Noise analysis of my Nikon D5300 DSLR

I have been using the winter months to try and learn more about how my DSLR works and maybe improve my technique for taking astrophotos. A big issue for astrophotography is reducing image noise. I decided to try and characterize the electronic noise in my camera. Many websites talk about Read Noise and Thermal Noise. While they quote noise values in electrons, I want to initially focus on using the values contained in the image files my camera creates. These values are the integer count values for each pixel. They are typically stored as unsigned 16 bit numbers which means they can have values as small as 0 and as big as 65,535. For a 14 bit camera, such as my D5300 the numbers can be no bigger than 16,383. For a 12 bit camera they can be no bigger than 4095.

I discovered a simple formula on the Photometrics website used in their Read Noise Calculator. https://www.photometrics.com/resources/imaging-tools/read-noise-calculator.php The formula is based upon a really simple method of taking the difference between two images and then calculating the standard deviation of the difference. They use what are called BIAS images which is a type of image that we generate as part of the astrophotography hobby.

A BIAS image is created by simply putting the lens cap on the camera and then setting the shutter speed to the fastest possible. Then you take 10 or 20 or more photos this way. The photos are essentially pitch black but they contain a tiny amount of variation that is generated by your camera as it reads all of the information from the imaging chip and stores it as an image file. Every imaging chip has unique variations that exist in these BIAS images. There could be specific pixels that always give higher values or lower values. Sometimes an entire row or column of pixels can be slightly different which may arise from a design flaw. In addition to these consistent "signals" or "flaws" there is some random noise that is different for every image. In astrophotography we use BIAS images to cancel out these "signals" or "flaws". The random noise remains as a problem we try to minimize by combining several BIAS images together to create a Master BIAS image.

The method described on the Photometrics website has the ability to cancel out these "signals" and "flaws" by subtracting one individual BIAS image from another individual BIAS image. The resulting difference image contains only the random noise. The math theory that kicks in here is that when you take the difference between two datasets that contain random noise that the resulting difference dataset contains more noise. If you express the noise by its standard deviation(SD) you can calculate the increase in noise using the following equation:

$(\text{SDdifference})^2 = (\text{SDdataset1})^2 + (\text{SDdataset2})^2$

If we make the assumption that both BIAS images have the same amount of random noise then we can say that:

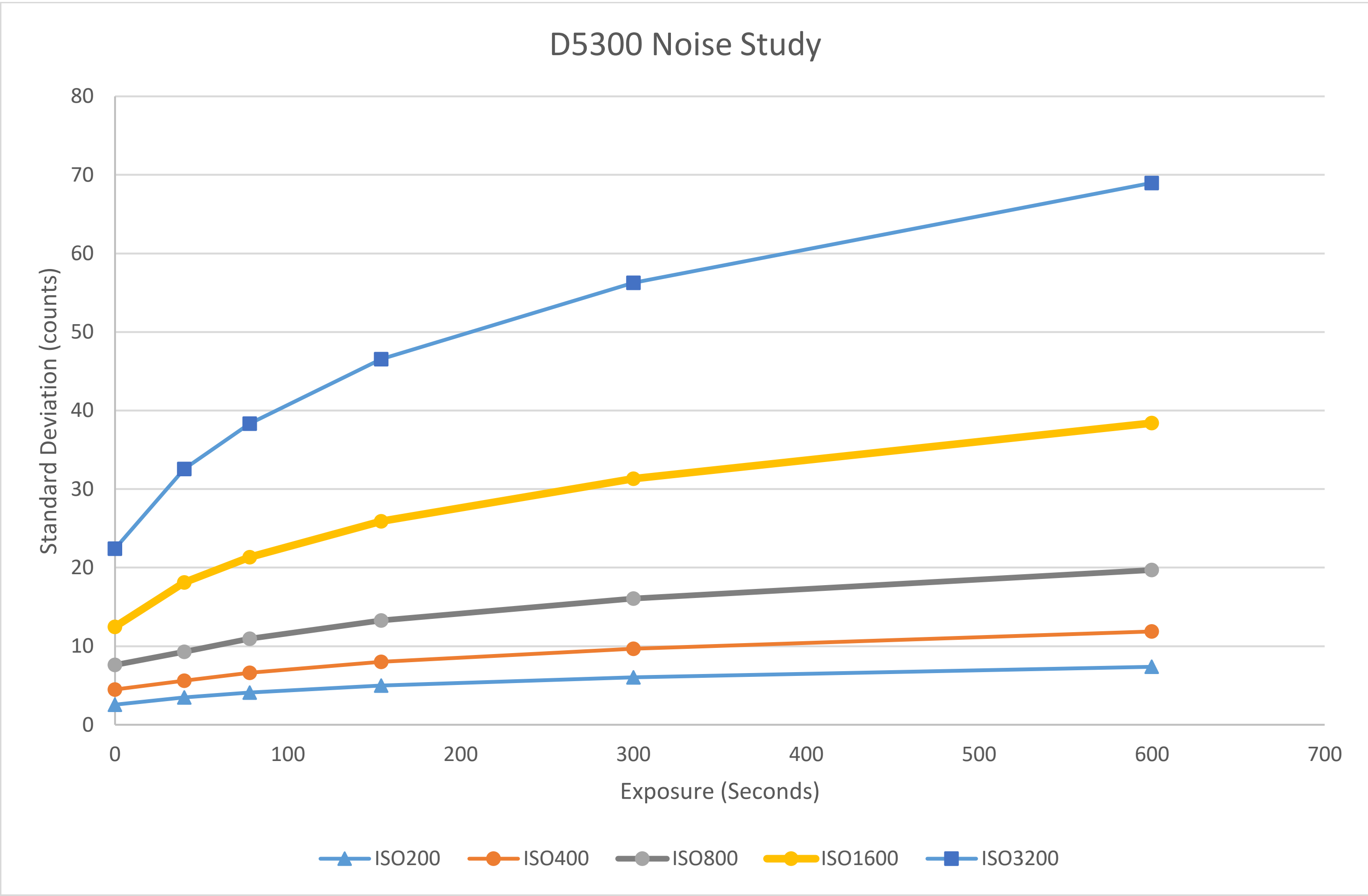
SDdataset1 = SDdataset2 = SDbias ; substituting we get the following equation

SDbias = SDdifference/sqrt(2) ; where sqrt(2) = 1.414 and SDbias is the Read Noise scaled in counts for a BIAS image.

The Photometrics website goes one step further and tries to calculate this Read Noise in electrons which requires you to calculate the camera gain. I don't want to bother doing this right now. I decided to also use this method with my DARK images.

DARK images are another type of image we need to generate for astrophotography. These images are generate by once again putting the lens cap on the camera. This time we set the exposure time to be very long so that it matches the exposure times we use in taking astrophotos. The main goal here is to try and generate photos that contain the "thermal" or "dark current" noise generated by our camera. Just like BIAS images, these DARK images contain a "signal" which indicates how the pixels in the camera respond during a long exposure. Typically these pixels accumulate thermal or dark current electrons which causes the values in the image files to increase with the exposure time. Just like BIAS images, these DARK images also contain random noise which we try to minimize by combining multiple DARK images.

The image difference method we used with the BIAS images should also be valid for the DARK images. Any "signal" should be cancelled out leaving only the random noise which we can use to calculate the noise in the DARK image. I wrote a program to calculate the difference between two images and then calculate the standard deviation. I divided these values by 1.414 to yield the standard deviation for the individual images. I had lots of BIAS and DARK images at various ISO settings so I decided to graph the result. I typically had 10 or more images for each datapoint. To arrive at one value for each datapoint I divided these images into several pairs and calculate standard deviations for each pair. I then averaged the standard deviations for the pairs to yield a single value. I would estimate that over 100 photos were used to generate this graph.



Exposure (Sec)	ISO200	ISO400	ISO800	ISO1600	ISO3200
0	2.56	4.49	7.61	12.48	22.42
40	3.48	5.60	9.29	18.12	32.55
78	4.10	6.60	10.95	21.35	38.35
154	4.98	8.01	13.29	25.91	46.55
300	6.02	9.69	16.07	31.33	56.28
600	7.38	11.88	19.70	38.40	68.98

The 0 exposure values are the values derived from BIAS images. The 300 second values are from an ISO study I did using DARK images. The full column for ISO1600 are from an exposure study I did last year using DARK images. The values shown in grey are interpolated values.

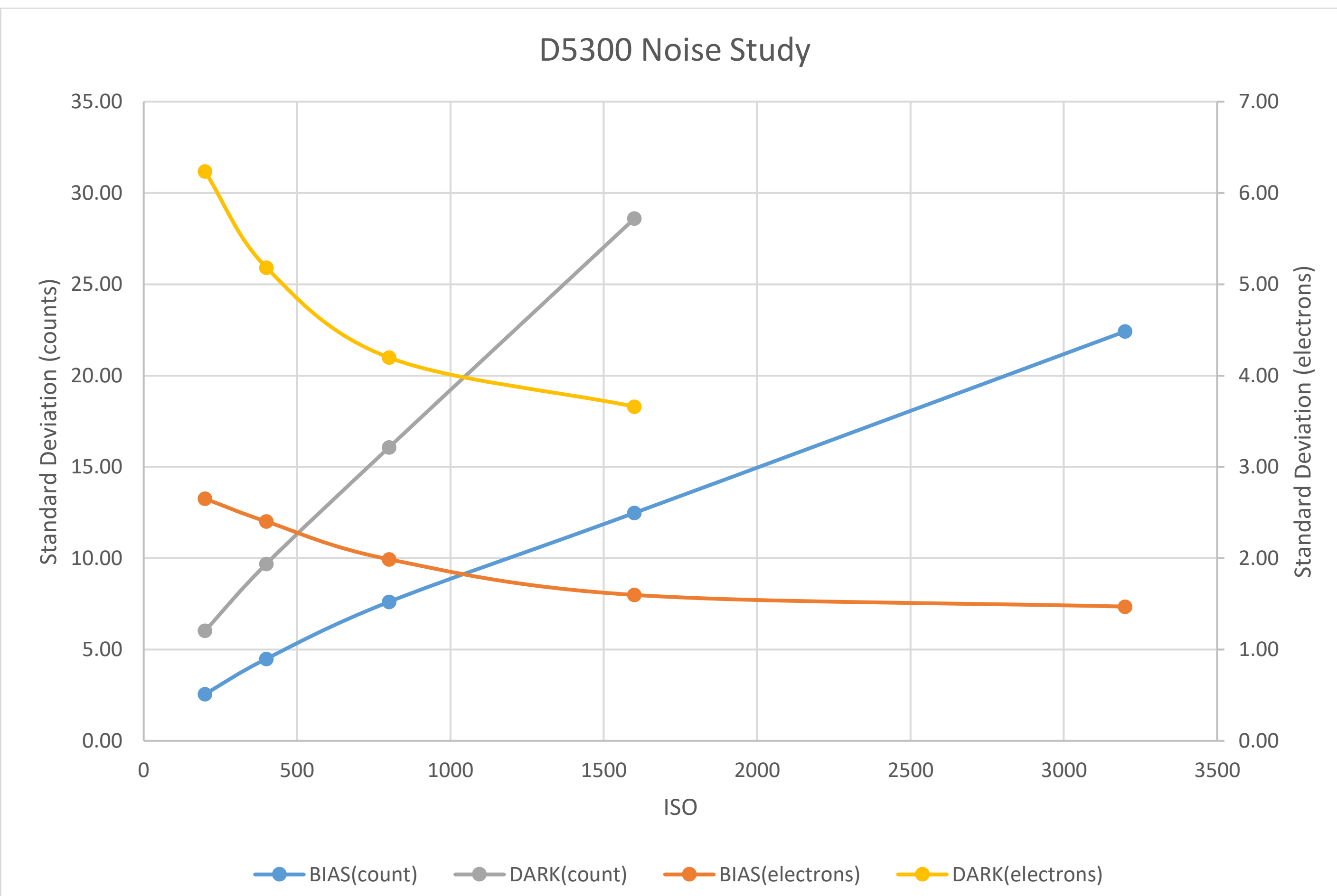
Clearly, the random noise in the DARK images increases with exposure time. In other words…the “Dark Current” or “Thermal signature” is not just a “signal” that can be compensated for. There is also a random noise component that has to be dealt with.

I decided that now I should try to convert these values to electrons. There is a website called www.sensorgen.info that contains a huge list of data for a wide variety of cameras. My Nikon D5300 is listed. The data includes Saturation values which Sensorgen says is the Saturation Capacity. Their definition is that Saturation Capacity represents the maximum number of electrons a camera pixel can hold before the image for that pixel is pure white. Any additional electrons are simply not counted. Pure white for my 14 bit image files corresponds to a value equal to 16,383. If I combine this Saturation Capacity and this 16,383 figure I can calculate a gain factor that will tell me how many electrons it takes to yield one count in my 14 bit image file. The Saturation value for ISO100 is 33925. This corresponds to the 16,383 value so, for ISO100 it takes 33925/16383 = 2.07 electrons per count. This crude method for calculating the camera gain allows me to translate all of my existing noise data from counts to electrons. I decided to focus on the BIAS data and the 300 second DARK data.

Sensorgen.info

Sensor data for Nikon D5300

Make	Nikon	ISO	Measured ISO	Read Noise (e-)	Saturation (e-)	DR (stops)
Model	D5300	100	78	3.4	33925	13.3
Sensor	Sony	200	157	2.7	16968	12.6
Tech	CMOS	400	311	2.9	8764	11.6
Date	17/10/2013	800	622	2.7	4279	10.6
Pixels	4016x6016	1600	1244	2.0	2097	10.0
Size	15.6x23.5mm	3200	2483	2.3	1074	8.9
Pixel size	3.9 micron	6400	5079	2.3	543	7.9
Bits	14	12800	9891	2.3	271	6.9
Q.E.	55%	25600	19842	2.8	137	5.6



			BIAS Noise		DARK Noise	
ISO	**Saturation**	**Gain 14b**	**Count**	**Electrons**	**Count**	**Electrons**
200	16968	1.04	2.56	2.65	6.02	6.23
400	8764	0.53	4.49	2.40	9.69	5.18
800	4279	0.26	7.61	1.99	16.07	4.20
1600	2097	0.13	12.48	1.60	28.6	4.01
3200	1074	0.07	22.42	1.47		

The two electron noise graphs are interesting. The graph for the BIAS(electrons) shows that the electron noise does increase slightly for lower ISO values. The values are close to the Sensorgen values for Read Noise (e-) which is encouraging. The graph for the DARK(electrons) is very interesting. It drops off quite quickly from ISO200 up to ISO800 and then seems to level off for the higher ISO1600 value.

This gives me the impression that I will get the best faint detail astrophotos if I shoot at ISO800 or higher. Since the improvement in noise seems to level out above ISO800 I don’t think I will benefit from shooting at higher ISO than ISO800 because at higher ISO is becomes too easy to have bright stars saturate.