ZWO ASI294MC Pro Versus Mallincam SkyRaider DS10C-TEC Comparison
Part 2 - Dark Frames
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Test Report - December 3rd, 2018

Introduction:
This report is a continuation of the Mallincam versus ZWO IMX294CJK CMOS camera comparison testing.

Objectives:
In this report I present a side by side comparison of dark frames captured with each camera. It is anticipated that three main factors will affect the appearance of the dark frames: exposure time, gain setting, and camera temperature. All three of those parameters were adjusted during my testing.

Methodology:
Testing began by allowing each camera to come to a stable temperature. This was done by running each camera un-cooled at 20s exposures for an initial 30 minutes. A minimum 15 minute stabilization period was used each time the temperature state of the camera was changed, ie. whenever the TEC settings were changed. Three TEC configurations were tested: TEC off, TEC on -5°C, and TEC on max cooling.

Three exposure times were used for the testing: 20s, 120s, and 600s. In the case of all three exposure settings, the camera software was allowed to stack frames as required to give a total effective exposure time of 10 minutes. This corresponds to 30 frames stacked at 20s, 5 frames stacked at 120s, and a single frame at 600s. The purpose of collecting data for 10 minutes duration total was to minimize the appearance of random noise in the recorded images, leaving only hot/warm pixels and amp glow.

Two gain settings were used: minimum gain, and maximum gain. On the ZWO camera the High Conversion Gain (HCG) engages automatically above a certain gain setting. Thus, when the camera was set to minimum gain it was in Low Conversion Gain (LCG) mode, and when at maximum gain it was in HCG mode. On the Mallincam camera the conversion gain setting is user controlled. By default the DS10C-TEC is set to HCG in the software, which is where I left it for all the testing.

Both cameras were set to their 14 bit output modes. Images were captured from each camera using the corresponding software. All other camera/software settings were at their defaults. Images from the ASI294 camera were captured full frame 1x1 bin (4144x2822). The DS10C-TEC images were captured using the widest output size 1x1 bin (4096x2160).

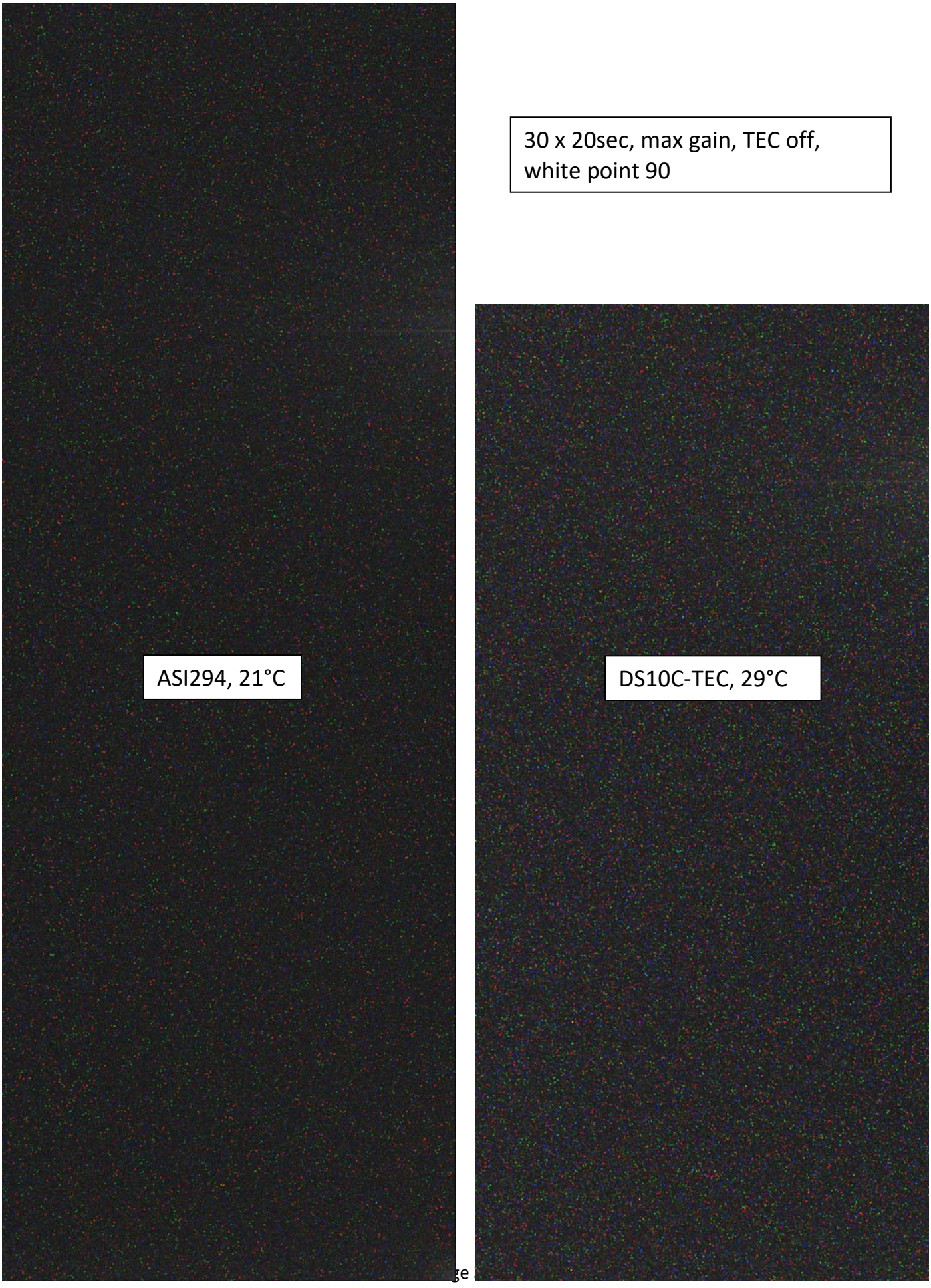
Results:
Inserted below are crops from the recorded dark frames. The original images can be downloaded from my website if desired:

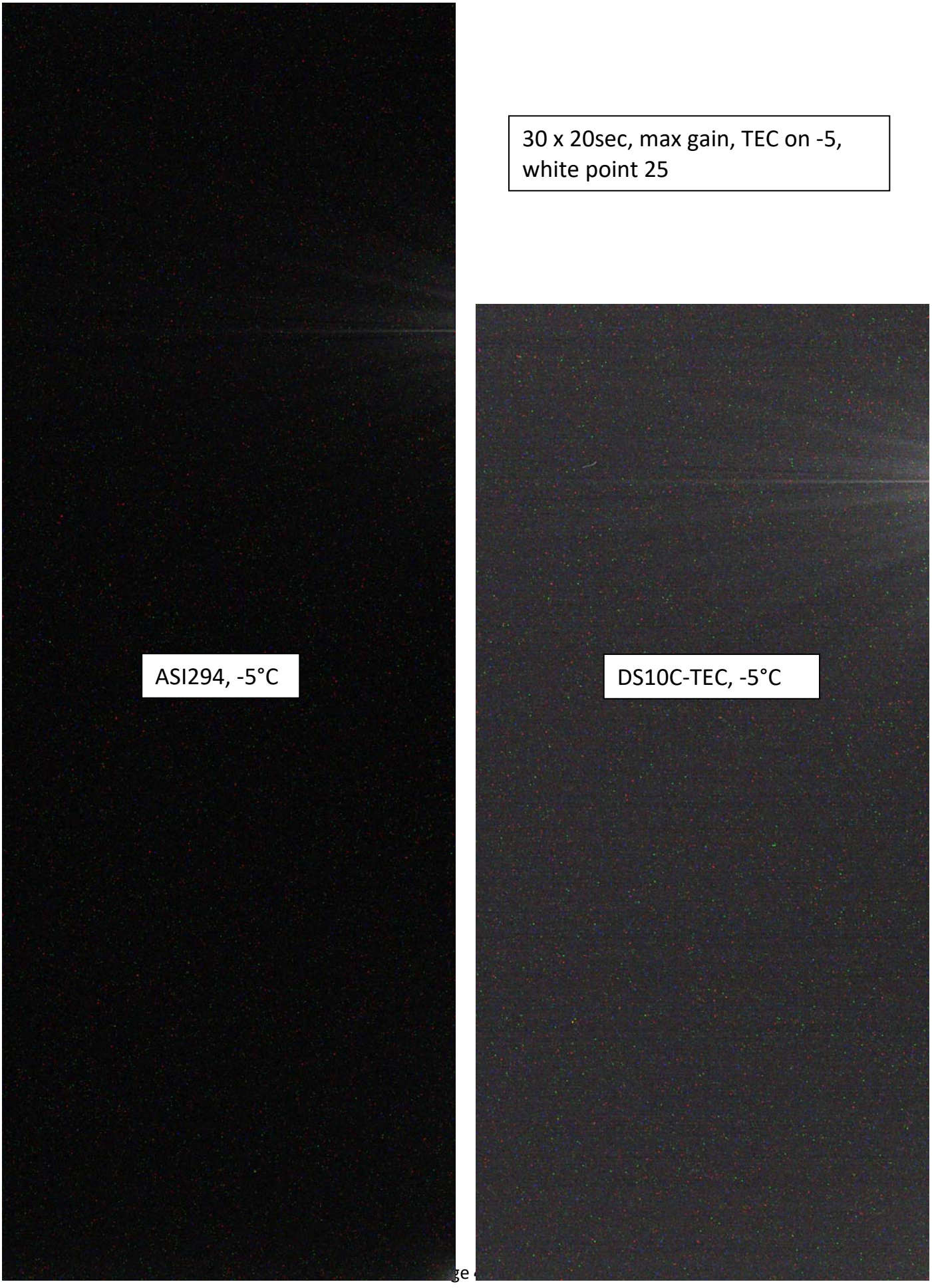
http://karmalimbo.com/aro/camtest/ASI294 darks.zip

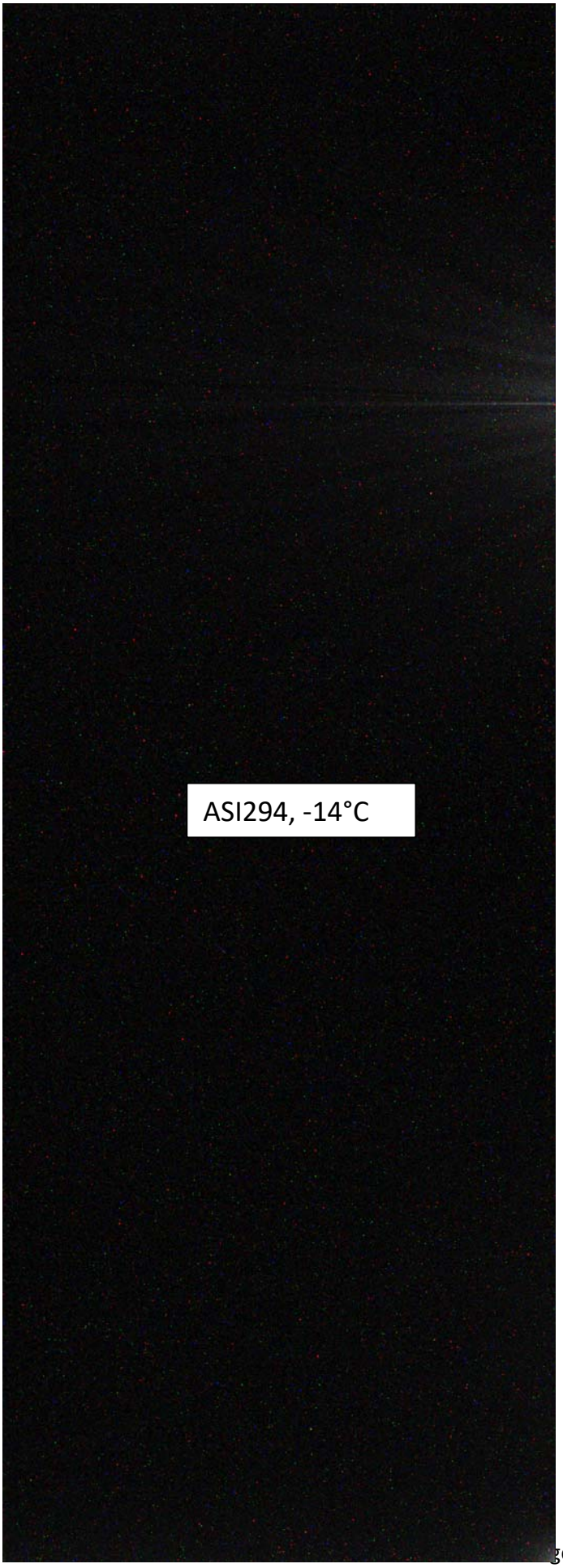
http://karmalimbo.com/aro/camtest/DS10C-TEC darks.zip

To better visualize the differences between the two cameras at each TEC/exposure/gain setting, I have adjusted the histogram white point down, brightening the images. The white point value I chose is listed with each of the pairs of images, as well as in the summary table below. In addition to just visually comparing the dark frames, I used the image analysis tool ImageJ to calculate the some basic statistics on each image. That information is also summarized in the table below.

Camera	TEC	Sensor Temp	Gain	Exposure	Average Pixel Intensity	Pixel Intensity Std Dev	Min Pixel Value	Max Pixel Value	Crop White Point
ASI294MC Pro	on	-5	max	30x20s	1.367	0.756	0	90	25
	on	-14	max	30x20s	1.184	0.566	0	87	20
	off	21	max	30x20s	12.208	4.755	0	146	90
	on	-5	min	30x20s	0.000118	0.0619	0	85	15
	off	21	min	30x20s	0.000247	0.0791	0	85	15
	on	-5	max	5x120s	3.396	3.002	0	125	90
	on	-14	max	5x120s	2.163	1.937	0	95	60
	off	20	max	5x120s	79.845	14.724	0	214	255
	on	-5	min	5x120s	0.000224	0.0811	0	85	20
	off	21	min	5x120s	0.00482	0.108	0	86	20
	on	-5	max	1x600s	14.557	11.172	0	255	255
	on	-14	max	1x600s	7.595	9.139	0	255	255
	off	21	max	1x600s	254.671	8.799	0	255	255
	on	-5	min	1x600s	0.00111	0.0767	0	85	30
	off	20	min	1x600s	1.003	0.256	0	99	30
DS10C-TEC	on	-5	max	30x20s	4.548	1.556	1	91	25
	on	-19	max	30x20s	4.352	1.077	1	88	20
	off	29	max	30x20s	27.516	6.716	19	139	90
	on	-5	min	30x20s	2.48	0.5	2	8	15
	off	31	min	30x20s	3.031	0.422	3	69	15
	on	-5	max	5x120s	8.94	4.03	3	113	90
	on	-19	max	5x120s	6.499	2.557	2	100	60
	off	30	max	5x120s	176.864	11.188	139	247	255
	on	-5	min	5x120s	2.928	0.317	2	26	20
	off	30	min	5x120s	5.099	1.468	4	92	20
	on	-5	max	1x600s	26.631	12.51	5	255	255
	on	-19	max	1x600s	18.076	10.285	1	247	255
	off	30	max	1x600s	255	0	255	255	255
	on	-5	min	1x600s	3.051	0.769	2	88	30
	off	31	min	1x600s	15.283	4.398	12	128	30

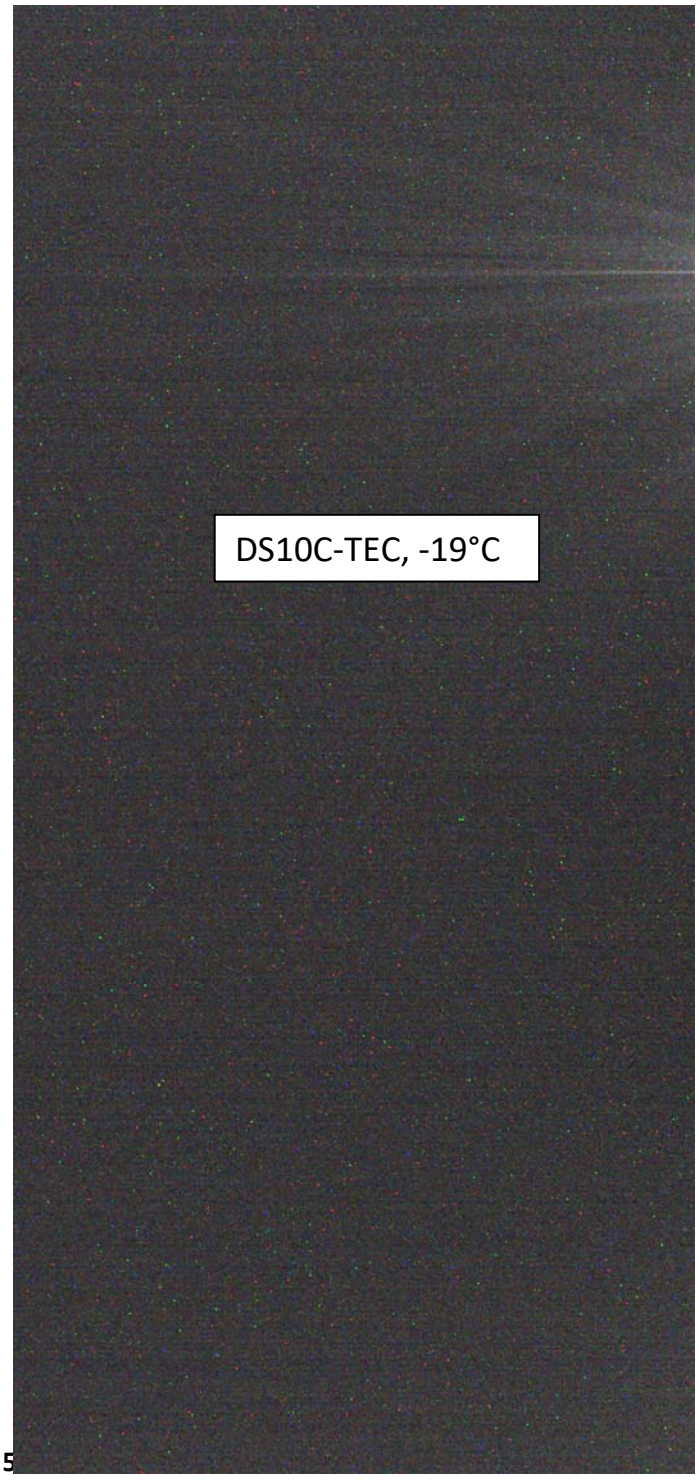

30 x 20sec, max gain, TEC off, white point 90
ASI294, 21°C
DS10C-TEC, 29°C


30 x 20sec, max gain, TEC on -5, white point 25
ASI294, -5°C
DS10C-TEC, -5°C

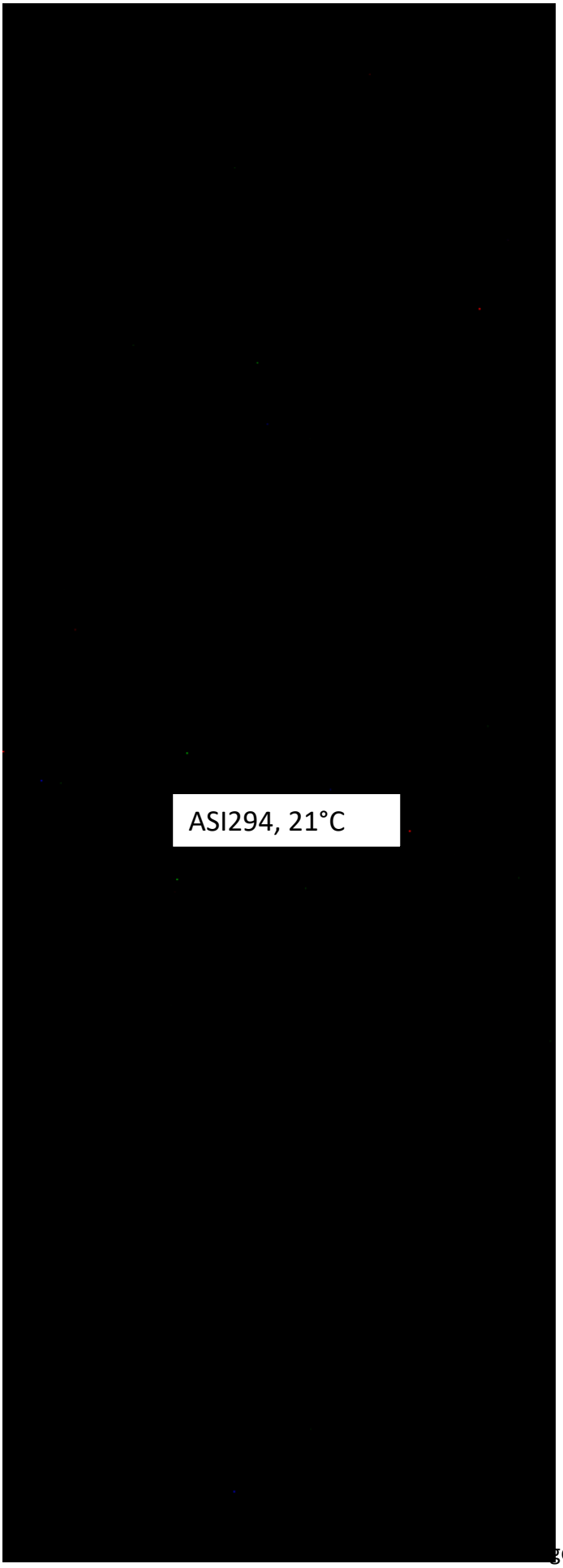


30 x 20sec, max gain, TEC on max, white point 20

ASI294, -14°C



DS10C-TEC, -19°C



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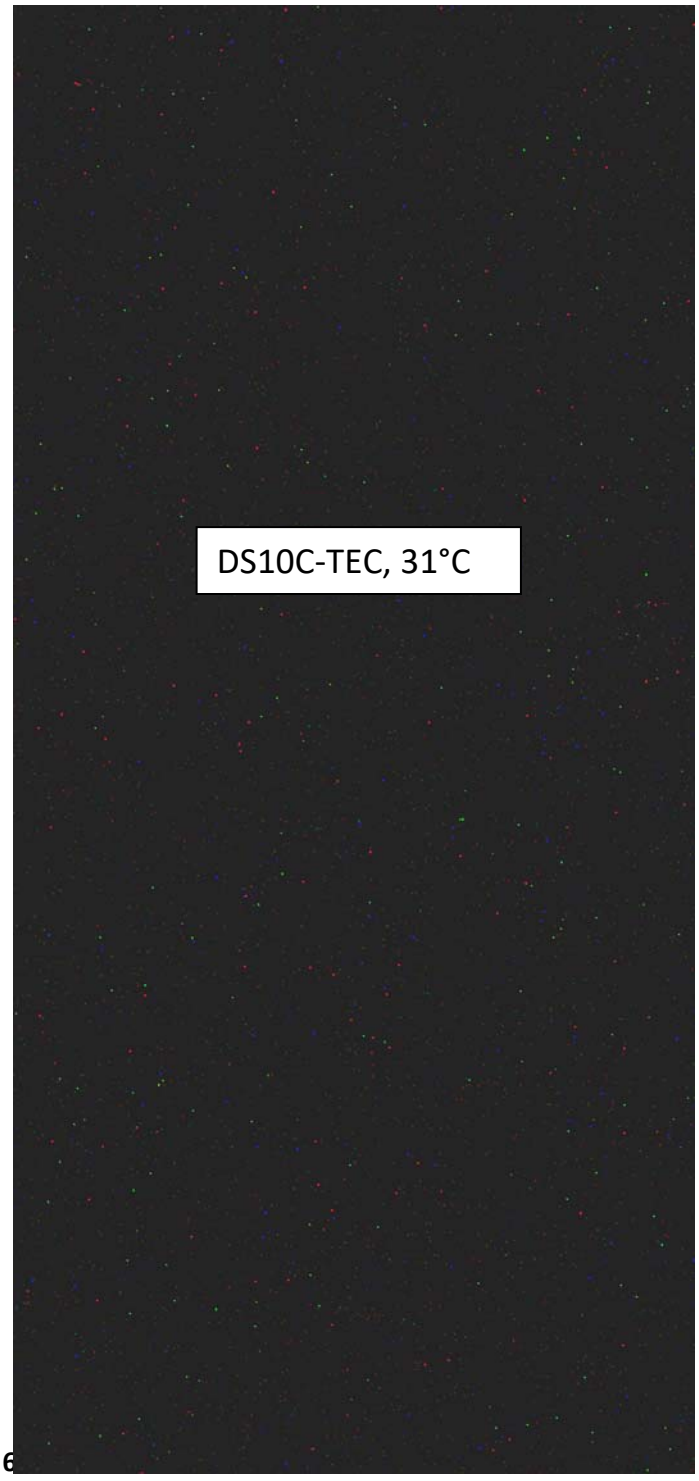
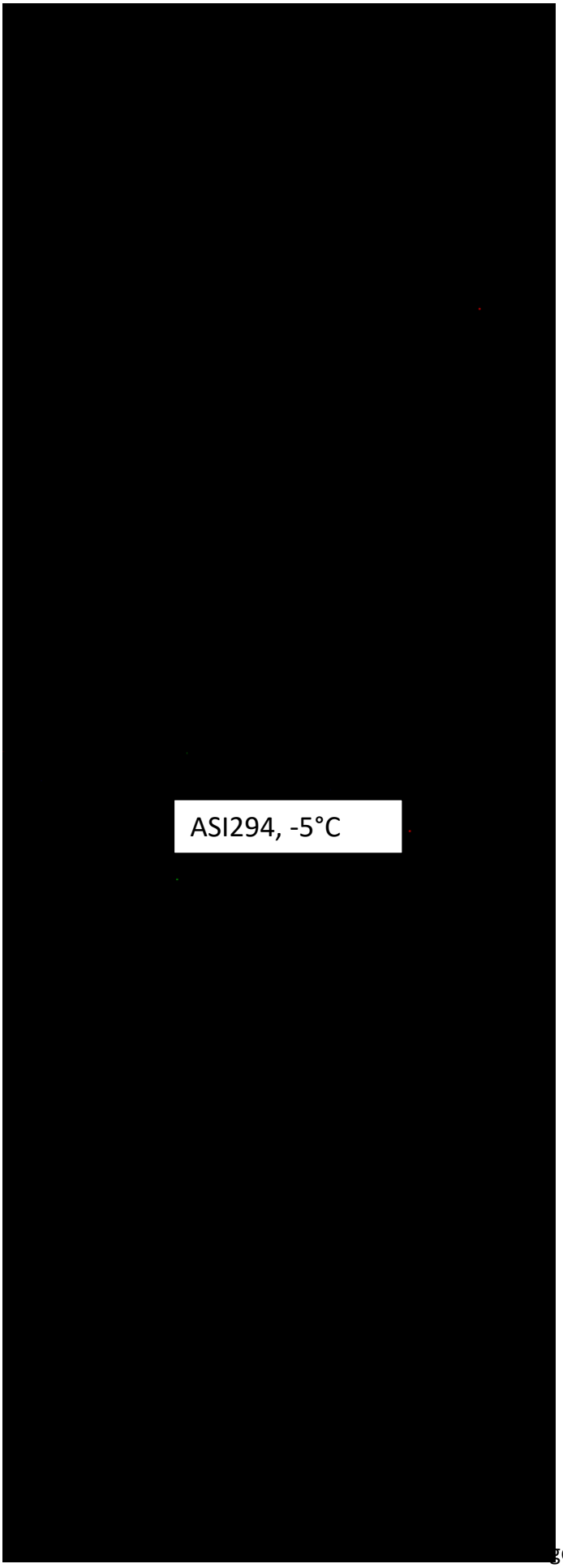
white point 15

ASI294, 21°C



DS10C-TEC, 31°C



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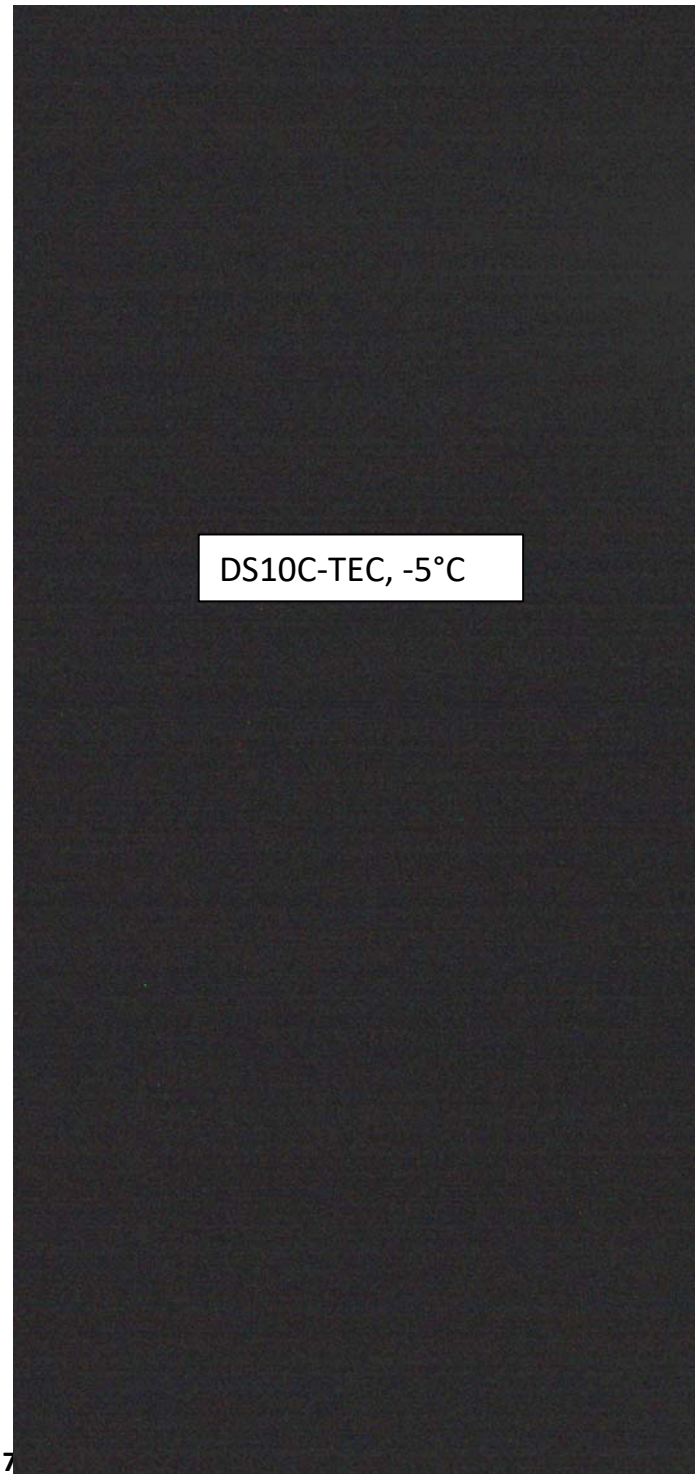
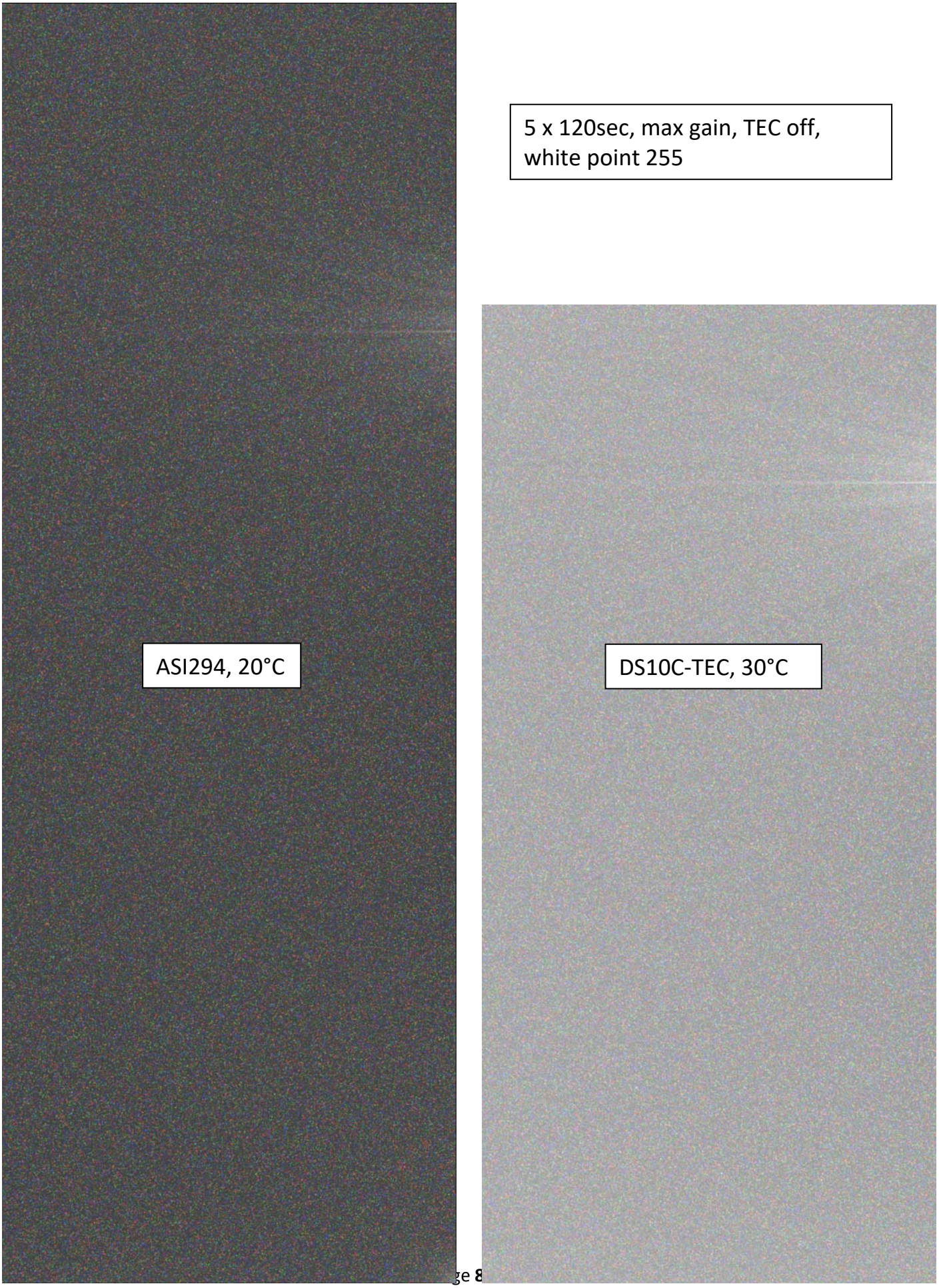
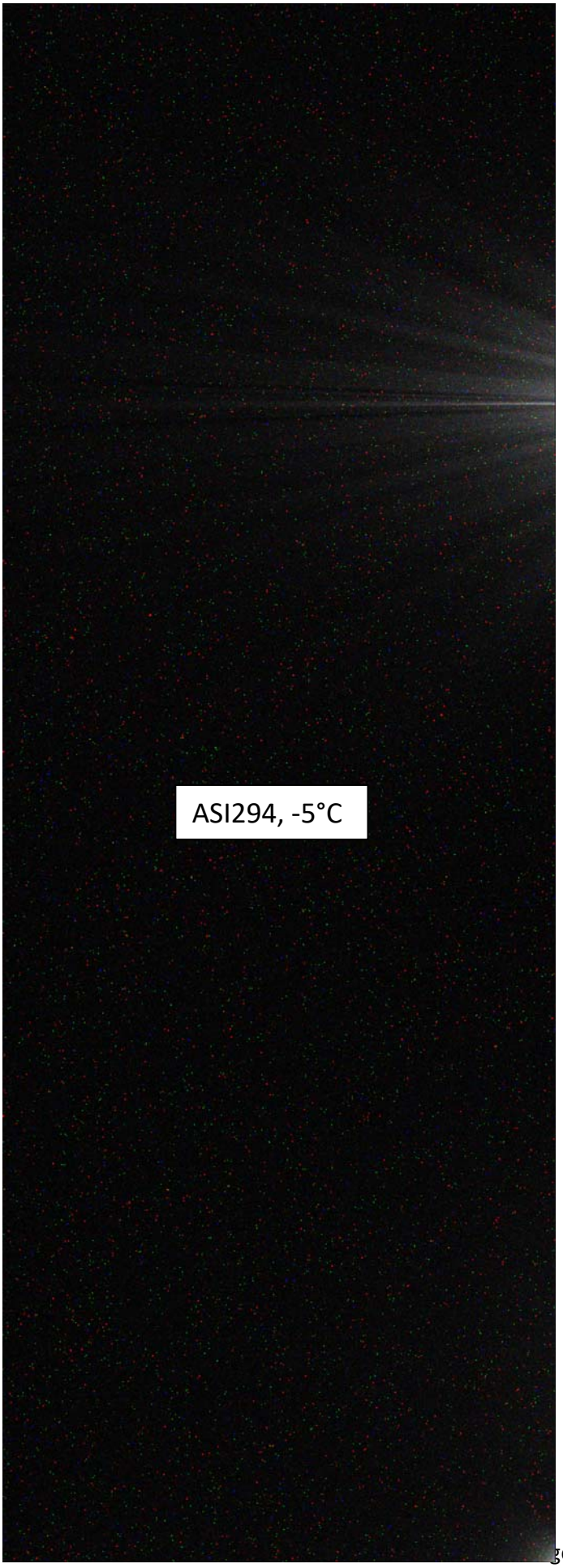
ASI294, -5°C

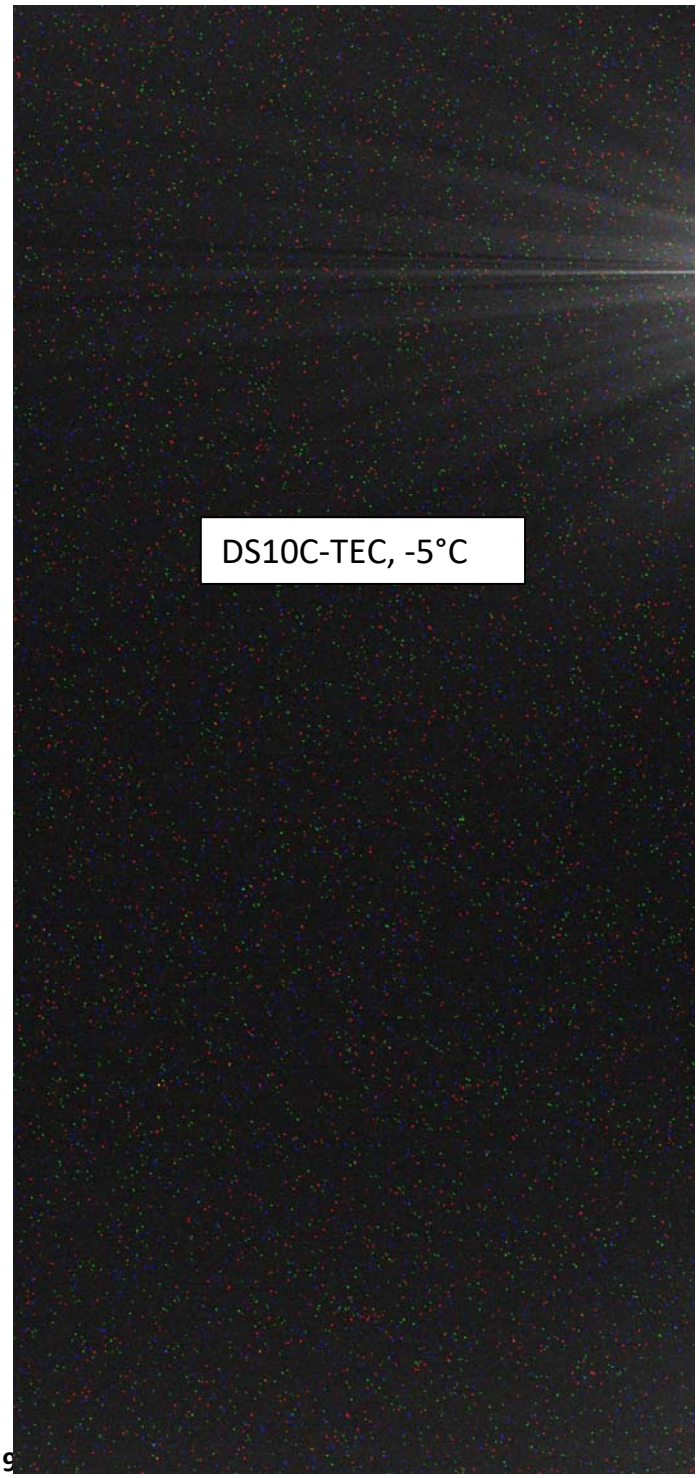


DS10C-TEC, -5°C


5 x 120sec, max gain, TEC off,
white point 255
ASI294, 20°C
DS10C-TEC, 30°C

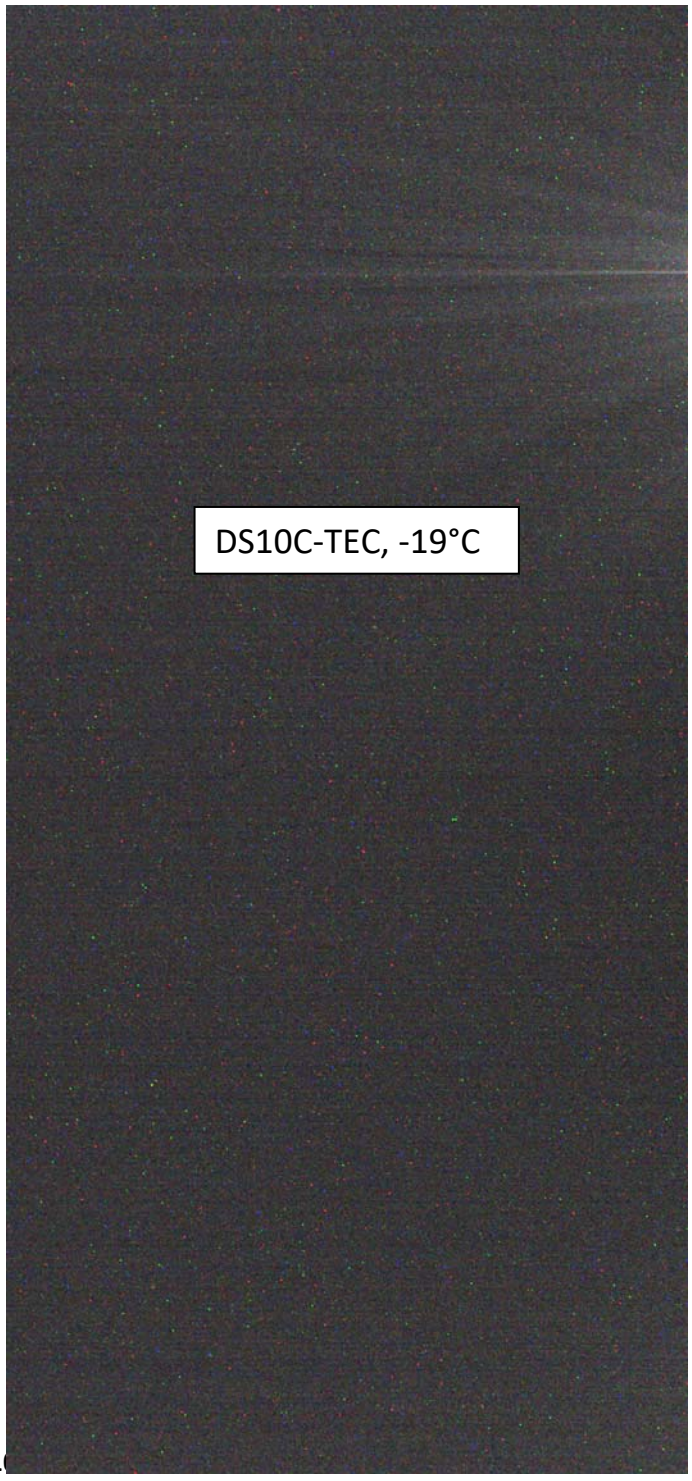


5 x 120sec, max gain, TEC on -5, white point 90

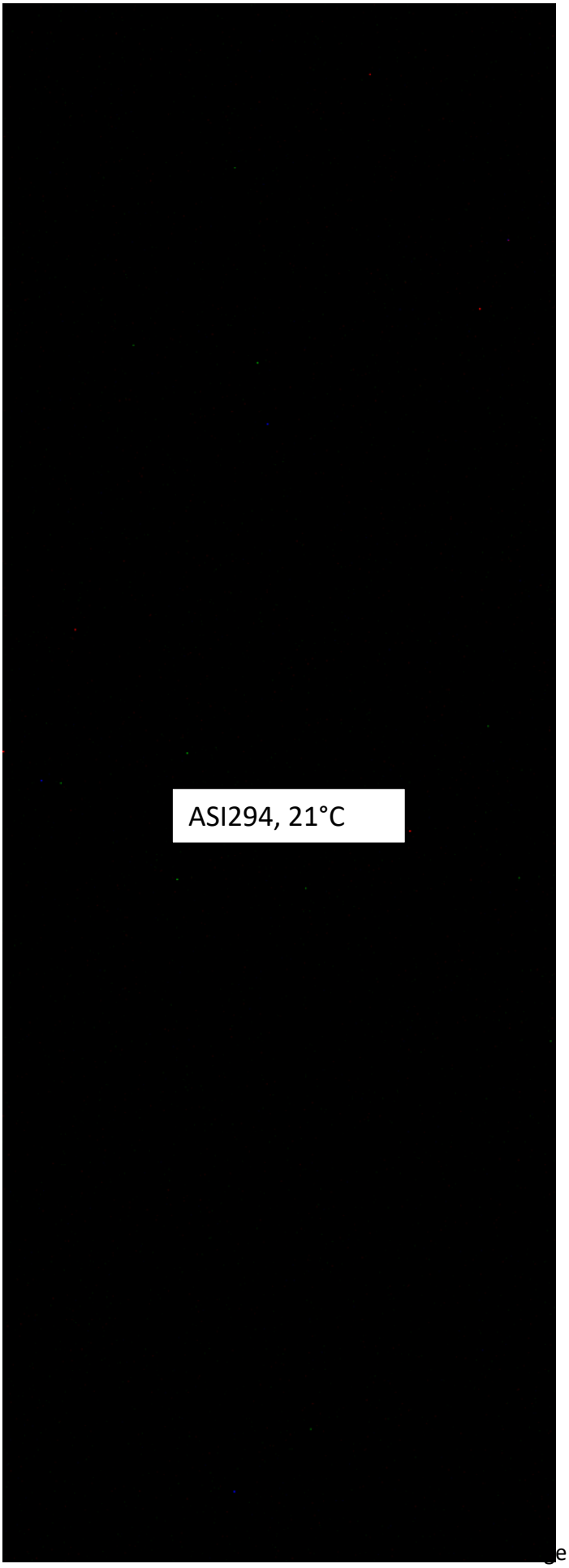


5 x 120sec, max gain, TEC on max, white point 60

ASI294, -14°C

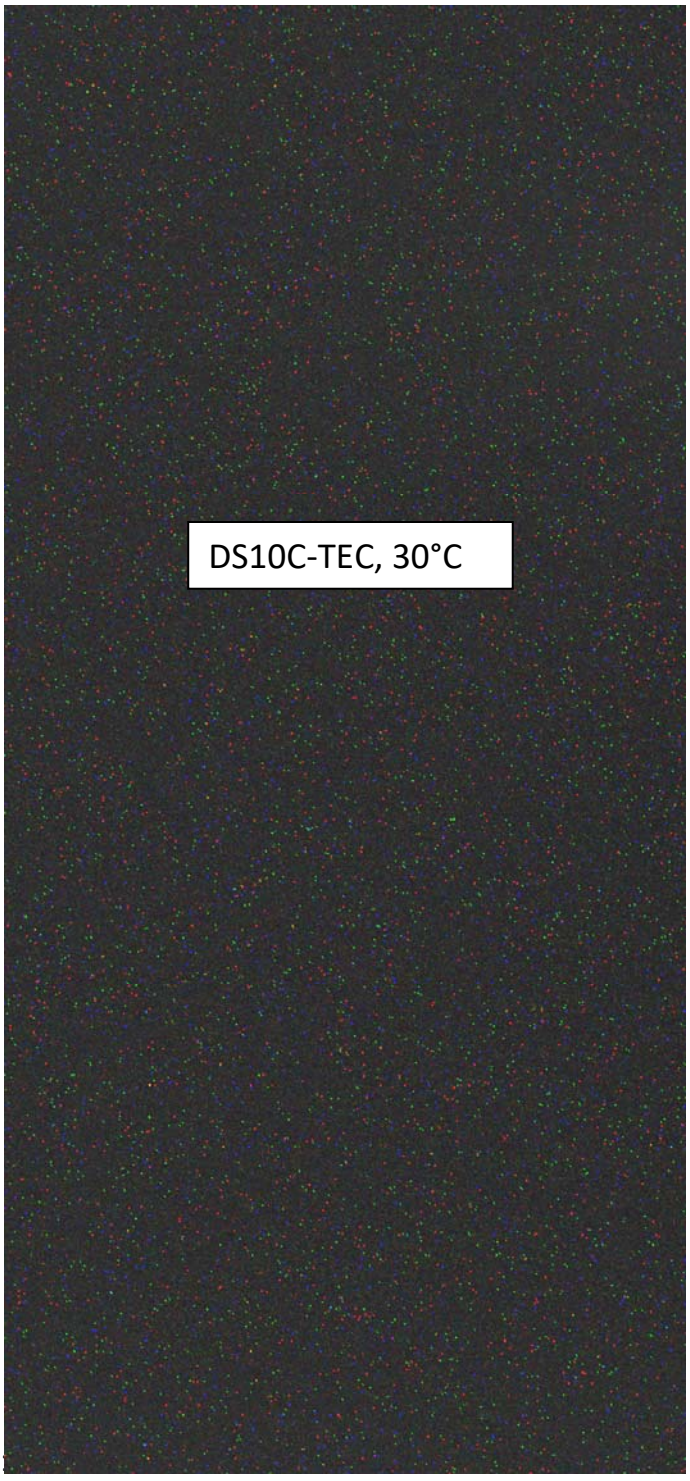


DS10C-TEC, -19°C

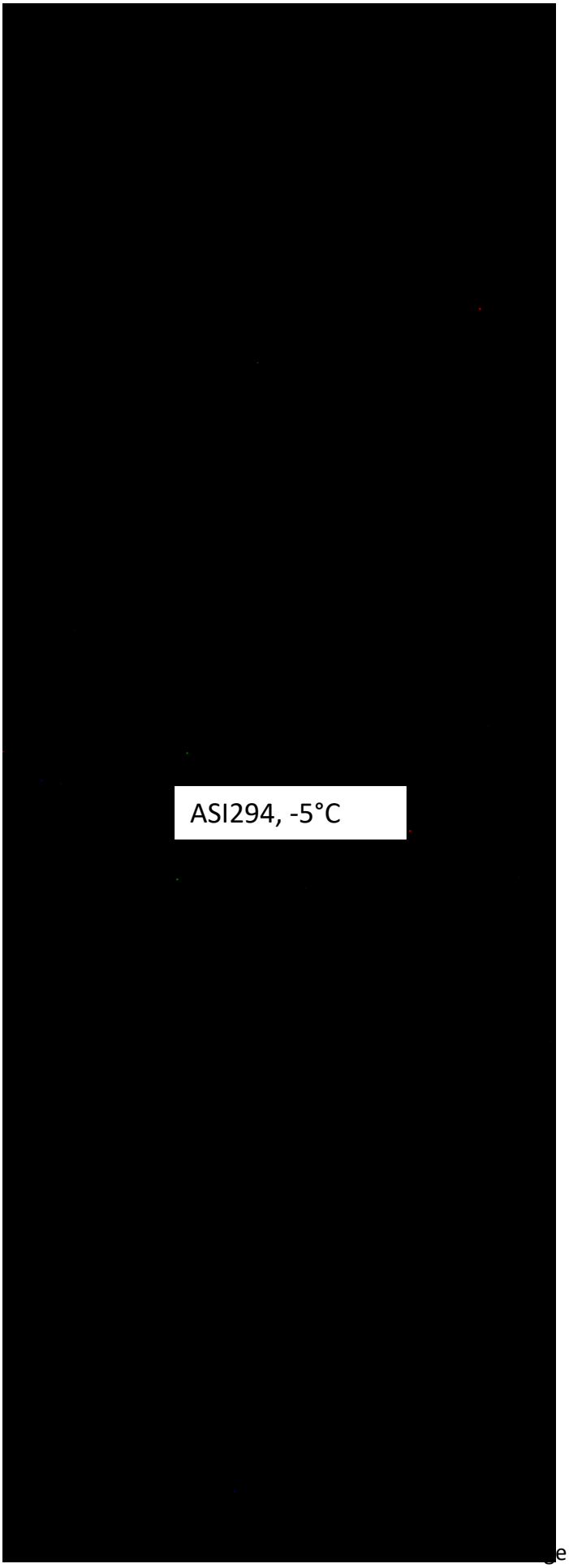


5 x 120sec, min gain, TEC off, white point 20

ASI294, 21°C

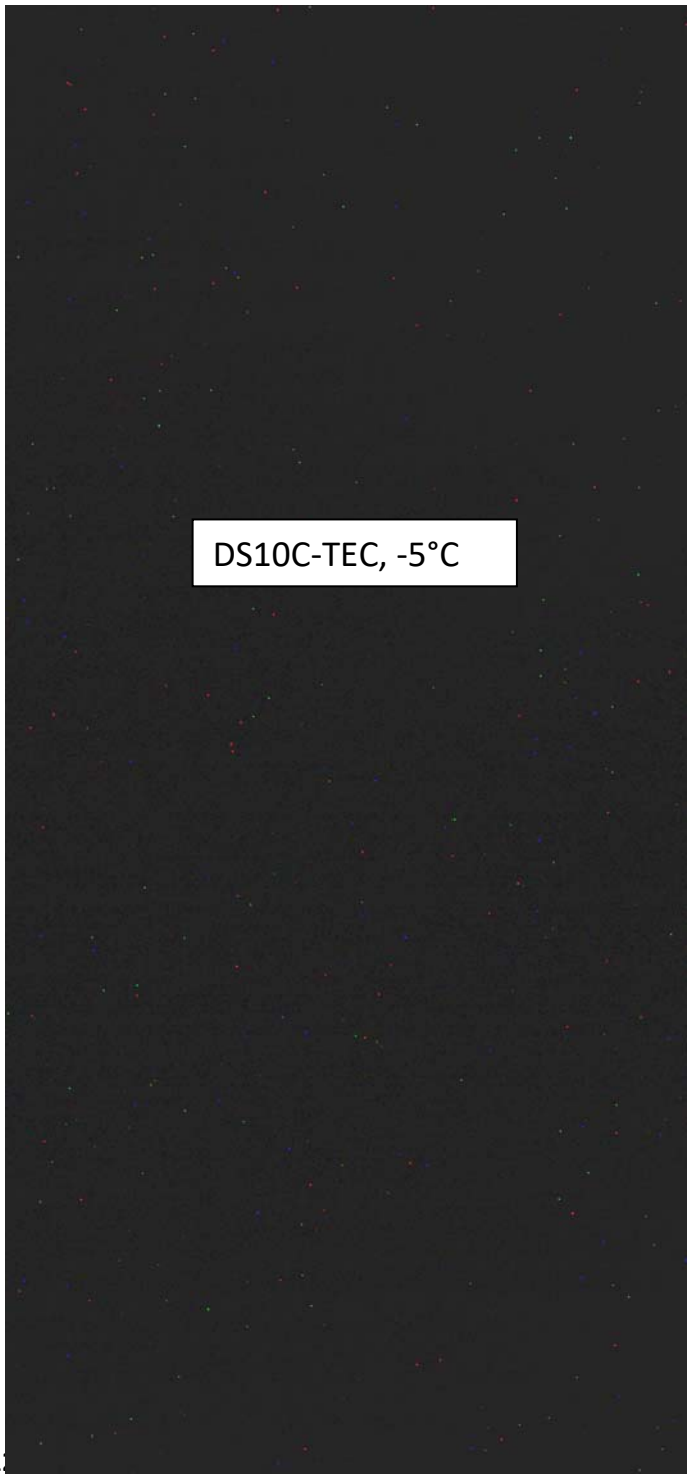


DS10C-TEC, 30°C



5 x 120sec, min gain, TEC on -5, white point 20

ASI294, -5°C



DS10C-TEC, -5°C

1 x 600sec, max gain, TEC off, white point 255

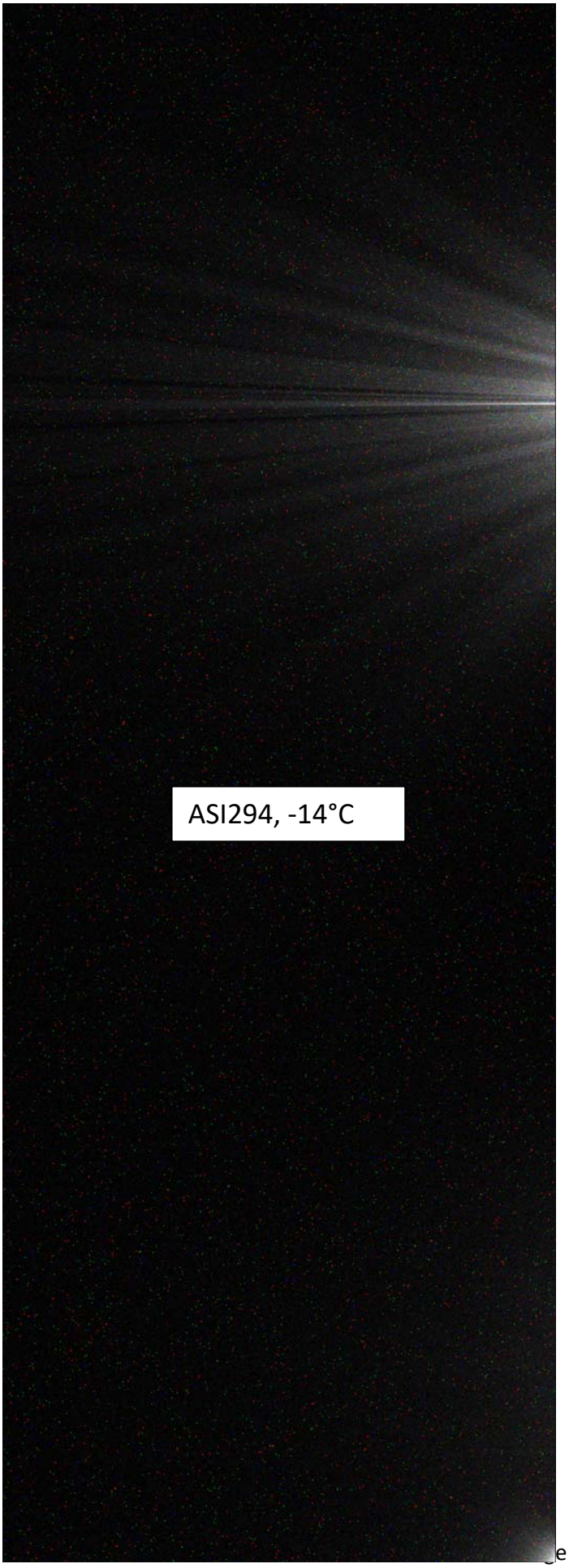
ASI294, 21°C

DS10C-TEC, 30°C

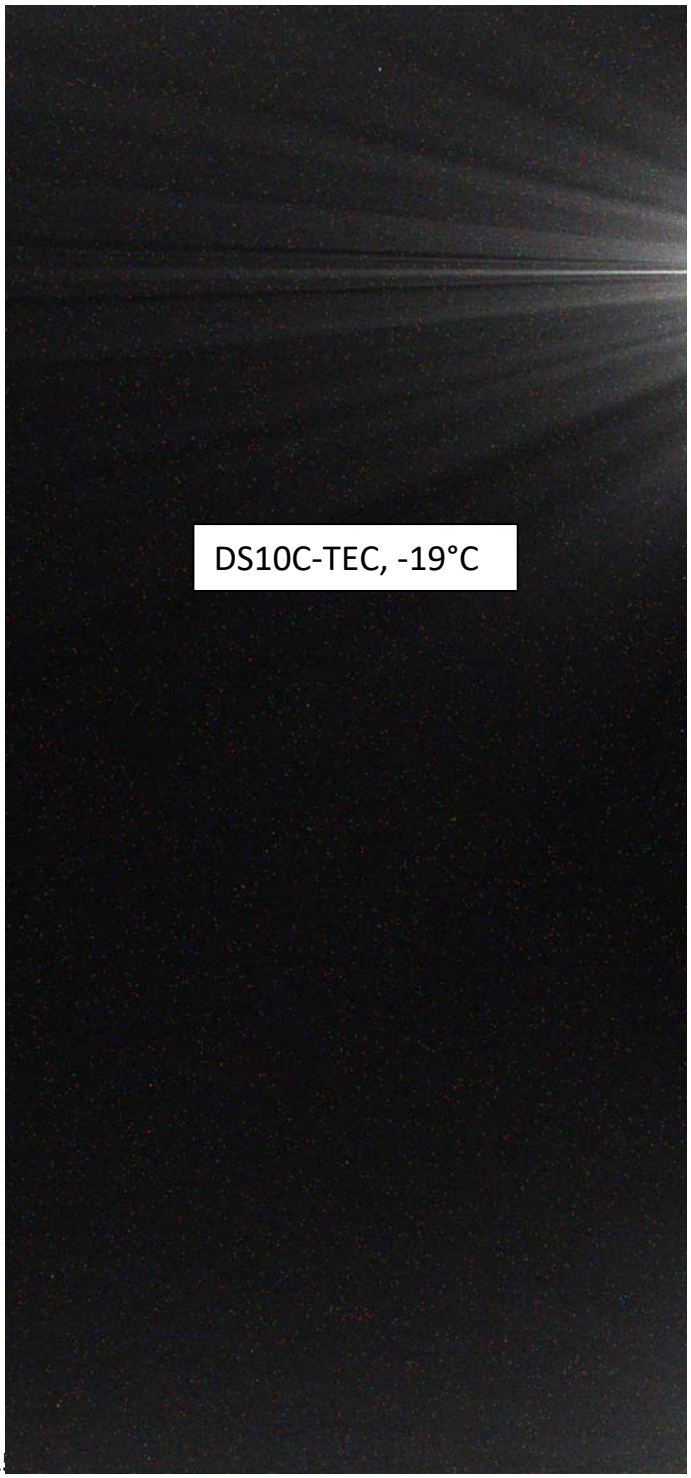
1 x 600sec, max gain, TEC on -5, white point 255

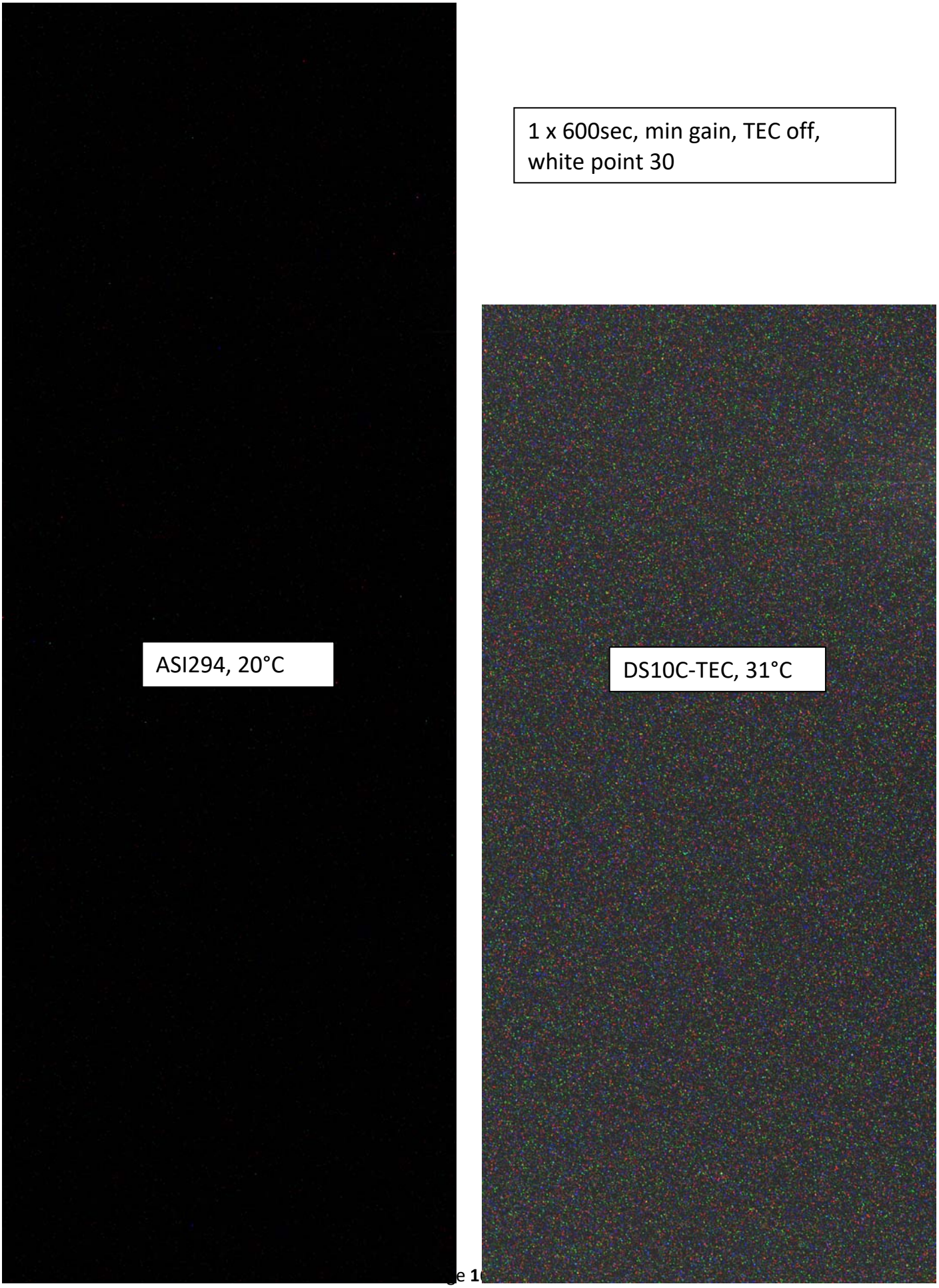
ASI294, -5°C

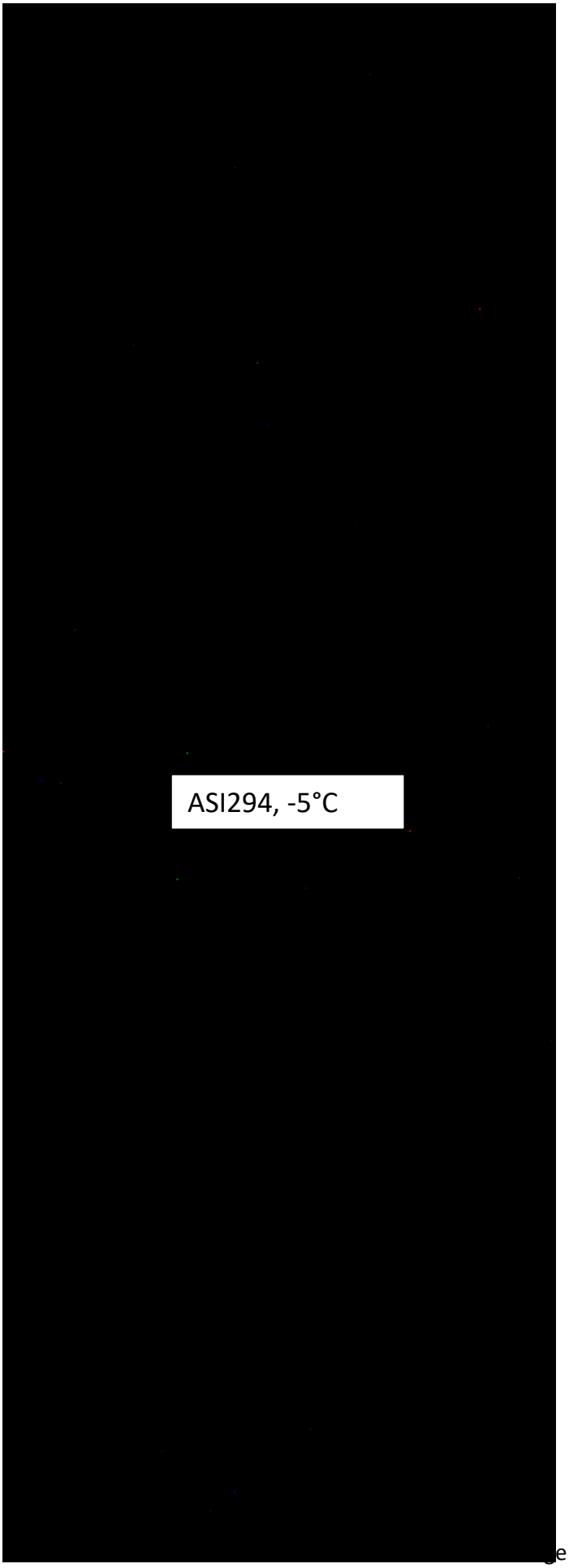
DS10C-TEC, -5°C



1 x 600sec, max gain, TEC on max, white point 255

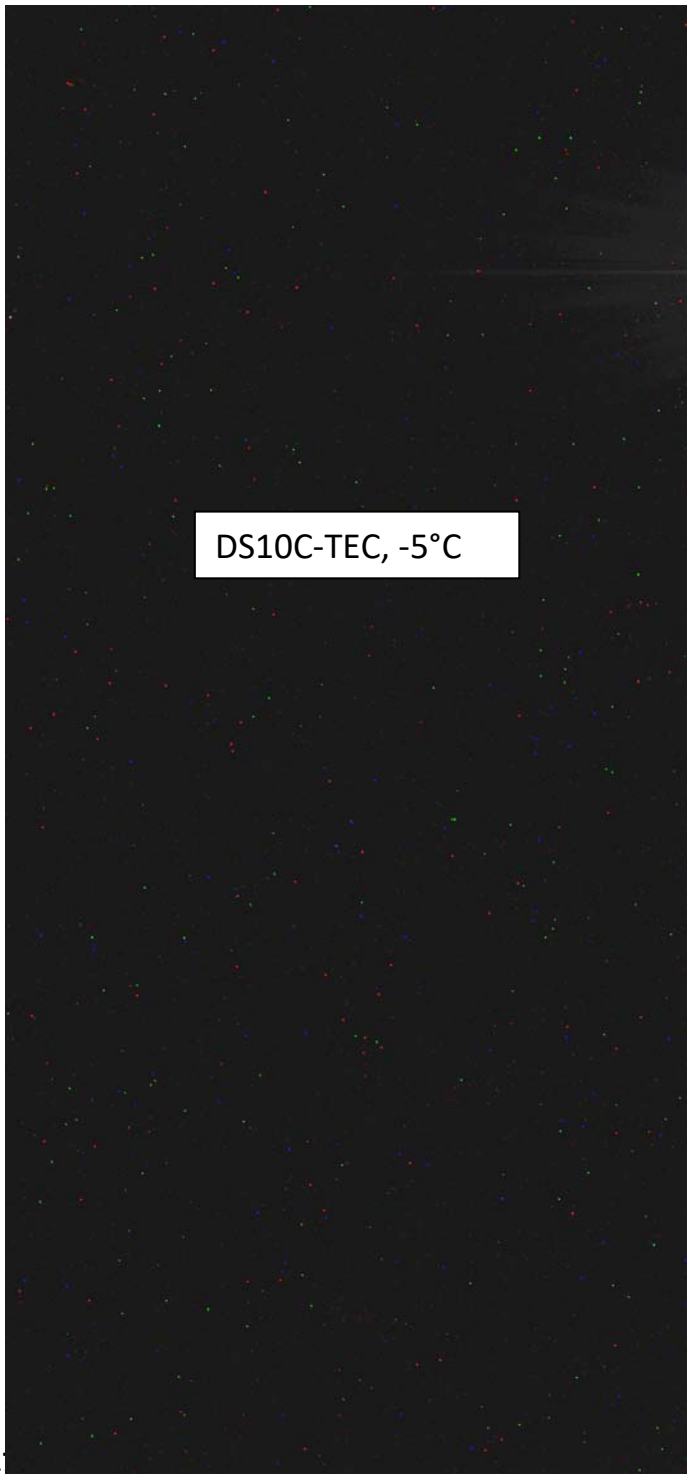



1 x 600sec, min gain, TEC off,
white point 30
ASI294, 20°C
DS10C-TEC, 31°C



ASI294, -5°C

1 x 600sec, min gain, TEC on -5, white point 30



DS10C-TEC, -5°C

Conclusions:

My observations/conclusions are as follows:

1. Both cameras exhibit a well defined star-burst amp glow pattern that is located along the upper right side of the image. The pattern for the most part is not visible when the gain was at minimum. The pattern is progressively more visible with longer exposure time per frame, or as the gain is increased.
2. The ASI294 also shows a localized amp glow in each of the two bottom corners of the frame. This glow is not as bright as the main star-burst pattern. A similar amp glow in the bottom corners of the DS10C-TEC images was not visible, but is probably cropped out due to the available image output sizes.
3. The appearance of ampglow and hot/warm pixels is more prominent in the images from the DS10C-TEC. In my opinion some, if not all, of this difference can be attributed to the gain each camera is applying. For example when set to min gain the DS10C-TEC was in HCG mode while the ASI294MC was in LCG mode. I don't know what the absolute gain applied by the DS10C-TEC is when at max gain, but it is possible that it is larger than the ASI294. This would be consistent with other Mallincam cameras which tend to have a larger range of user definable gain than other brands. This assertion, that the DS10C-TEC is applying more gain than the ASI294MC, will be confirmed when my SNR measurements are completed.
4. For all of the images captured using the ASI294MC camera, the minimum pixel intensity values in the images were always zero out of 255. This is in contrast with the DS10C-TEC which always produced images with a minimum pixel value >0. The histograms for the images produced by the ASI294 camera are also not symmetrical, skewed towards the black end of the histogram. These observations lead me to believe that the ASI294MC camera is clipping data at the dark end of the histogram. Such clipping would give the ASI294 camera the appearance of a less noisy dark frame compared with the DS10C-TEC. It is however a behaviour that is not desirable for observing very dim objects. It is possible that there is a non-default camera setting that avoids or reduces the observed clipping.
5. The effect of cooling on noise and hot/warm pixels is very obvious on both cameras. Referring to the summary table above, even cooling to just -5°C (absolute temp) results in a large reduction in the average dark frame pixel intensity value and the standard deviation.

The final bench test to be performed is a measurement of SNR for various gain and exposure times. Stay tuned...

Jim Thompson