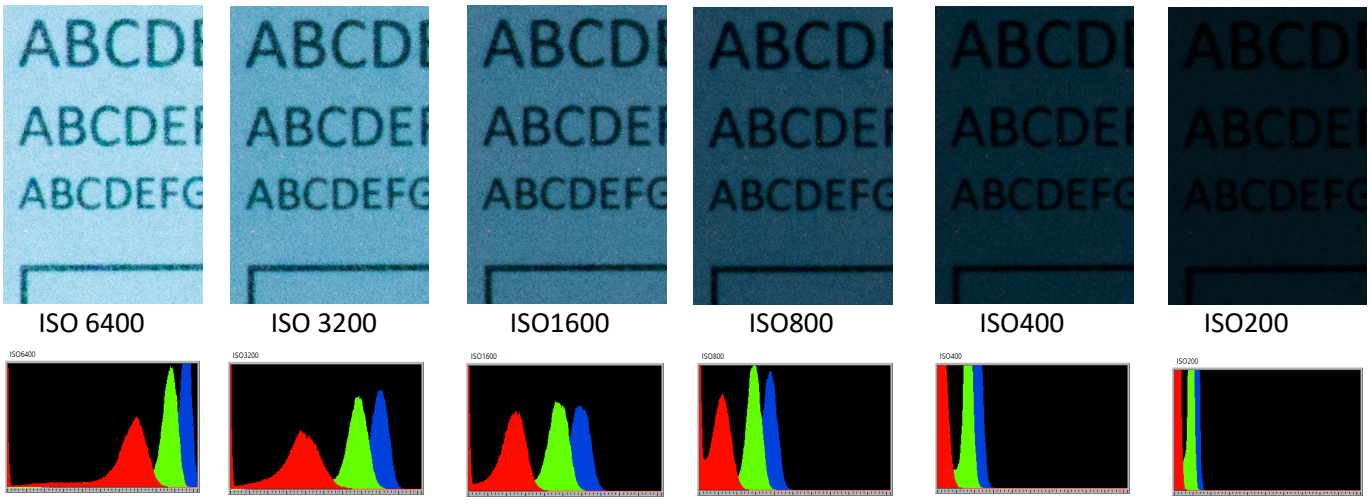
Nikon D5300 ISO Invariance Testing

I read on a web site that my D5300 camera is ISO invariant. ISO invariance means that the ISO setting on the camera tends to not be important. You can dramatically underexposure a photo and when you brighten the photo using a photo editing program there is little to no loss in quality. They also said that I should conduct my own test to prove this. They used evening sky photography with exposures that were only a few seconds in length. I decided that I would like to know if the long exposure thermal noise in my camera was ISO invariant. Thermal noise is inherent in all imaging chips and its main characteristic is that it grows steadily with exposure. This means that long exposures needed for astrophotography will have much more thermal noise than images where the exposure is only a few seconds. In other words…

"If I want to take a 300 second exposure of a DSO(Deep Sky Object)…is there a best ISO to use?" or

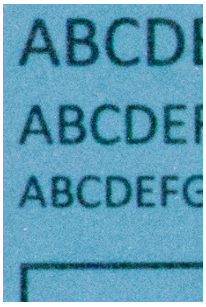
"You always want as much dynamic range as you can get your hands on because stars over-expose so easily…BUT…if you try to use a low ISO will you capture less of the faint details?

I decided to conduct the test in my darkened basement wood shop. There are no windows so I had full control of exactly how much light was available. I used a single white LED as my light source and, after some fiddling, I was able to take 300 second (5 minute) exposures at various ISOs ranging from 6400 down to 200. I created a target which was a piece of white paper with some lettering and some squares printed on my laser printer. The paper target was placed roughly eight feet away from my camera. I took all the photos at full resolution (6000x4000) and using 14 bit RAW format. Here are the RAW cropped images I created and there histograms. The histograms all use the same X and Y-axis scale. I did not white balance the images…they all came out with a blue tint. The smallest font is 8pt.

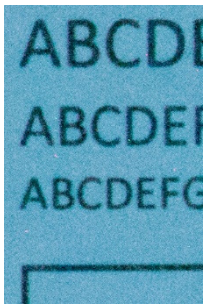


These are all 300 second exposures. I used my telephoto lens and set the aperture at f29 and the focal length to 300mm. I focused manually and set the camera to MANUAL so that the aperture, ISO and exposure were held fixed. The main difference in each photo is that the pixel values in the RAW files were progressively reduced from the ISO6400 image down to the ISO200 image. The histograms clearly showed this to be true.

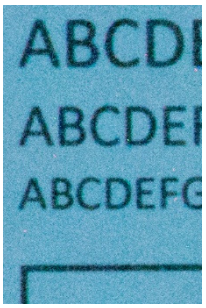
The test for ISO invariance says that I should now use a photo program to adjust the exposure by whatever stops are required to compensate for the differences in ISO. What I chose to do was to lower the ISO 6400 image by one stop, leave the ISO 3200 as is and then brighten the remaining images by 1 stop, 2 stops, 3 stops and 4 stops respectively. I used Lightroom to alter the images. Here is what I got.



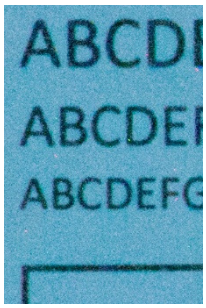
ISO6400 -1 stop



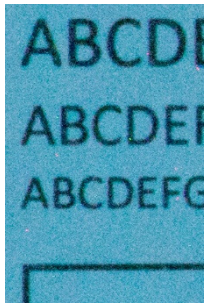
ISO3200



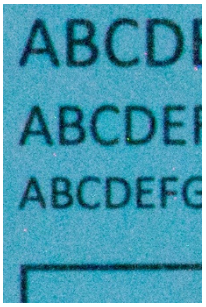
ISO1600 +1 stop



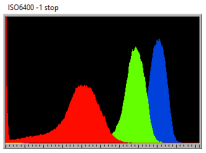
ISO800 +2 stops

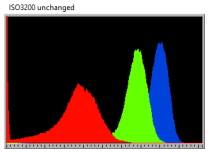


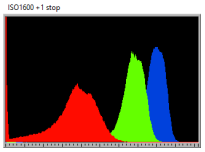
ISO400 +3 stops

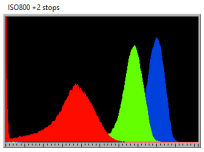


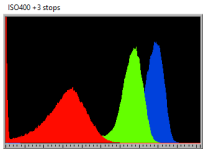
ISO200 +4 stops

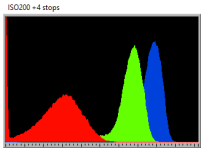












Interesting result…They are now all very close in brightness. The ISO400 and ISO200 images are just slightly darker. The other thing to note is that the noise in each image is pretty much the same. The ISO400 and ISO200 images are slightly noisier. A key point here are that the number of photons, or signal, in each of these images is virtually identical. Same aperture…same focal length…same exposure time. The only difference is the ISO, which for a digital camera is effectively a gain or scaling factor for the RAW data.

My interpretation of this result tells me that my NIKON D5300 DSLR appears to be ISO invariant…including long exposure thermal noise. Does this mean it doesn't matter at what ISO I take an astrophoto? In this specific case the visible noise in the images didn't change much no matter what ISO I used. What did change was the available dynamic range. Given this fact, I conclude that shooting astrophotos with my Nikon D5300 at ISO200 or ISO400 should give me good results in spite of the fact that the dim DSO may well be pitch black in the RAW photo. After stacking and digitally developing, the resulting noise may not be any worse or better using a lower ISO but the available dynamic range will be superior. An important find…but still not conclusive.

My D5300 camera can shoot at ISO100 but the web page I read gives me the impression that this would not be a good choice. This conclusion comes from visiting the Sensorgen website https://www.sensorgen.info/ On this website you will find testing data for virtually all cameras of all makes. For each camera you can find test data for a large range of ISO settings. The most significant parameter for me is the Saturation (e-) values. The Sensorgen site states that the Saturation (-e) values are actually "Saturation Capacity" values. The value is meant to represent how many electrons can be stored in a pixel before the resulting image is pure white. Adding any more electrons will not alter the value obtained from the pixel. The interesting point here is that this saturation value changes with ISO. As ISO is increased it takes less and less electrons in a pixel to end up with a pure white image. This hints at the fact that there are some electronics in the camera that, based upon the ISO, amplifies the analogue signal coming from each pixel and when the amplified signal reaches a limit the resulting value stored in the RAW image file is clamped at its maximum. What is not indicated here is that the number of bits used by the analog to digital conversion in the camera also plays a role.

For a 12 bit camera the values in the RAW image file can range from 0 - 4095. For a 14 bit camera this range increases to 0 - 16383. When you combine these ranges with the Sensorgen "Saturation Capacity" values you discover something important about your camera. Here is a subset of the data for my D5300 camera taken from the Sensorgen site.

ISO	Saturation (e-) "Saturation Capacity"
100	33925
200	16968
400	8764
800	4279
1600	2097
3200	1074

At ISO100 my camera's pixels can hold 33925 electrons before the electronics reaches its maximum…BUT…at 14 bit resolution my camera can only discern 16383 distinct values. This means that my camera might be able to collect lots of electrons but the resulting RAW file will have rounded off the results. It's as if I wasted my time collecting all those electrons…I don't get to see any increase in detail possible by collecting 33925 electrons. The one advantage here is that the dynamic range of the resulting image is maximized. This might be something to consider if my goal is to take an astrophoto of a bright star cluster where there isn't faint details such as nebulosity.

At ISO200 the story is better. At ISO200, my camera's pixels can hold 16968 electrons before the electronics reaches its maximum. My camera can discern 16383 distinct values so this is pretty close to 1:1 ratio. Virtually every electron I collect will add to the detail in my image. This situation is described as being the unity gain point for a camera. I give up a little in dynamic range but I still preserve my ability to record faint details. On the website http://dslr-astrophotography.com/iso-dslr-astrophotography/ they have tried to summaries the best ISO for various cameras. For my Nikon D5300 they suggest ISO200 or 400 which is what I am concluding right now. I am going to do a little more research while I wait for the snow to melt…stay tuned.