**ZWO ASI294MC Pro Versus Mallincam SkyRaider DS10C-TEC Comparison**
**Part 4 - Fixed Noise & Anti-Fogging**
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Test Report - January 7th, 2018

## Introduction:

This report covers the last of my Mallincam versus ZWO IMX294CJK CMOS camera comparison testing. The final two topics to be investigated are: fixed noise, and anti-fogging. By fixed noise I mean noise in the image that is not randomly distributed and/or does not change with time. The most common example of fixed noise that we see in cameras we use for EAA is hot/warm pixels. In the previous test report (Part #3) I made an assumption that all the noise in my recorded frames was random and time varying when I calculated TTOI (Time To Observable Image). If some of the noise in a single frame is not random and time varying, stacking successive frames will not average it out, and the theoretical improvement in SNR that stacking is supposed to provide will not be achieved. The larger the fraction of the noise that is fixed, the further away from the theoretical SNR the resulting stack will be. I use this fact as a means of comparing the relative amount of fixed noise in the frames generated by each camera.

Anti-fogging in my testing refers to the resistance to the formation of dew or frost on the sensor window or the sensor itself when the TEC is applied. Condensation of any type on the sensor or sensor window is undesirable as it greatly reduces the performance of the camera.

## Objectives:

In this forth part of my comparison testing I will measure the SNR for each camera using one particular gain and exposure setting, but for a range of stacked frame counts. This measured SNR versus frame count will be compared to what theory would suggest. In a separate test I will expose the sensor windows on each camera simultaneously to moist ambient air and see how long it takes for condensation to form when the TEC is turned on.

## Methodology:

The main component of the first half of this test is the measurement of SNR. I achieved this using exactly the same method described in my previous test report (Part #3). The only difference was that I used a single gain/exposure setting, and varied the number of stacked frames. I used an exposure of 20sec per frame, and had gain on both cameras set to maximum (HCG on). To generate the stacked frames I used the software that comes with each camera, namely: MallincamSky with the DS10C-TEC, and SharpCap with the ASI294. I also varied the amount of TEC cooling, repeating each sequence of frame stacking for: TEC off, +10°C, -5°C, and max TEC. The TEC off sensor temperature for each camera was recorded at: +25°C for the DS10C-TEC, and +16°C for the ASI294MC. The max TEC sensor temperature for each camera was recorded at: -20°C for the DS10C-TEC, and -16°C for the ASI294MC.

To calculate the theoretical SNR after stacking I used the SNR measured for a single frame and scaled it by sqrt(n), where 'n' is the number of frames stacked. During my testing I found that the different TEC settings resulted in different single frame SNR values (SNR went up as sensor temp. went down...see Part #3 report), so I came up with a normalized way of presenting the results. The final results are plotted as: ($SNR_{measured}$ / $SNR_{ideal}$). Plotted in this way, results that are closer to a value of 1.0 are better.

To test the anti-fogging I simply placed both cameras outside with their dust covers removed, exposing the sensor windows to free air (see Figure 1 below). I ran both cameras at their minimum exposure and minimum gain, with their TEC set initially to off and then switched both to -15°C as close to simultaneously as I could (within ~ 5sec of each other). I performed the test in the late afternoon on a cloudy day with light precipitation (snow flurries). The ambient air temperature was +2°C, and the dew point temperature was -1°C (ie. 78% R.H.). To capture the timing of dew or frost formation I had a third camera recording a time lapse, images being recorded every 5 seconds for the duration of the test. Both cameras reached a stable sensor temperature of -15°C after approximately 5 minutes. I let the cameras run in this configuration with TEC on for 1 hour.

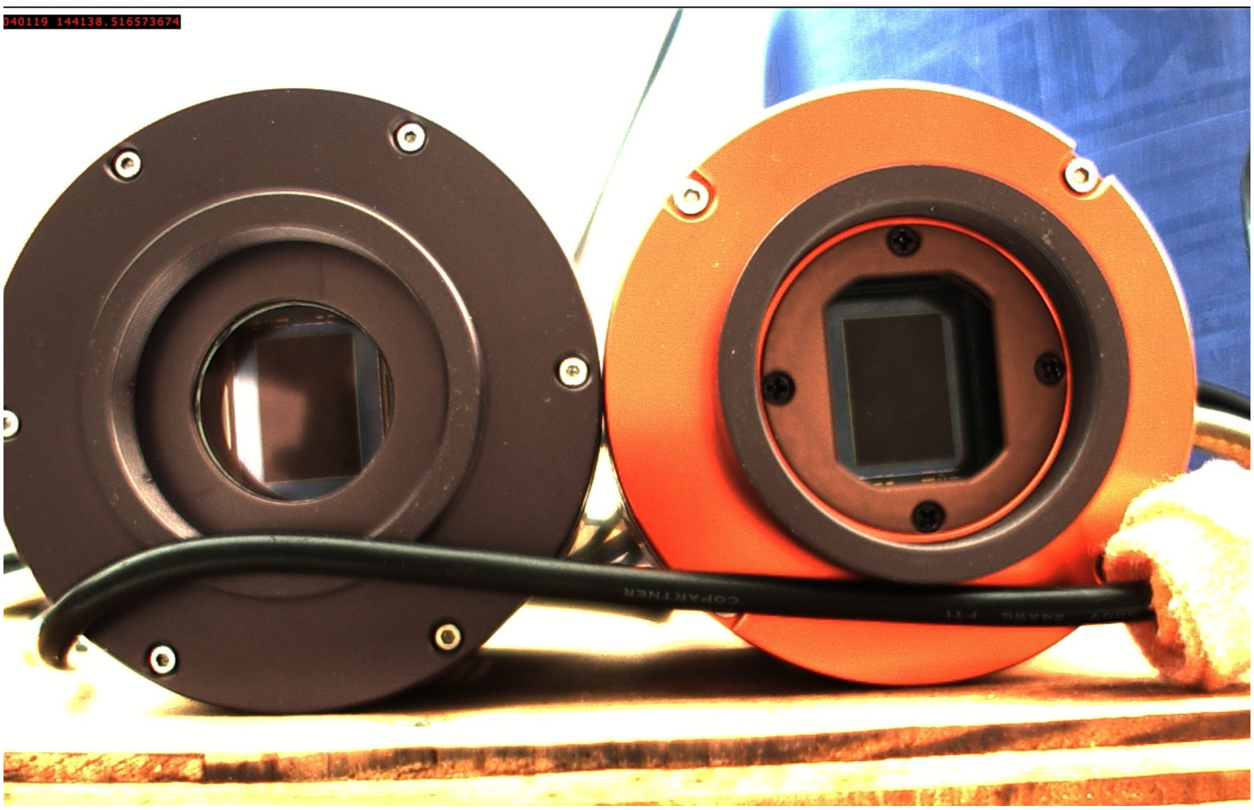

**Figure 1 Image of Cameras During Anti-Fogging Test**

**Results:**
To be honest I did not know what to expect when I did these last few tests. I was surprised to find that the measured SNR resulting from stacking was dramatically lower than what theory says it should be. Take for example the data plotted in Figure 2 for the ASI294MC-Pro camera with TEC off. Very quickly the measured SNR deviates from what theory would predict based on the SNR measured from a single frame.

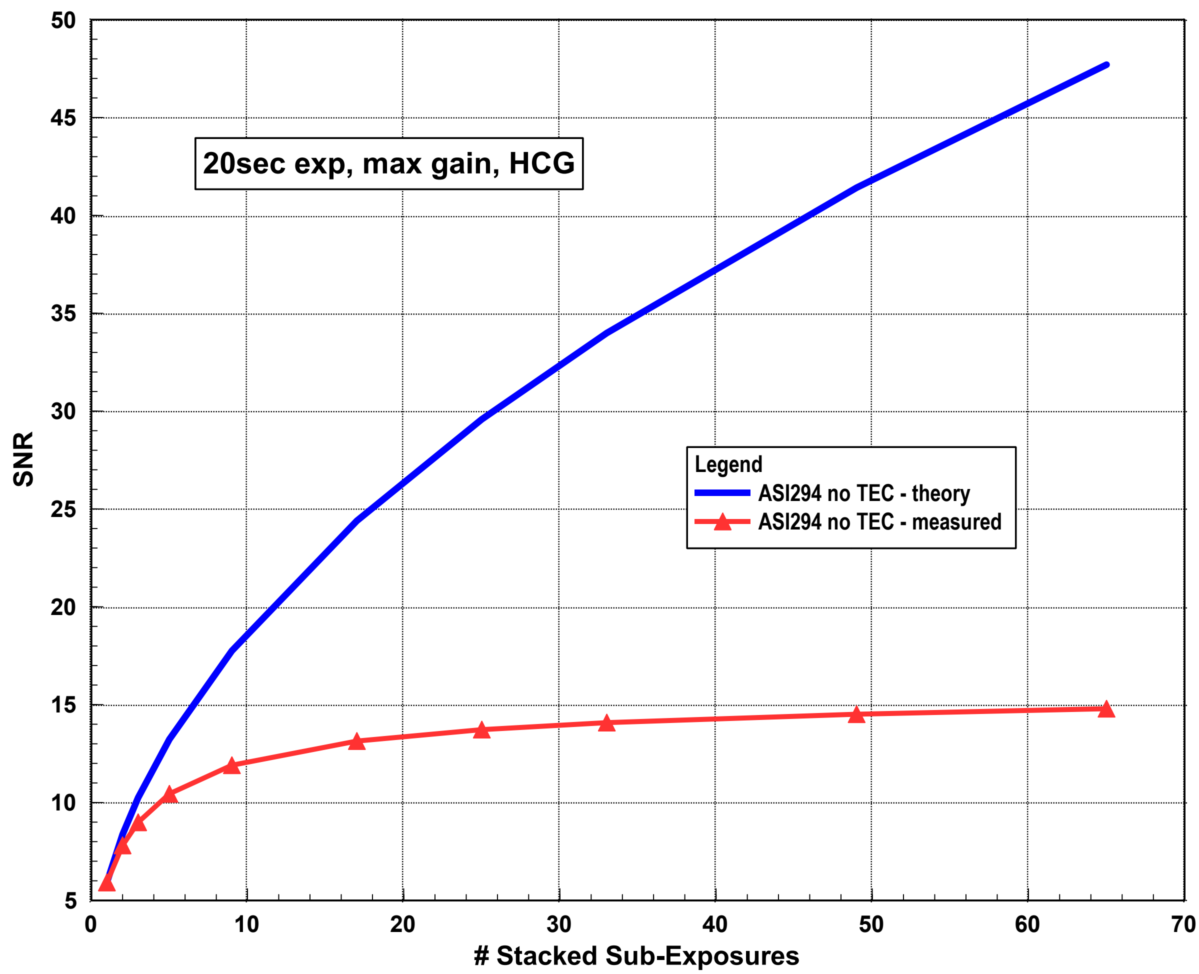


**Figure 2 SNR Measured vs. Theory, ASI294MC Pro - no TEC**

This suggests that a large percentage of the noise in the frame is not random and time varying. This is confirmed when you visually compare the images from the different amounts of stacked frames. Figure 3 compares a crop from the same part of the image for the 1 frame, 9 frame, and 65 frame captures from the ASI294 with no TEC. Clearly a large amount of the noise is due to warm pixels. This observation was true for both cameras, at all TEC settings. By the way, I think it is important to re-iterate that my calculation of SNR uses the 2-Sigma Mean (hot/warm pixels not included in mean signal) divided by the normal Standard Deviation (hot/warm pixels are included). Using this calculation method results in the lowest SNR values, and treats hot/warm pixels like any other source of noise in the image.

Continuing with the data analysis, the interesting thing that I found was that the extent of TEC applied had a large positive influence on how much the measured SNR deviated from the theoretical value. By reducing the visibility of warm pixels, the TEC effectively moves the camera performance closer to theory. This effect is illustrated in the graph of all the measured data, plotted as a ratio of $SNR_{measured}$ / $SNR_{ideal}$ in Figure 4.

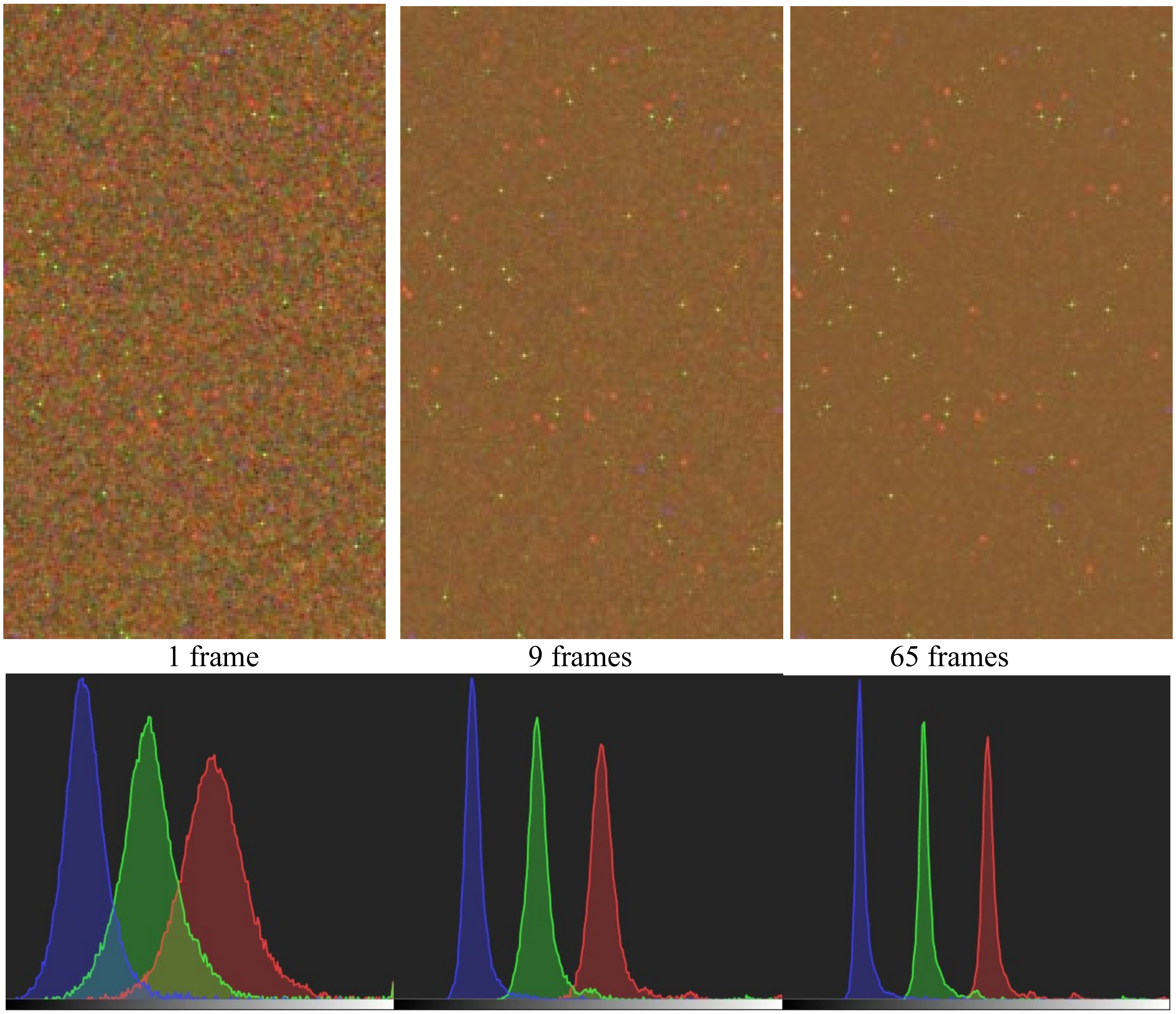


**Figure 3 ASI294MC-Pro Signal Images @ Various # Stacked Frames, no TEC**

Looking at all the results plotted together it would appear that the ASI294MC-Pro is able to produce stacked images with SNR's closest to what theory says is possible. At max TEC the DS10C-TEC performs below the ASI294, but not by a large margin. When you combine this observation with the one made in my Part #3 report, that the DS10C-TEC produces a better single frame SNR at exposure times below 100sec, it would seem that the overall performance in terms of TTOI for these two cameras is very similar.

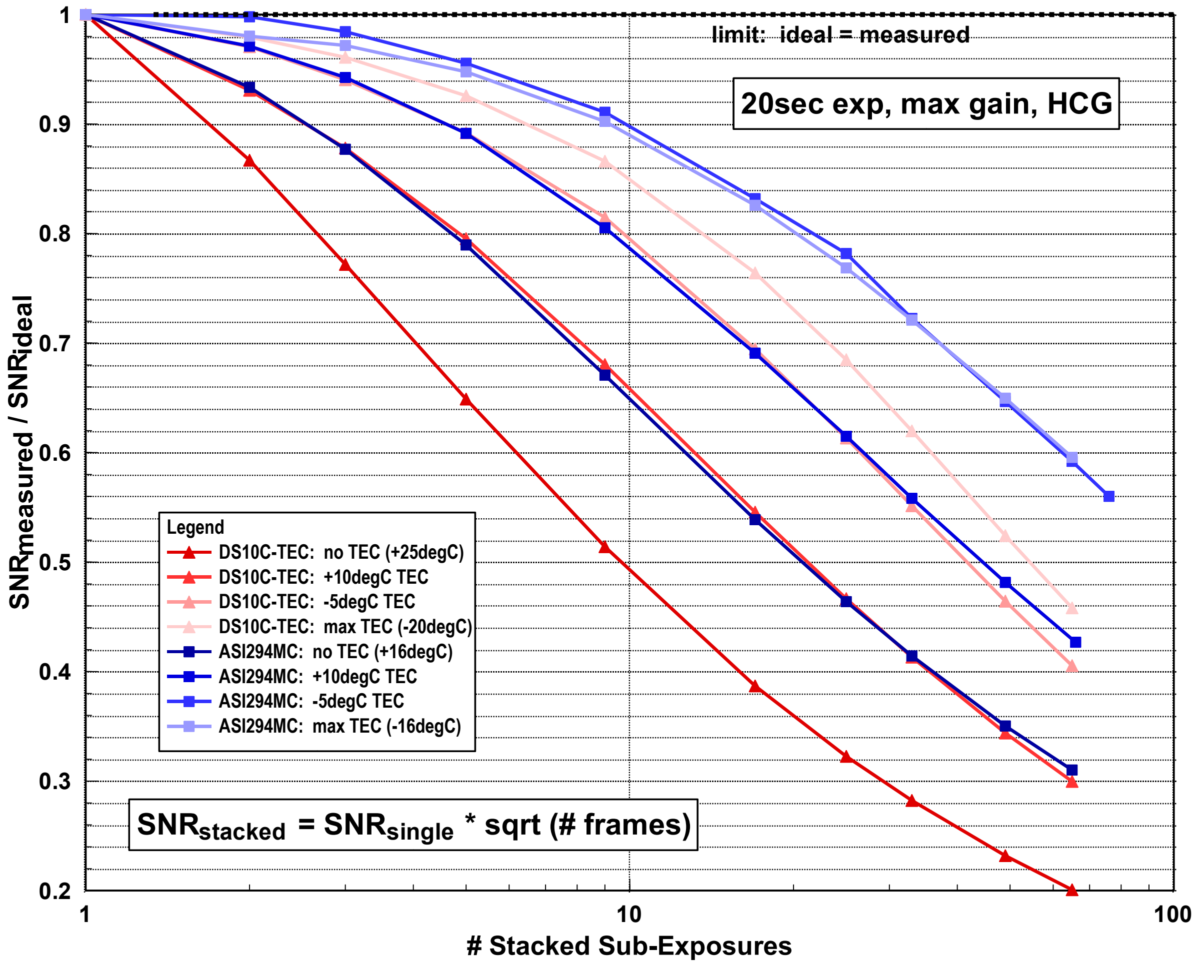


**Figure 4 $SNR_{measured}/SNR_{ideal}$ For Both Cameras**

Another interesting observation is that the ASI294MC-Pro does not seem to benefit from cooling below -5°C, but the DS10C-TEC does. In fact the DS10C-TEC appears like it would benefit from cooling below even -20°C. I strongly suggest confirming that cooling to such low temperatures is acceptable from the camera manufacturer – I believe it is not recommended.

Even with max TEC, both cameras fall short of achieving the theoretical SNR through stacking, a reality that in all likelihood applies to all cameras in practice. The only way to get even closer to the theoretical limit than what cooling alone provides would be to employ image calibration techniques common in astrophotography: dark frames, bias frames, and flat frames. I have no desire to go down that rabbit hole, but others please be my guest. ;) The easiest calibration to implement is applying a dark frame since both camera softwares have this capability built in.

It is also important to take into account the intended application of the camera. In my case I am primarily interested in observing, so my TTOI criteria of a total SNR of 20 means that the total number of frames I need to stack is on the order of 8 to 10. At that number of stacked frames both cameras are not that far from theory, around 85 to 90% of ideal. Perhaps not enough of a difference to worry about using dark frames or other calibration. If my application was astrophotography I would probably be more concerned over the difference between measured and ideal SNR since my objective would be to achieve an image with much higher SNR than 20.

The other half of my testing was less exciting but produced an equally interesting result. After an hour of running both cameras at a sensor temperature of -15°C, exposed to ambient humid air, there were no signs of condensation on either sensor window. Evidently both cameras have an effective anti fogging system, at least for the conditions under which I performed my test.

**Conclusions:**
In summary, I have drawn the following conclusions from the last batch of testing:

- The presence of fixed noise, a common example of which is hot/warm pixels, has a big impact on the performance of both cameras. Measured SNR for stacked frames deviated by a large amount from what theory would predict for an image with purely random time varying noise.
- In general the ASI294MC-Pro showed normalized stacked SNR performance most similar to theory. When uncooled the DS10C-TEC had normalized stacked SNR performance much lower than the ASI294MC, but with cooling the DS10C-TEC had performance only a small amount below the ASI294.
- When you combine the difference in single frame SNR performance (Part #3 report, DS10C-TEC better) with the difference in normalized stacked frame SNR performance (ASI294 better), it appears that these two cameras perform at a very similar if not equal level when used for EAA.
- Cooling has a big impact on how close the stacked SNR from each camera is to theory. The impact of cooling was more dramatic for the DS10C-TEC. Cooling below -5°C did not seem to improve performance of the ASI294, but it did for the DS10C-TEC.
- For the ambient conditions to which I exposed the cameras, both cameras were effective at preventing the formation of condensation on their sensor window.

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