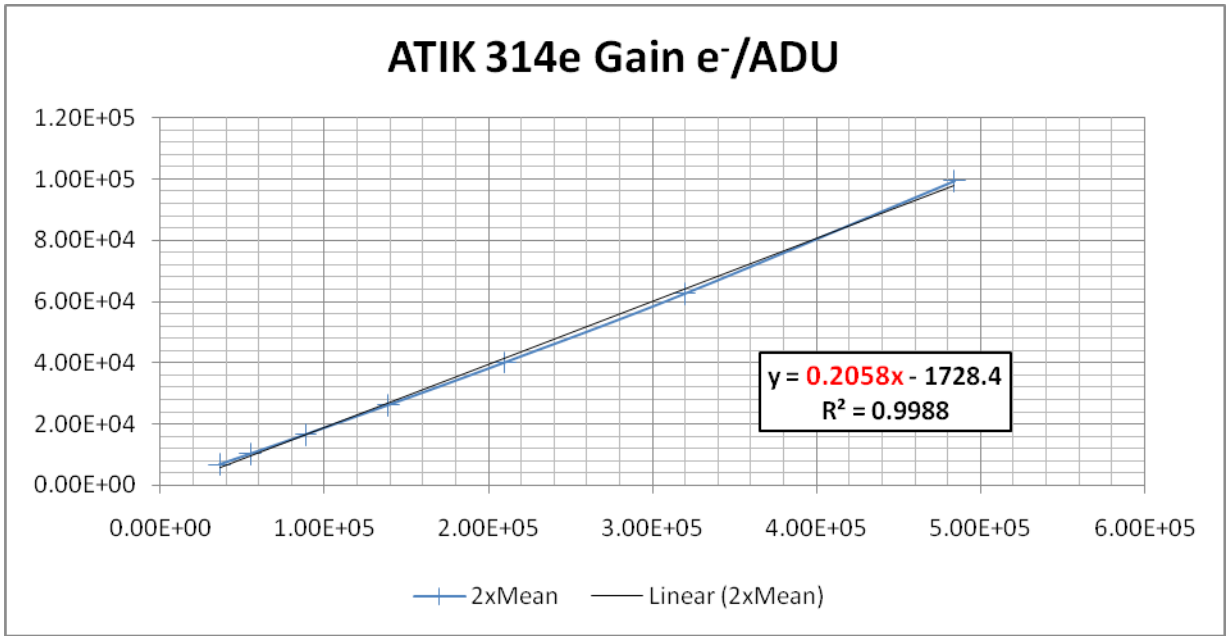
ATIK 314e Camera Performance Testing

Referring to the article by Craig Stark:
http://www.stark-labs.com/craig/articles/assets/CCD_SNR3.pdf

I followed Craig's instructions and used AIP4Win [2] and Microsoft Excel for the first few sections (through page 8 of 13) and obtained the following information and generated the following charts (All images obtained at an ambient temperature of approximately 70°F):

Gain Calculation:
I used the white office paper method (second method page 3 of 13) to diffuse and control the amount of light the imager was exposed to. The flat number refers to the number of thicknesses used. I was able to estimate the uncertainty based on the least squares fit:

File	Mean	SD	Variance	2xMean	Gain e^-/ADU
Flat3	49710.60	695.786	484118.16	99421.20	0.20537
Flat4	31279.60	565.255	319513.22	62559.20	0.19580
Flat5	20074.30	458.272	210013.23	40148.60	0.19117
Flat6	13106.70	372.642	138862.06	26213.40	0.18877
Flat7	8296.73	297.660	88601.48	16593.46	0.18728
Flat8	5133.15	234.246	54871.19	10266.30	0.18710
Flat9	3383.67	189.867	36049.33	6767.34	0.18772



Full Well Depth	**13484.2**	**±81.2**	**e^-**
Gain	**0.20575**	**±0.00124**	**e^-/ADU**

Readout Noise Calculation:

I obtained 100 Bias Frames and used every tenth frame (starting with frame 5) and measured the $\sigma_{Readout}$. I was also able to estimate the uncertainty based on the standard deviation of the mean.

File	SD
Bias_005	21.4837
Bias_015	21.5549
Bias_025	21.5496
Bias_035	21.5768
Bias_045	21.5629
Bias_055	21.5895
Bias_065	21.5986
Bias_075	21.6037
Bias_085	21.5851
Bias_095	21.5804

Mean SD	21.56852	ADU	
SD Mean	±0.03470	ADU	
$\sigma_{Readout}$	**4.4378**	**±0.0071**	**e^-**

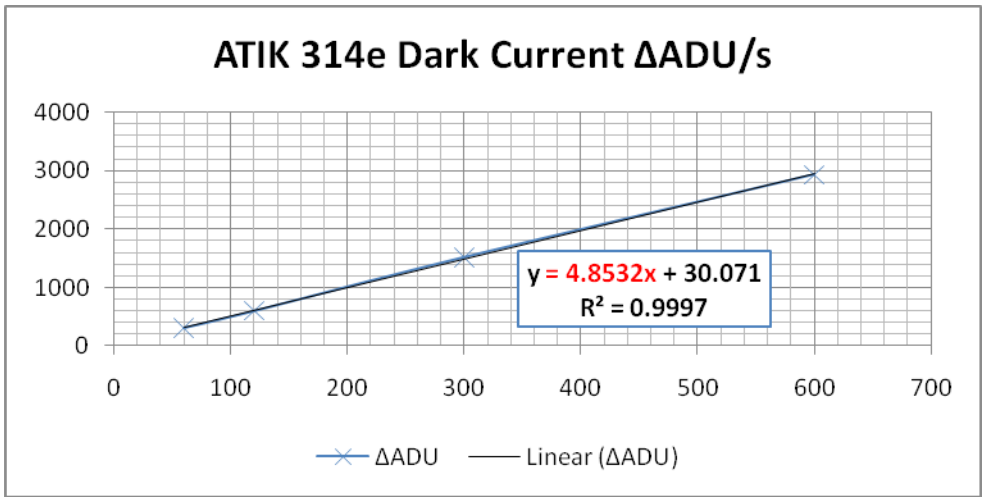
Dark Current Calculation:

I used the exposures suggested in the article and was able to calculate an uncertainty for the Dark Current $Dark_{e^-}$ based on the least squares fit:

File	Seconds	Mean	ΔADU	ADU/s	e^-/s
M Bias		211.367			
Dark60	60	523.704	312.337	5.20562	1.07107
Dark120	120	813.692	602.325	5.01938	1.03275
Dark300	300	1729.675	1518.308	5.06103	1.04132
Dark600	600	3140.14	2928.773	4.88129	1.00434

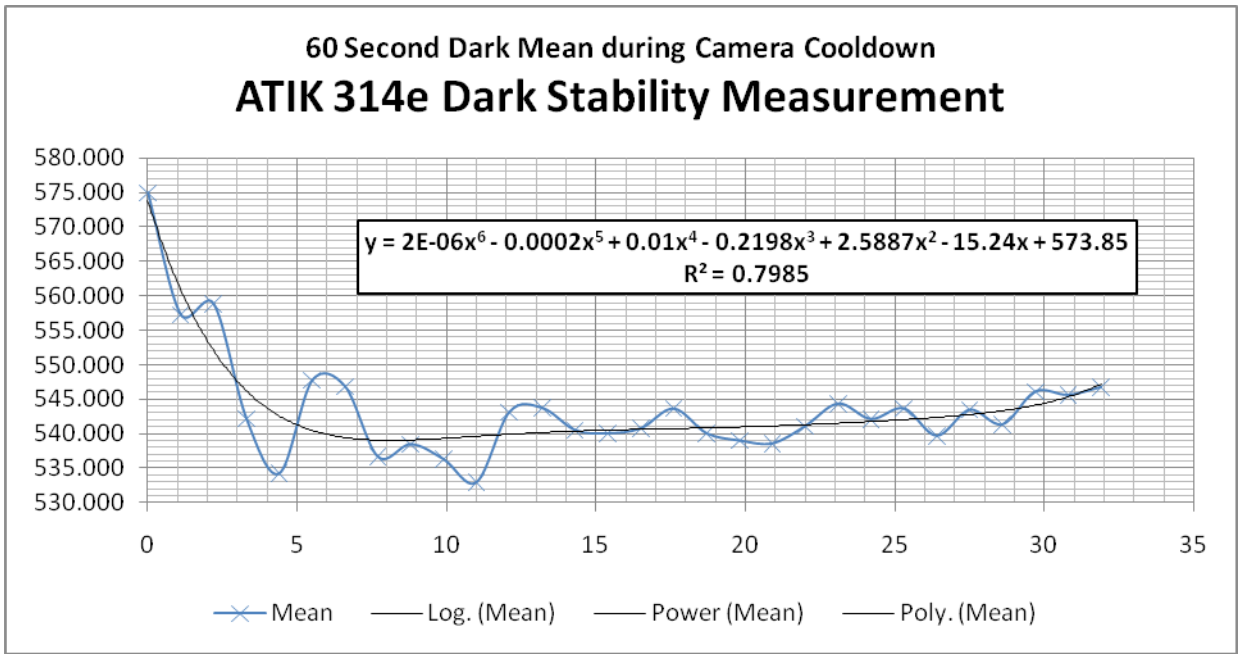
Dark Current	**4.85320**	**±0.00034**	**ADU/s**
	0.99856	**±0.00007**	**e^-/s**

The following chart depicts the very linear relationship (R^2 of 0.99856 for e^-/s) between exposure time and integrated Dark Current.



Dark Stability:

I followed Craig's advice and measured my Dark Stability to see how long it took my camera to cool-down and stabilize before taking the measurement frames. I was somewhat surprised by the oscillations in the mean values, especially since this camera's cooler is always on, and does not have a temperature control point. The measured data (as depicted on the chart) makes it look like it does though. I got a little carried away with the polynomial, but it took the six order poly to fit the curve as shown. The slight rise at around 28 minutes is when I turned the cooling off.



The camera seems to take from T_0 to T_5 to get to temperature but the oscillations do not settle out until around T_{15}. Cooling was in effect from approximately T_0 to T_{27}. The mean data as recorded:

Number	File	Time	Mean
0	Dark0	0	574.958

1	Dark1	1.1	557.260
2	Dark2	2.2	558.847
3	Dark3	3.3	542.149
4	Dark4	4.4	534.209
5	Dark5	5.5	547.700
6	Dark6	6.6	546.829
7	Dark7	7.7	536.637
8	Dark8	8.8	538.445
9	Dark9	9.9	536.255
10	Dark10	11	532.933
11	Dark11	12.1	543.126
12	Dark12	13.2	543.700
13	Dark13	14.3	540.480
14	Dark14	15.4	540.024
15	Dark15	16.5	540.751
16	Dark16	17.6	543.607
17	Dark17	18.7	540.015
18	Dark18	19.8	538.978
19	Dark19	20.9	538.559
20	Dark20	22	541.075
21	Dark21	23.1	544.330
22	Dark22	24.2	542.099
23	Dark23	25.3	543.637
24	Dark24	26.4	539.674
25	Dark25	27.5	543.435
26	Dark26	28.6	541.329
27	Dark27	29.7	546.086
28	Dark28	30.8	545.599
29	Dark29	31.9	546.731

The stability seems to be very good, although I was not able to measure the actual temperature. The ambient temperature for all the testing was approximately 70°F.

Results

Overall, this camera does everything I expect it to do, and the results from recent testing compare favorably to the initial testing performed in March 2009. There is sizable decrease in the Readout Noise, and the Gain and Dark Current has a slight increase. The results from 01 January 2010 are:

Gain g :	**0.20575 ±0.00124**	**e^-/ADU**
$\sigma_{Readout}$:	**4.4378 ±0.0071**	**e^-_{rms}**
$Dark_{e^-}$:	**0.99856 ±0.00007**	**e^-/pixel/sec**
Full Well Depth:	**13484.2 ±81.2**	**e^-**

I think the Readout Noise decrease may have been caused by allowing the camera to stabilize over 30 minutes before taking the Bias frames versus how I performed the test in March 2009. I usually allow the camera to cool-down and stabilize at least 30 minutes before taking my twilight calibration frames, but it is good to know the results of the stability measurements to know for a fact that I have to wait a good 15 – 20 minutes before taking calibration frames.

I am also learning about how important the signal to noise ratio (SNR) is in obtaining the best images possible. I want to thank Craig Stark, Richard Berry and Jim Burnell for their work in producing the tools and information necessary for a relatively newcomer to progress as far as I have over the past few months.

Conclusion

I hope that this demonstrates that anyone can test and calibrate their camera systems to get the most out of them and understand better how they work. I would be curious to know if my measurements are comparable or meet what ATIK expects of their cameras. I would also like everyone to know that the ATIK 314e is a very capable and provides a lot of bang for your buck. In lieu of the recent Kodak KAF8300 chip cameras making such a splash (I am eying the CCD Labs QHY9-m) with their small pixel size, maybe it would be worth it to take another look at the ATIK 314e. Future pursuits include obtaining an AstroTech 8" Ritchey-Chretien telescope (AT8RC) and the previously mentioned CCD Labs QHY9-m. I have been using the PinPoint Astrometric Engine to help calculate the frame centers for my images and have developed an EQMOD utility called EQMOD Telescope Position Recorder (EQMOD TPR) to log mount pointing values, among other values. This program is available in the Yahoo EQMOD Technical Group Files/Utilities section.

About the Author

Jerry Hubbell resides in Locust Grove, Virginia with his wife Michelle, 4 children out of 8 that are still at home, and 4 dogs of various types and ages. He works for Dominion Virginia Power in the Nuclear Design Engineering group as a Nuclear I&C Technical Specialist and is a Six Sigma Black Belt. He has almost 30 years experience in the nuclear and utility Industry and has worked on all manner and shape of analog and digital nuclear and non-nuclear instrumentation.