Test Plan

Astro-Video Camera Performance

Rev. 1

by

Jim Thompson, M.Eng, P.Eng

November 2015

Revision History

Rev 0.	Original issue	January 2014
Rev 1.	Update camera list, update test matrix, add camera pictures	November 2015

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1.0 Introduction

The use of a video camera to assist in live astronomical observation has been around for more than a decade, and yet it is still regarded by many to be an idea in its infancy. I find it very exciting to be involved in this field during these growth years as ideas and technology are flying around and changing rapidly. There is no doubt in my mind that using an astro-video camera, that is a video camera specifically designed for astronomical use, is the best way to observe from an urban light polluted location. I am not alone in my belief as there is now an assortment of astro-video camera models available from a number of different vendors for consumers to choose from. The only thing to do now is figure out which camera is best suited for different applications.

Figure 1 An Example of Astro-Video Cameras In Use

2.0 Objectives

The objective of this plan is to outline a test with the purpose of evaluating the performance of an assortment of astro-video cameras. The primary objectives of the test will be to evaluate the following parameters:

1. **Noise**: The inherent self generated noise of the camera not related to the incoming light, which would exist with or without light hitting the detector;
2. **Sensitivity**: The ability of the camera to detect and differentiate a target from the background;
3. **Acuity**: A combination of resolution and signal-to-noise that defines how well the details in an object can be observed relative to the background, whether sharp and small or big and wispy; and
4. **Ease of Use**: The intuitiveness, responsiveness, simplicity, etc. of the camera setup and user interface.

In addition to the four primary objectives, some other basic parameters of each camera will be assessed such as: weight, dimensions, and cost. Details regarding how each of the primary objectives will be evaluated are presented in the rest of this test plan.

All of the cameras being considered for testing have numerous settings available that affect their performance. This ability to tune the camera's image to suite the wants and needs of the observer is one of the main benefits of video astronomy. The inherent adjustability does however make it challenging to establish a list of common camera settings at which each camera's performance is compared. As much as possible, camera settings will be selected based on what is typical of use in the field, as determined by my own experience.

3.0 Scope

The intention is to test a number of different camera models and compare them back-to-back with each other. The video cameras selected for use in this comparison will depend on availability, but in general will all be cameras that are either specifically designed and marketed for the purpose of video astronomy or are used regularly for that purpose. A number of security cameras that have been used extensively for video astronomy have been added as a baseline, as well as a number of USB based cameras. This test program does not consider cameras built for astrophotography or DSLR's. Cameras to be tested are also all colour cameras, except the two models of Stellacam. At present the list of cameras to be included in the testing is summarized in Table 1, with additional information about the sensors used in these cameras provided in Table 2.

Cam #	Camera Model	Manufacturer	Type	Cooling	Dimensions (mm) L	W	H	+/- 5g Mass (g)	Sensor	Retail $
1	DIY (PQ0133) heatsinked	SC2000	NTSC/PAL	passive	30	36	36	115	ICX638BKA	35
2	Starshoot DSVC II	Orion	NTSC/PAL	passive	60	50	64	230	72S85HN-EX-R*	600 obs
3	LN300 - NTSC	LNtech	NTSC/PAL	passive	77	42	46	130	ICX672AKA	70
4	LN300 - PAL	LNtech	NTSC/PAL	passive	77	42	46	130	ICX673AKA	70
5	SDC-435	Samsung	NTSC/PAL	passive	127	58	58	310	ICX638BKA	150
6	Stellacam EX	AstroVid	NTSC/PAL	passive	102	50	50	305	ICX248AL	695 obs
7	Stellacam III	AstroVid	NTSC/PAL	TEC	65	65	48	170	ICX418ALL	995 obs
8	DSO-1	Astro-Video Systems	NTSC/PAL	passive					ICX810AKA	110
9	Mk-IV	Astro-Video Systems	NTSC/PAL	fan					ICX810AKA	469
10	APU-1	Astro-Video Systems	NTSC/PAL	TEC					ICX810AKA	699
11	Junior-EX	Mallincam	NTSC/PAL	passive	58	50	64	230	ICX428AKL	500 obs
12	Junior Pro	Mallincam	NTSC/PAL	passive	102	50	55	300	ICX418AKL	600
13	Xtreme XT418	Mallincam	NTSC/PAL	TEC	102	72	50	425	ICX418AKL	1500
14	Micro EX	Mallincam	NTSC/PAL	passive	77	42	46	130	ICX672AKA	100
15	Micro Super	Mallincam	NTSC/PAL	passive	77	42	46	130	ICX810AKA	110
16	Xterminator	Mallincam	NTSC/PAL	TEC					ICX828AKA	1850
17	SkyRaider-AGc	Mallincam	USB	passive					ARO130	200
18	SkyRaider-DSc	Mallincam	USB	passive	47	67	67	385	ICX829AKA	750
19	SkyRaider-DS2.3	Mallincam	USB	fan					IMX185LQJ	900
20	Universe	Mallincam	USB	TEC	92	105	105	950	ICX413AQS	1900
21	SSI-c	Mallincam	USB	passive	42	89	89	270	IMX035LQR	500
22	Lodestar-C	Starlight Xpress	USB	passive	70	31	31	70	ICX419AKL	595 obs
23	Lodestar-X2C	Starlight Xpress	USB	passive	85	31	31	85	ICX829AKA	649
24	ASI 185MC	ZWO	USB	passive	35	61	61	125	IMX185LQJ	400
25	DBK 51AU02.AS	Imaging Source	USB	passive	57	50	58	215	ICX274AQ	1000

* specs identical to ICX428AKL

Table 1 List of Cameras Under Test

Sensor #	Sensor Model	Sensor Technology	Chip Size [mm]	Effective Resolution [pixels]	Pixel Size [µm]	Colour Matrix	Reported Typical Sensitivity [mV]	Dark Signal [mV]	Reported Sensitivity Calculation Based On... [mV]	Effective Pixel Average Sensitivity [mV]
1	ICX248AL	EXview HAD CCD	8	768x494	8.4x9.8	mono	5500	2	Ys ≈ Vs	790
2	ICX274AQ	Super HAD CCD	8.923	1628x1236	4.4x4.4	rgbg	420	8	Ys ≈ avg(Vg)	326
3	ICX413AQS	Super HAD CCD	28.4	3040x2024	7.8x7.8	rgbg	1250	4	Ys ≈ avg(Vg)	922
4	ICX418ALL	? HAD CCD	8	768x494	8.4x9.8	mono	1100	2	Ys ≈ Vs	1100
5	ICX418AKL	? HAD CCD	8	768x494	8.4x9.8	cmyg	1300	2	Ys ≈ (Vc+Vm+Vy+ Vg)/2	650
6	ICX419AKL	? HAD CCD	8	752x582	8.6x8.3	cmyg	1300	2	Ys ≈ (Vc+Vm+Vy+ Vg)/2	650
7	ICX428AKL	EXview HAD CCD	8	768x494	8.4x9.8	cmyg	1600	2	Ys ≈ (Vc+Vm+Vy+ Vg)/2	800
8	ICX638BKA	Super HAD II CCD	6	768x494	6.35x7.40	cmyg	2250	2	Ys ≈ (Vc+Vm+Vy+ Vg)/2	1125
9	ICX672AKA	EXview HAD II CCD	6	976x494	5.0x7.4	cmyg	2450	2 (?)	Ys ≈ (Vc+Vm+Vy+ Vg)/2	1225
10	ICX673AKA	EXview HAD II CCD	6	976x582	5.0x6.25	cmyg	2400	2 (?)	Ys ≈ (Vc+Vm+Vy+ Vg)/2	1200
11	ICX810AKA	Super HAD II CCD	6	976x494	5.0x7.4	cmyg	2350	2	Ys ≈ (Vc+Vm+Vy+ Vg)/2	1175
12	ICX828AKA	EXview HAD II CCD	8	768x494	8.4x9.8	cmyg	2800	2 (?)	Ys ≈ (Vc+Vm+Vy+ Vg)/2	1400
13	ICX829AKA	EXview HAD II CCD	8	752x582	8.6x8.3	cmyg	2800	2 (?)	Ys ≈ (Vc+Vm+Vy+ Vg)/2	1400
14	72S85HN-EX-R*	EXview HAD CCD	8	768x494	8.4x9.8	cmyg	1600	2	Ys ≈ (Vc+Vm+Vy+ Vg)/2	800
15	ARO130	Aptina CMOS	6	1296x976	3.75x3.75	rgbg	5.6V/lux-s	?	Ys ≈ avg(Vg)	(?)
16	IMX035LQR	Exmor CMOS	6.08	1329x1049	3.63x3.63	rgbg (?)	460	?	Ys ≈ avg(Vg)?	345 (?)
17	IMX185LQJ	Exmor CMOS	8.58	1920x1200	3.75x3.75	rgbg (?)	1120	?	Ys ≈ avg(Vg)?	840 (?)

* specs identical to ICX428AKL

Table 2 List of Camera Sensor Characteristics

The testing will be broken into three phases:

- I Initial inspection & familiarization
- II Bench testing; and
- III Field testing.

During Phase I the secondary parameters such as dimensions and weight will be recorded. I will also take time with each camera to familiarize myself with the camera hardware and any associated software and accessories. I will review any published manuals and experiment with the camera to understand the camera menu and how to configure the camera for different situations. Phase II will contain the bulk of the testing effort. One of the most important aspects of this testing is that the cameras must all be tested under the same conditions in order for the results to be meaningful. Due to the nature of live observing, the way conditions can change in real time, it is not practical to field test all the cameras. I have instead selected to compare the cameras using a series of bench tests that have been specifically designed to evaluate the camera performance characteristics of interest. Phase III will be performed more for general interest, and to confirm qualitatively the results from Phase II. My ability to field test all of the cameras will be limited largely by weather conditions, which is another reason for performing the bulk of the testing indoors.

4.0 Apparatus

To execute the test method outlined in detail below, a list of equipment will be required as defined in Table 3 and 4. The equipment is all owned and maintained by myself. Images of each piece of equipment can be found in the following pages.

Figure 2 USB Fibre Optic Spectrometer

Item	Brand	Model	S/N	Calibration Status
XP desktop PC	generic	generic	n.a.	n.a.
Win8 laptop	Samsung	NP740U3E	JC3R91MD300143H	n.a.
USB fibre optic spectrometer	Ocean Optics	USB4000-VIS-NIR	USB4F04273	factory: 23-Sep-09, user: 03-Dec-12
Short focal length zoom telescope w/ Crawford type focuser, f/5	hand built by myself	"Mighty Mouse" (Computar wide format portrait lens 105-150mm f.l., GSO focuser)	n.a. (unique)	n.a.
Light meter	CEM	DT-1308	09104326	factory: Jan-10
Digital multimeter	Mastech	MS8229	09110075335	factory: Jan-10
2" Neutral density filters	Baader Planetarium	ND3.0, ND1.8, ND0.9, ND0.6	n.a.	factory: Dec-13
2" Colour correction filter (IR cut)	LDP LLC	X-Nite CC1 (CM500S)	n.a.	factory: Aug-11
Monochromatic light source	Unihedron	Nu-B-IR-Orange	n.a.	factory: Dec-11
USB video capture device	Pinnacle	DVC107 rev. 1.1	82410111301781717072	n.a.
Spring scale	Starfrit	5kg – 25g	n.a.	user: Feb-12

Table 3 Summary of Bench Test Equipment

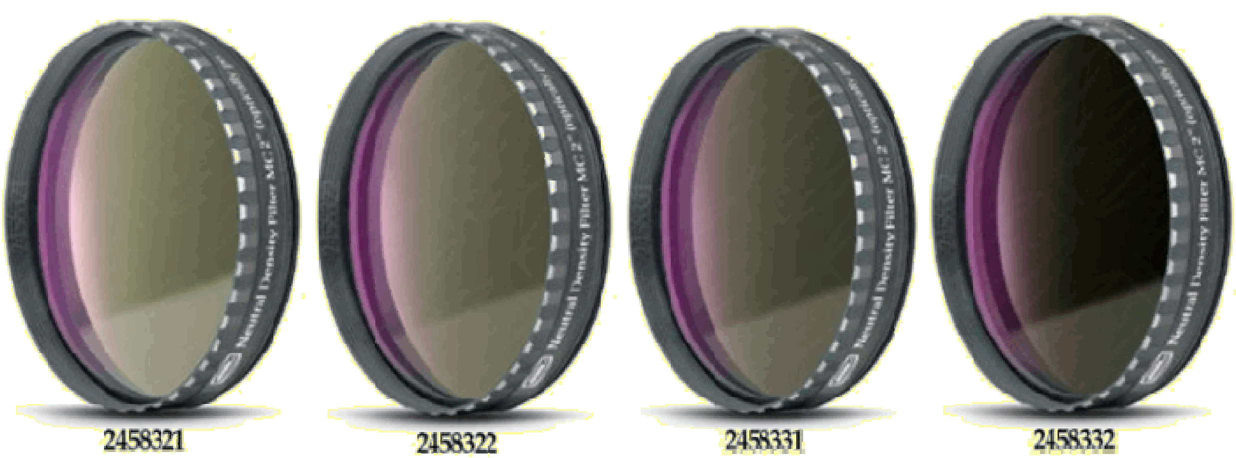


Figure 3 Baader Planetarium 2" Neutral Density Filters

Figure 4 Light Meter

Figure 5 "Mighty Mouse" Short Focal Length Telescope

Figure 6 Digital Multimeter

Figure 7 Monochromatic Light Source

Figure 8 2" Colour Correction Filter

Figure 9 USB Video Capture Device

Figure 10 Spring Scale

Figure 11 My Bench Test Work Area

Item	Brand	Model	S/N	Calibration Status
XP desktop PC	generic	generic	n.a.	n.a.
Win8 laptop	Samsung	NP740U3E	JC3R91MD300143H	n.a.
GOTO German Equatorial Mount	Orion	Atlas EQ/G	n.a.	n.a.
10" Ritchey-Chrétien telescope	Mallincam (OEM GSO)	VRC-10	n.a.	n.a.
98mm triplet refractor	Williams Optics	FLT-98	n.a.	n.a.
USB video capture device	Pinnacle	DVC107 rev. 1.1	82410111301781717072	n.a.
Sky quality meter	Unihedron	SQM-LE	n.a.	factory: Dec-11
Light pollution filter	Astronomik	UHC	n.a.	factory: Dec-09

Table 4 Summary of Field Test Equipment

Figure 12 Sky Quality Meter

Figure 13 VRC-10 Telescope On Orion Atlas EQ/G Mount

Figure 14   FLT-98 Telescope on Orion Atlas EQ/G

Figure 15   Light Pollution Filter

5.0 Method

Each of the primary objectives will be assessed in an identical manner on each camera. Wherever possible the manner of assessment shall be performed under controlled repeatable conditions. Also, when possible the primary objectives will be evaluated quantitatively via the measurement of some definable parameter. Raw data gathering will be in the form of images, stored in 24-bit RGB TIF format, as captured from the live video stream of each camera using the USB Video Capture Device listed in Table 3, or by using the software that accompanies the USB based cameras under test. The same video capture device with the same settings on the same computer will be used between all analog video cameras. In some tests it will be required to adjust the video capture device settings to achieve the optimum image, as will be noted below.

Camera generated heat has a large impact on the performance of the CCD detector, especially where noise is concerned. It is therefore important to replicate a similar thermal boundary condition during the testing as would be encountered in the field. To achieve this all tests will be performed with the camera installed in one of the telescopes noted above in Table 3 and 4. In addition, data collection on each camera will have to wait until after the camera has been in the powered-up condition for at least 15 minutes, with a 2 minute stabilization time between changes in camera settings. The ambient temperature will be recorded throughout the testing.

All cameras will be tested with their respective GAMMA set to 1.0. White balance will be set to manual with RED=50% and BLUE=50%. Capture device HUE and SATURATION will be set to defaults and left the same for all cameras and all measurements. Capture device and camera SHARPNESS settings will be set to 0 unless otherwise noted. Capture device CONTRAST will be set to maximum for all measurements, and left at default for USB based cameras. On-camera or software based frame stacking will be turned off for all data collection.

5.1 Noise:

Noise is defined here as video signal that is not generated by the observed scene, and includes: CCD ampglow, CCD dark current noise, hot/warm pixels, and random electronic noise. Noise shall be evaluated by installing each camera into a bench mounted telescope, and capturing a series of "grey" frames. A traditional dark frame alone will not be used in this test since the noise reduction algorithm in each camera's Digital Signal Processor (DSP) requires a signal (light source) to function effectively. Three levels of grey frame will be used:

GREY1 - A sky glow typical of night sky at a dark site (no light pollution)
GREY2 - A sky glow typical of an urban night sky
GREY3 - A typical light level one would get observing a planet at f/10

Each grey level will be generated by staring at a reference light source using the "Mighty Mouse" telescope, combined with a number of neutral density filters as required to achieve the desired light intensity. The reference light source was custom built by myself, and consists of a special 12VDC halogen bulb with 4700K colour temperature. The bulb shines into an enclosed box with a sheet of opal glass at one end. The opal glass diffuses the light from the halogen bulb, which is viewed through a hole in the box on the other side of the glass. The brightness for the two grey levels was measured at the camera sensor plane using a SQM, with the results summarized in Table 5. Figure 16 shows some pictures of the reference light source, and Figure 17 shows an example plot of the emission spectrum from the reference light source with the spectrum of a few deep sky objects as reference.

Grey	Description	Brightness (mag/arcsec)	Limiting Visual Magnitude
GREY1	Light off - dark frame	21.2	+6.2
GREY2	ND3.0+1.8+0.9+0.6	17.4	+3.5
GREY3	ND3.0	14.2	+0.4

Table 5 Grey Frame Brightness Measurements

Figure 16 Pictures of Reference Light Source

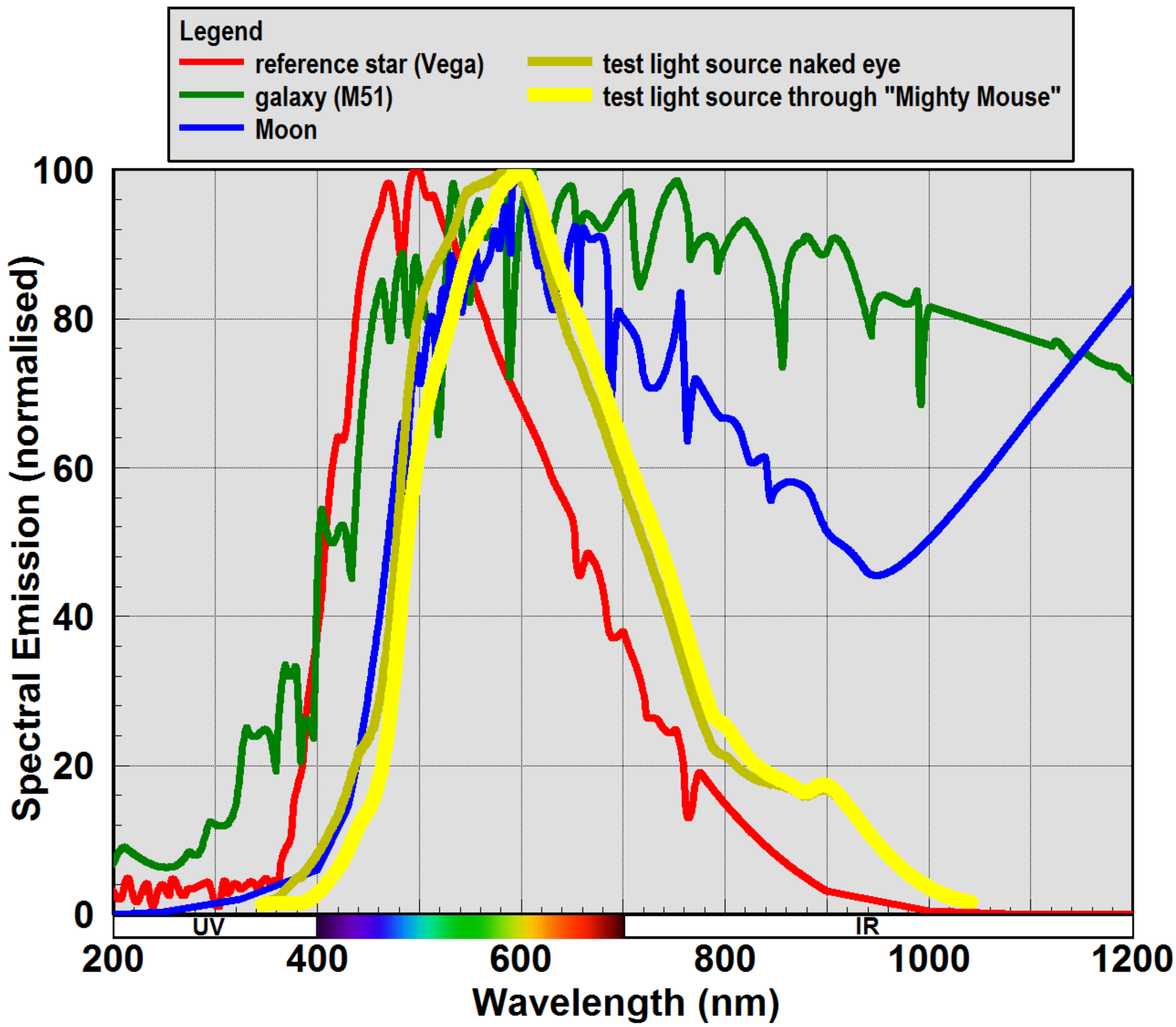


Figure 17 Sample Emission Spectrum from Reference Light Source

Grey frames will be recorded from each camera for a range of gain and exposure settings as defined in Appendix A. For some cameras it will not be possible to achieve all combinations of exposure time and gain setting due to the limitations of each camera; either there is a limit on available settings, or the settings result in an under/over saturated image. There will at least be a couple of common measurement points however that will be achievable on all the cameras being tested. Since the sensitivity of each camera differs, it will be necessary to adjust the video capture device BRIGHTNESS each time so that the viewed scene is dark – but not clipping. Any variation in my manual adjustment of the BRIGHTNESS will be compensated for in the noise analysis by normalizing each individual captured frame by its calculated frame average brightness.

The setting of gain on all of the analog video cameras is straight forward, but on some of the USB based cameras there is no user adjustable gain. Instead there is only a histogram presented in the respective camera control software that allows the user to adjust black and white points, giving the same effect as adjusting brightness/gain. The bit depth of the camera outputs in question is 16bits per colour channel. Image data will be captured for these cameras with the histogram set points such that 16, 12, and 8 bits of the source data is displayed, thus giving the effect of minimum/medium/maximum gain settings.

There are a number of ways of evaluating the noisiness of a video frame. I have selected four different methods that I believe reflect the needs of video astronomers:

1. Single frame pixel luminance standard deviation (PLSTD);
2. Single frame frequency weighted average noise intensity (WANI);
3. 5 frame (average) stack hot/warm pixel count (HWPC); and
4. 5 frame (average) stack mean-squared non-uniformity (MSNU).

The single frame pixel luminance standard deviation (PLSTD) is calculated by converting a single captured colour frame to luminance (grayscale) and using the appropriate image analysis software to calculate the average and standard deviation of all the pixels in the image. In this case I have written a FORTRAN console program that reads an image in and calculates the average and standard deviation. A large standard deviation will indicate a large variation in pixel intensity due to noise. A low standard deviation is desired.

The single frame frequency weighted average noise intensity (WANI) will be calculated by first performing a Fast Fourier Transform (FFT) on the grey scale image mentioned above. This process will show how the image noise is distributed with respect to frequency (ie. number of times of occurrence). The resulting plot will separate out low frequency high intensity noise due to hot/warm pixels from higher frequency electronic and dark current noise. The FFT data will then be used to calculate a frequency weighted average noise intensity, with more weight being put on higher frequency noise (ie. noise that is more frequent in the image is more annoying and affects observing more than lower frequency noise). The FFT and resulting weighted average will be calculated using a FORTRAN console program I wrote. The desire is for the tested camera to have as low a WANI as possible.

The five frame stack hot/warm pixel count (HWPC) will be done manually. It begins by making a stack of 5 individual captured colour frames in order to reduce the random noise in the image. Then the number of individual lit up pixels that are remaining in the image will be counted. Hot/warm pixels are not eliminated by stacking since they are related directly to the physical condition of the CCD detector, and so don’t change position from refresh to refresh. It is desirable to have as few hot/warm pixels as possible.

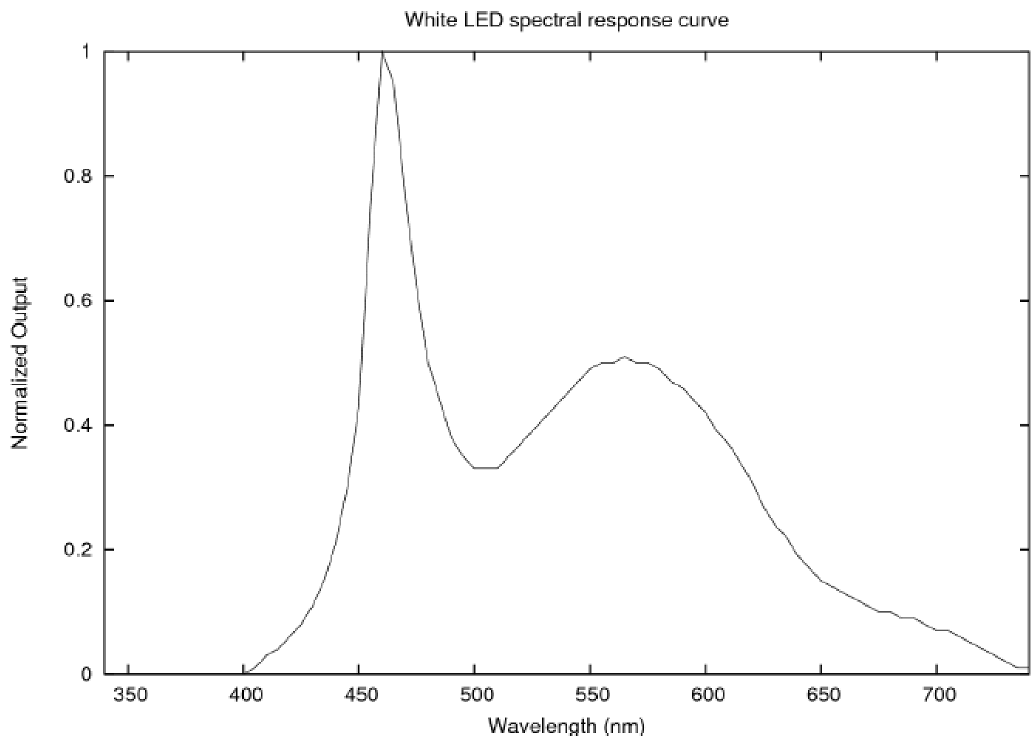
The five frame stack mean-squared non-uniformity (MSNU) will use the same stacked image from the hot/warm pixel count. After having been stacked, the only remaining non-uniformity in the frame besides hot/warm pixels will be due to sensor artifacts like ampglow or column defects. The image will be converted to luminance and the individual pixel values normalized by the frame average value. The mean-squared non-uniformity is then calculated by summing up the square of the difference between the normalized pixel values and the image mean value, and then dividing by the total number of pixels in the image. It is desirable for the image to be as uniform as possible, which will be reflected in a MSNU value as close to zero as possible.

5.2 Sensitivity:

The term sensitivity as it is used in this test program refers to a camera's ability to "detect" a dim target. The word "detect" is shown in parenthesis because there are many definitions of that word, especially when talking about machine vision. In the case of an astro-video camera detection depends on a human observer's ability to extract a dim object from background noise.

The bench test will involve the use of a Nu-B monochromatic light source made by Unihedron. This device presents a light source in several narrow bands using carefully selected LEDs and filters. The wavelengths emitted by the device, either together or individually, are: white (400-700nm), blue (450nm), green (515nm), orange (610nm), red (625nm), and near infrared (940nm). Figure 18 presents the spectral emission of each of the channels on the device.

The Nu-B device will be observed indoors at a fixed distance of 4m using the "Mighty Mouse" telescope described in Table 3 and illustrated in Figure 5. A combination of ND filters will be used to adjust the final light intensity at the camera detector to bring it into the range typical of an actual astronomical target. One such configuration will be used for all the tests. There will be no other light sources in the room during the testing (similar level of darkness to GREY1 in Table 5). Images of the Nu-B will then be captured with each camera for the range of settings listed in Appendix A. For each camera setting the video capture device BRIGHTNESS will be adjusted to provide a dark background – but with no clipping. The resulting images will be converted to 16 bit grayscale, and the maximum pixel grey value for each Nu-B light source (colour) measured relative to the average background grey level. In theory the measured value should scale directly with the exposure time used, but non-linearity is expected at either end of the exposure range due to either auto-gain limiting the image brightness (low end) or the light source being saturated (high end). For cameras with manual gain or when AGC is turned off, it is expected to have a linear response to exposure right down to 1/250 second. Figure 19 illustrates graphically what is expected for a typical measurement. The slope of the linear section of the curve should be equal between cameras, and the magnitude at any one fixed exposure time on this line will indicate the camera's full up system relative sensitivity.



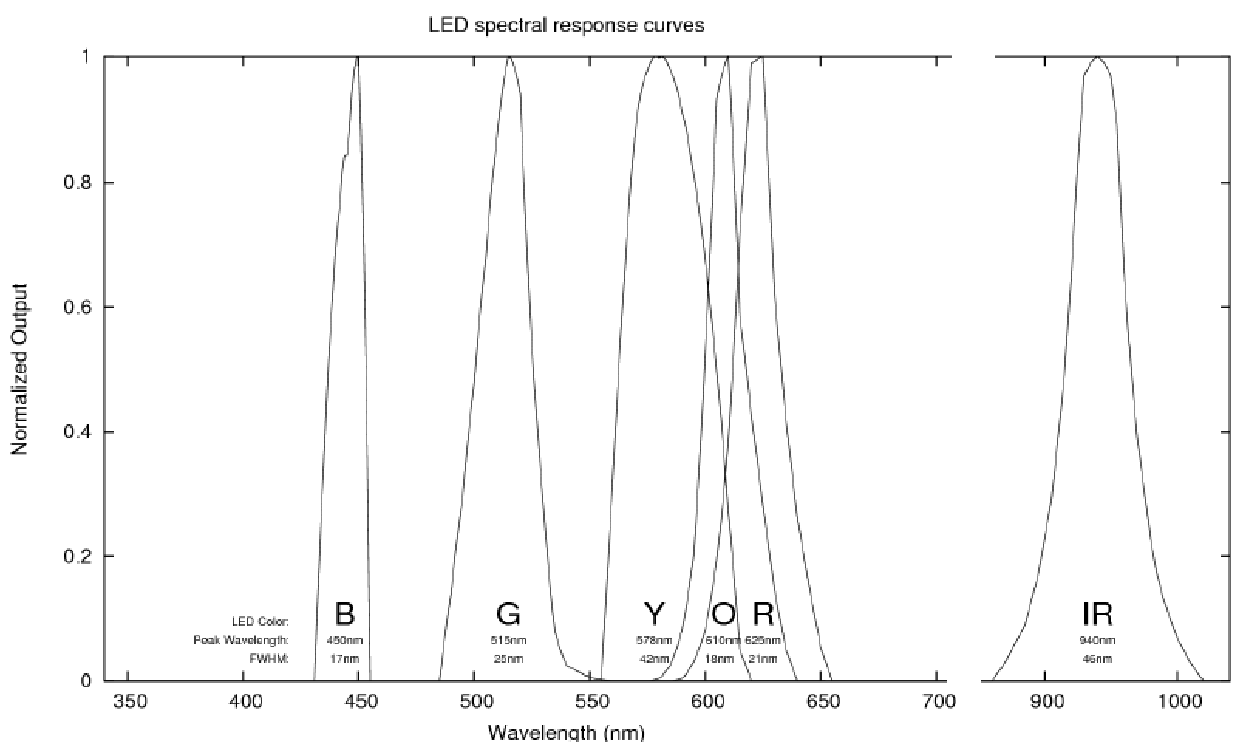


Figure 18 Unihedron Nu-B LED Spectral Emission

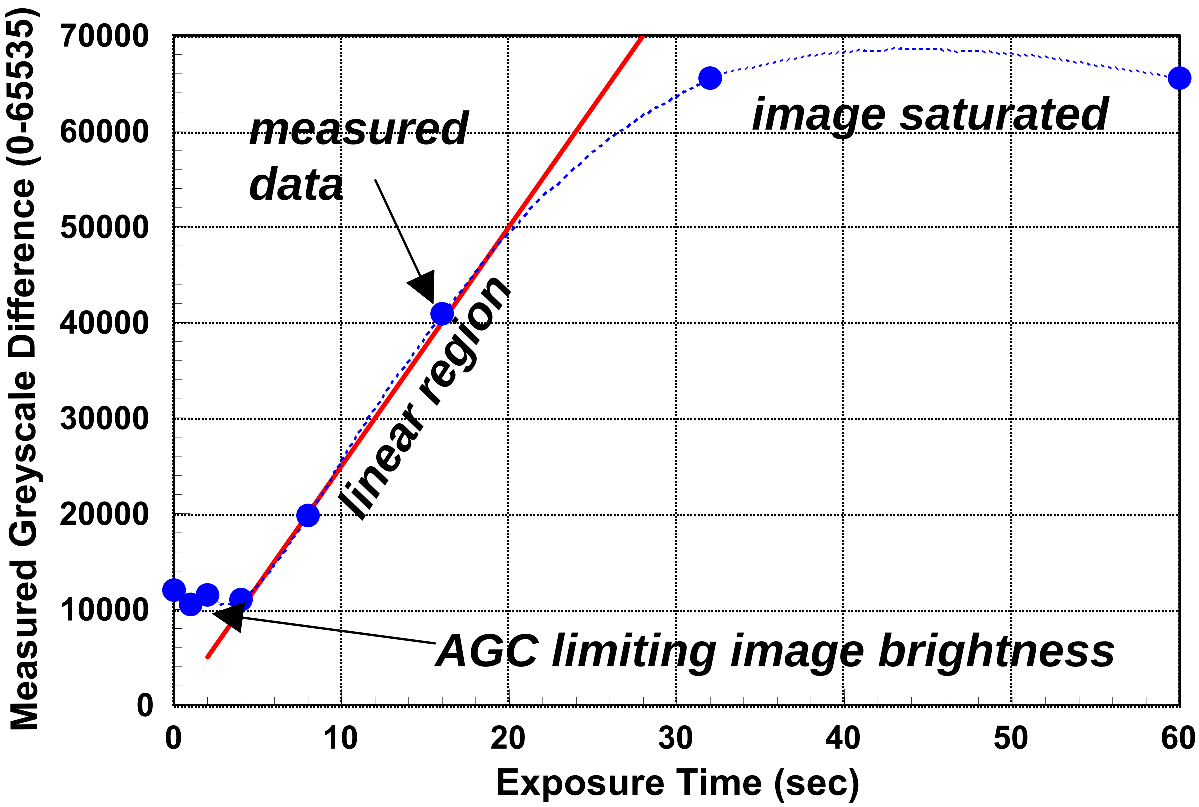


Figure 19 Anticipated General Appearance of Sensitivity Measurements

5.3 Acuity:

Acuity will be the most difficult parameter to evaluate objectively as the results will depend entirely on my own perception. To evaluate acuity in a bench test environment it will be necessary to present some sort of representative test pattern to the camera that looks for how the camera is going to respond to a real life astronomical target. Based on my own video astronomy experience I have developed my own acuity test pattern, which is displayed in Figure 20. The test pattern was designed to evaluate a couple of (what I think are) key aspects of acuity:

- perceived sensitivity for varying degrees of edge definition and colour;
- linear detail resolution; and
- point detail resolution.

Perceived sensitivity is a fancy way of saying how easy it is to see faint detail such as would be typical of an emission nebula or galaxy. Our ability to detect a faint detail depends heavily on the contrast of that detail relative to its immediate surroundings in the image. For this reason I have varied the sharpness of the edges in the test pattern from 0% feather (sharp edge) to 100% feather (very gradual edge). I have also varied the colour (Red, Green, Blue, & Grey) and the intensity (grayscale 0 to 255). At this time I can not predict how well this part of the test pattern will work in evaluating a camera's ability to resolve faint details, but it is at least a place to start.

Detail resolution, whether it is linear details or point details, is a typical parameter in test patterns, and I have based what I have heavily on what is done in practice by others in the video field. In all cases, both for the detail resolution and the perceived sensitivity, I have applied a scale that will allow a quantitative evaluation of each camera.

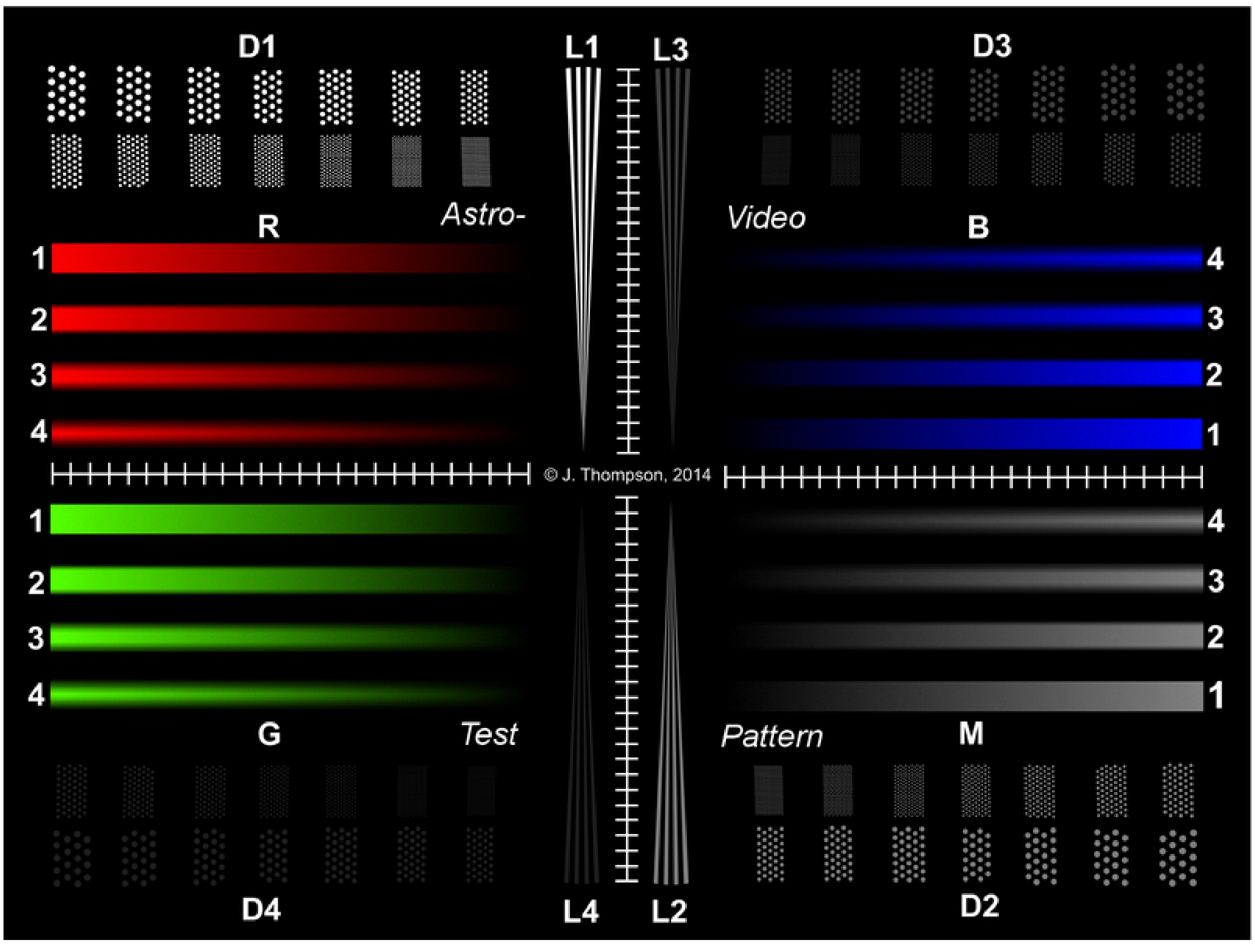


Figure 20 Acuity Test Pattern

The actual measurement of acuity will be performed by presenting the test pattern on my laptop computer at a fixed distance from the camera. The camera will observe the test pattern through the "Mighty Mouse" telescope, and image captures will be made. Captures will be taken with the camera at a range of operational conditions, a sub-set of those listed in Appendix A. To achieve a range of camera exposure times it will be necessary to use a combination of ND filters which will be determined at the time of the testing. For each camera setting the video capture BRIGHTNESS will be adjusted so that the test pattern border is dark – but not clipping. The acuity score for each camera for each setting will be read off the image captures based on my own perception of what is visible and what is not. It is not clear at this time how the results will be presented, in a single summed up score or graphically. Once I have collected some of the data I will have a better idea.

There is also a range of capabilities between the different cameras that can help to enhance the appearance of the video image. I will try to capture images with cameras set to the same condition (no bells and whistles) as well as the best I can achieve using all the bells and whistles. I will not specifically evaluate the impact of in-camera stacking (3D DNR) or in-software stacking. I am choosing to make frame stacking outside the scope of my test program since if the native video frames of one camera are of poorer quality compared to another camera, the stacked frames will also be similarly poor. I may include some qualitative observations regarding the effectiveness of stacking in my general observations for each camera.

In addition to the test pattern I will observe high resolution images of astronomical objects and compare qualitatively how well they are resolved. Captured images will be judged based on: colour, sharpness, and level of detail observed. The astronomical target list will include the following:

- galaxy
- globular cluster
- emission nebula
- Moon
- Jupiter

The images will be presented to the camera using a laptop in the same manner as the test pattern. An optimum setting for each camera will be used based on the results of the test pattern measurements. For information, the spectral emission from my laptop when projecting a picture of the Moon (grayscale) is presented in Figure 21.

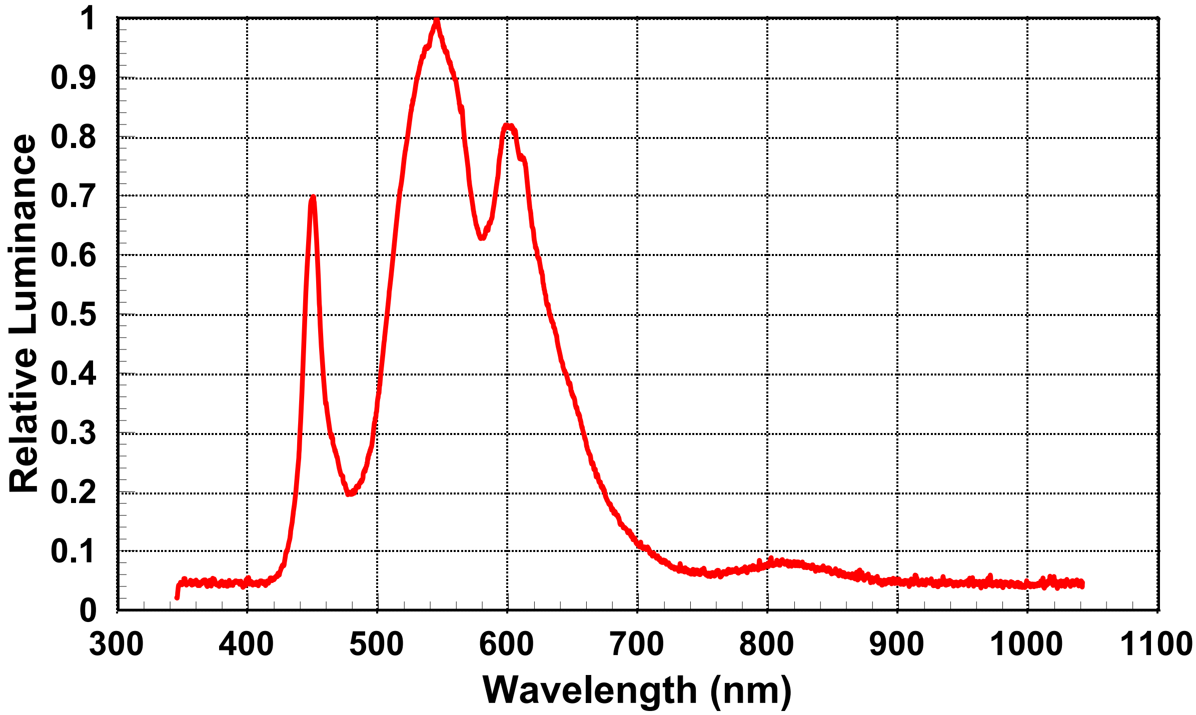


Figure 21 Laptop Spectral Emission – Lunar Image

5.4 Ease of Use:

Ease of use is an entirely subjective parameter to evaluate. Over the course of my testing I hope to have enough exposure to each camera and their associated accessories and software to be able to comment on how easy each camera is to use. Big things I will be looking for will be how long does it take to setup and start observing, and how easy it is to switch between different types of targets (eg. from the Moon to a nebula). My several years of experience using Mallincam brand cameras will undoubtedly result in a bias of my observations, so that is to be taken into account when presenting the results.

6.0 Reporting

With the scope of the testing outlined above, I expect it to take several months to complete the work. One benefit of performing the testing indoors will be that I am not limited by weather conditions. The order in which the testing is performed may be different than that listed above; if it is clear out then I may opt to do in field testing over bench testing. That being said, if testing for one of the four primary objectives is complete, I will probably right up a summary and release it instead of waiting for the testing of all four primary objectives to be completed.

7.0 Conclusions

The test methodology I have presented in this document was developed based on my own ideas and experience as well as input from the video astronomy community. My desire is to answer some basic questions about how these different cameras perform relative to each other. I anticipate however that the results of this test will very likely spawn more questions and possible follow-on testing. For now this test will be the first step, and to where it leads I do not know!

I hope my work is useful to the Video Astronomy community. If you have any questions or suggestions on this test plan, please feel free to contact me at: top-jimmy@rogers.com.

Cheers,

Appendix A - Camera Test Matrix

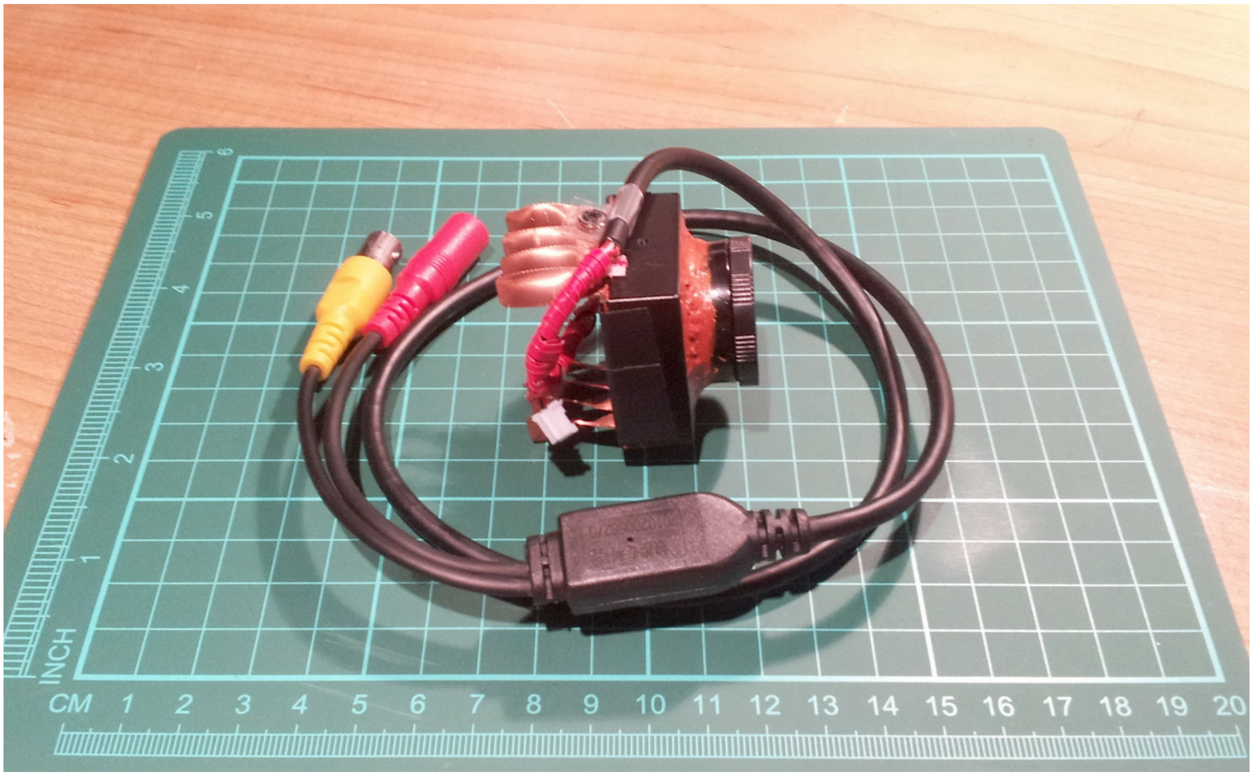
Cam #	Camera Model	1/250s	64x (1.07s)	256x (4.27s)	1024x (17.07s)	60s
1	DIY (PQ0133) heatsinked	N,M,F	N,M,F	N,M,F	N,M,F	-
2	Starshoot DSVC II	N,A	N,A	N,A	-	-
3	LN300 - NTSC	N,M,F	N,M,F	N,M,F	N,M,F	-
4	LN300 - PAL	N,M,F	N,M,F	N,M,F	N,M,F	-
5	SDC-435	N,A	N,A	N,A	N,A*	-
6	Stellacam EX	N,A	N,A	N,A**	-	-
7	Stellacam III	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
8	DSO-1	N,M,F	N,M,F	N,M,F	N,M,F	-
9	Mk-IV	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
10	APU-1	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
11	Junior-EX	N,A	N,A	N,A	-	-
12	Junior Pro	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
13	Xtreme XT418	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
14	Micro EX	N,M,F	N,M,F	N,M,F	N,M,F	-
15	Micro Super	N,M,F	N,M,F	N,M,F	N,M,F	-
16	Xterminator	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
17	SkyRaider-AGc	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
18	SkyRaider-DSc	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
19	SkyRaider-DS2.3	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
20	Universe	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
21	SSI-c	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
22	Lodestar-C	8,12,16	8,12,16	8,12,16	8,12,16	8,12,16
23	Lodestar-X2C	8,12,16	8,12,16	8,12,16	8,12,16	8,12,16
24	ASI 185MC	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F
25	DBK 51AU02.AS	N,M,F	N,M,F	N,M,F	N,M,F	N,M,F

N=min gain, M=mid gain, F=full gain, A=auto gain, 8/12/16=bit depth of displayed image

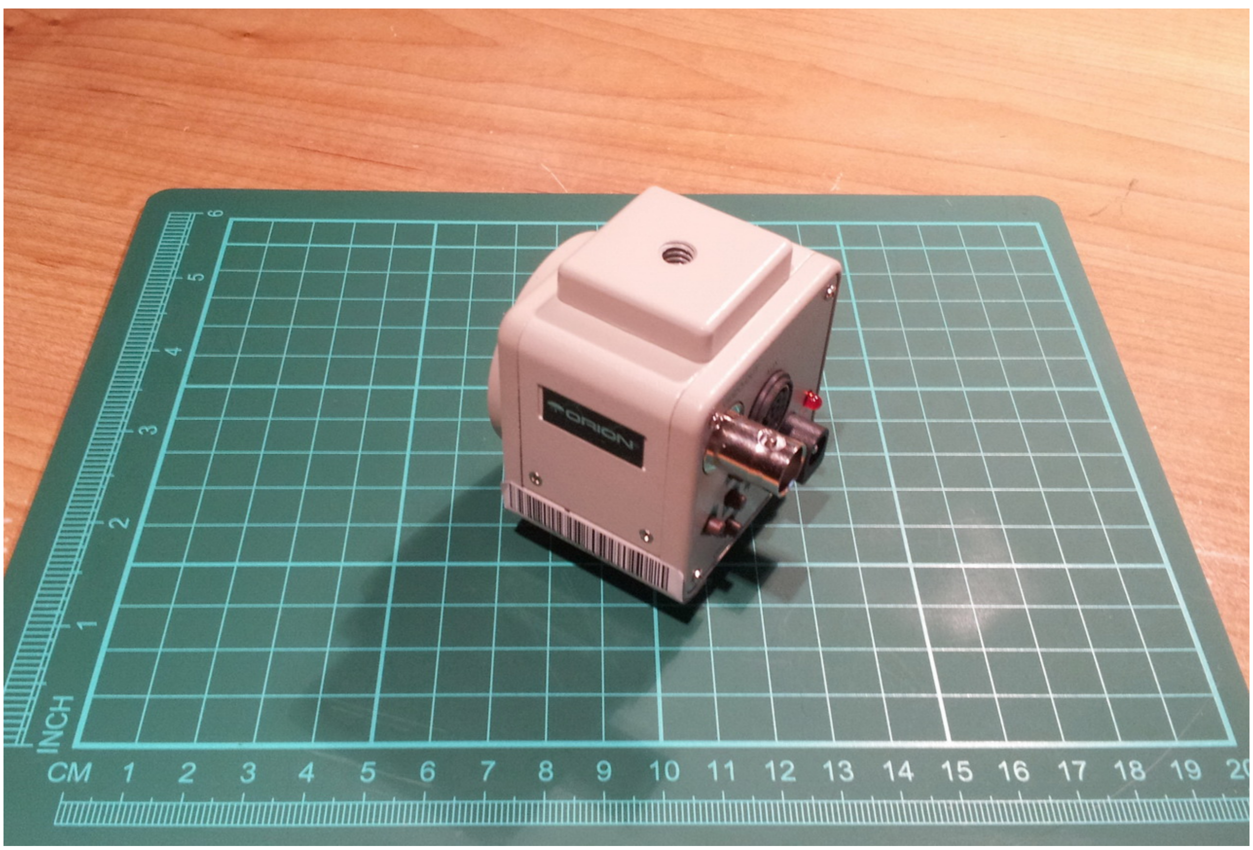
* max exposure = 512x

** max exposure = 128x

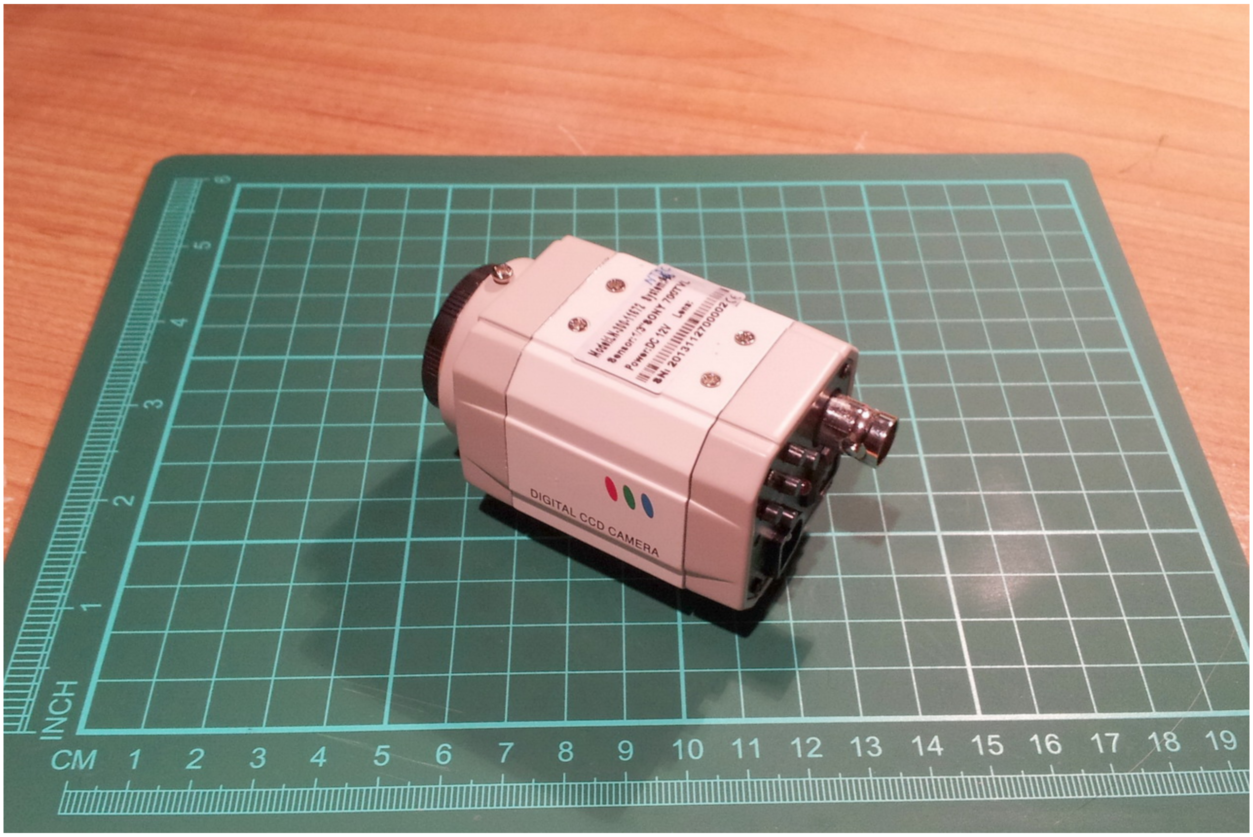
Appendix B - Camera Photos



Cam #1: DIY (PQ0133) heatsinked



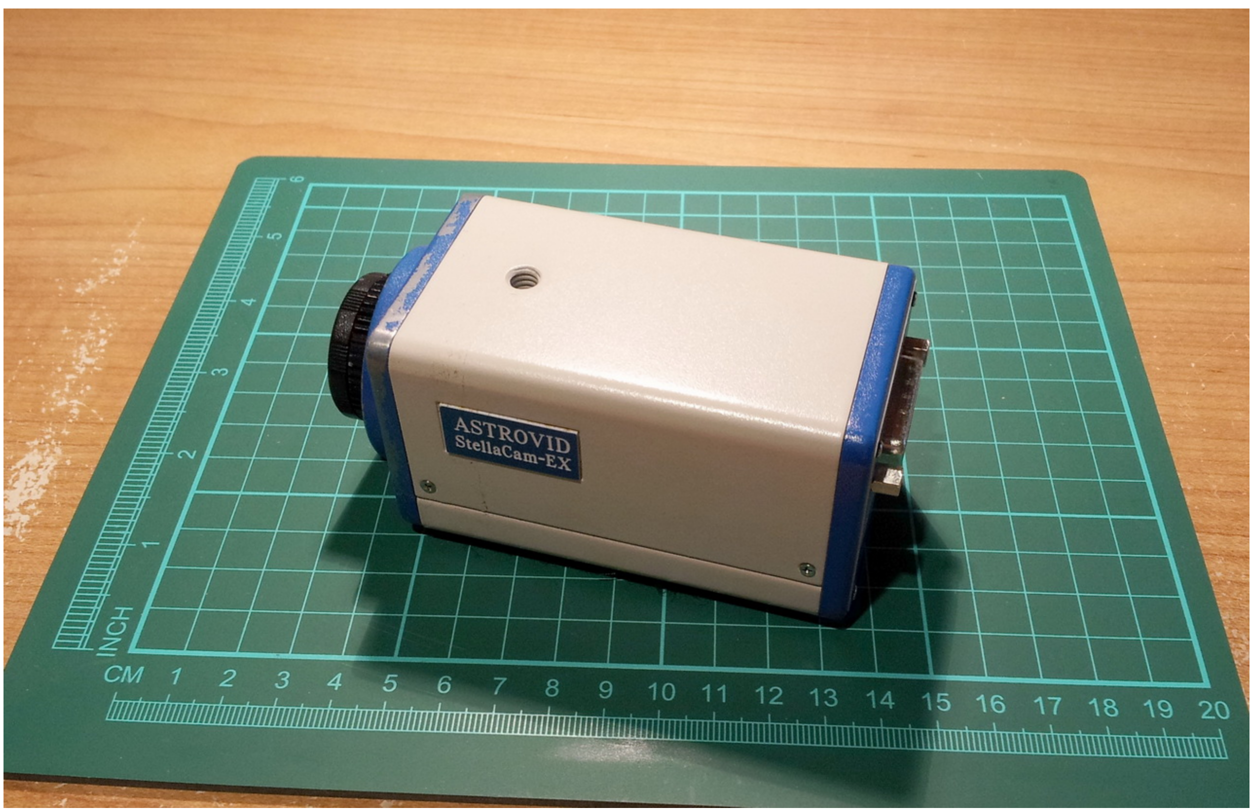
Cam #2: Starshoot DCVC II



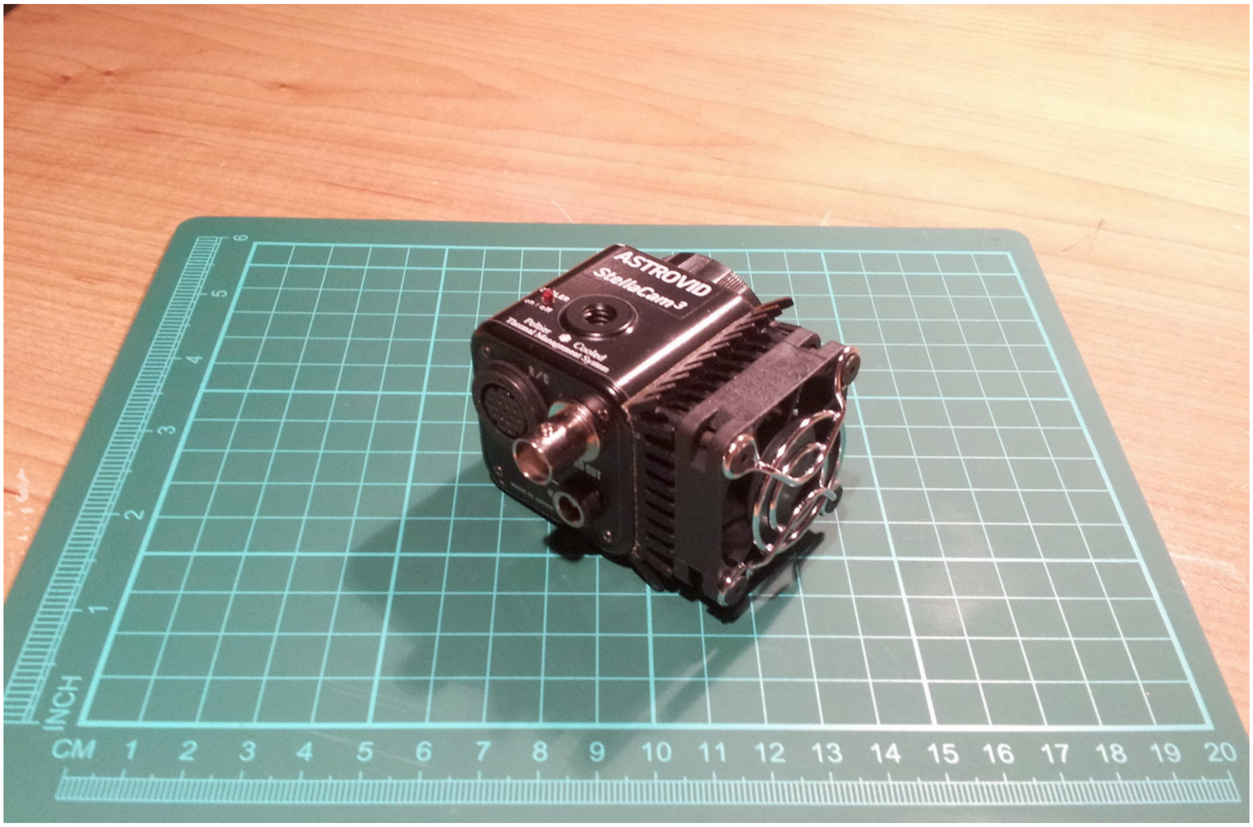
Cam #3: LN300 - NTSC

Cam #4: LN300 - PAL (non-standard enclosure)

Cam #5: SDC-435



Cam #6: Stellacam EX

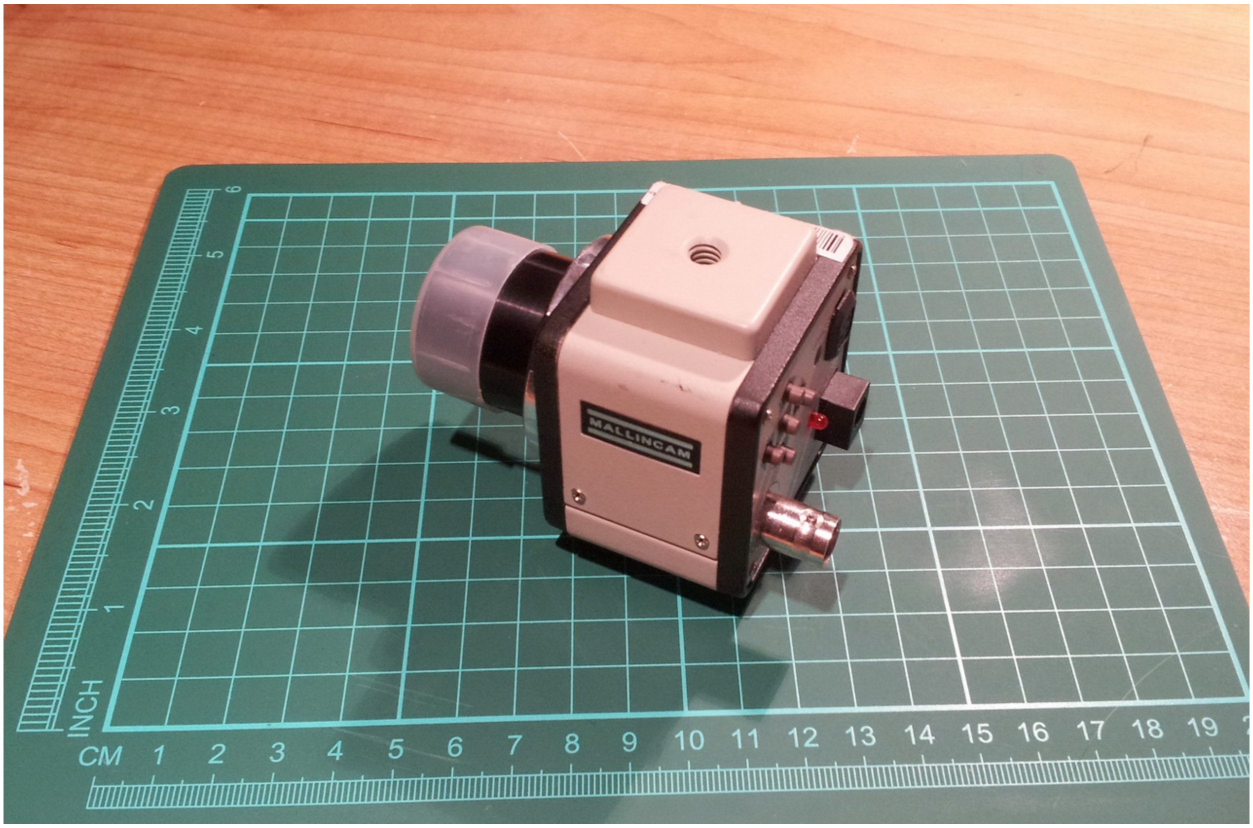


Cam #7: Stellacam III

Cam #8: DSO-1

Cam #9: Mk-IV

Cam #10: APU-1

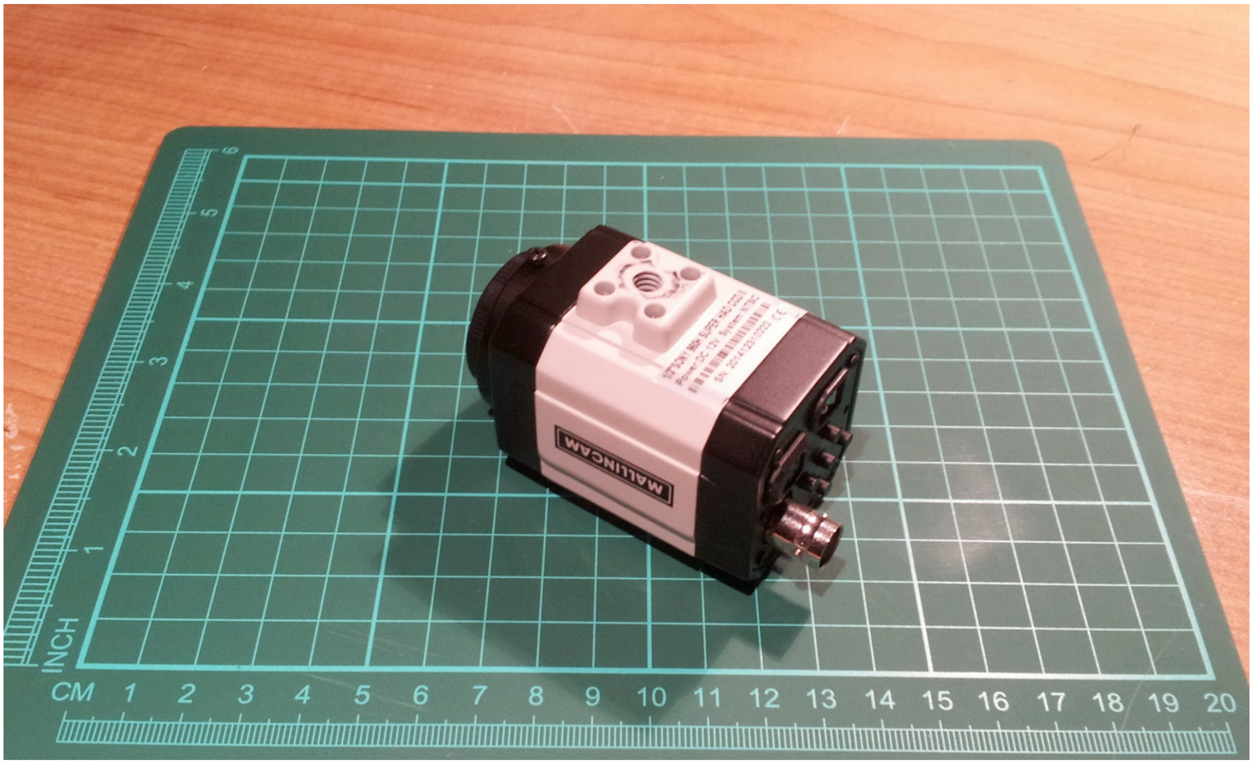


Cam #11: Junior-EX

Cam #12: Junior Pro

Cam #13: Xtreme XT418

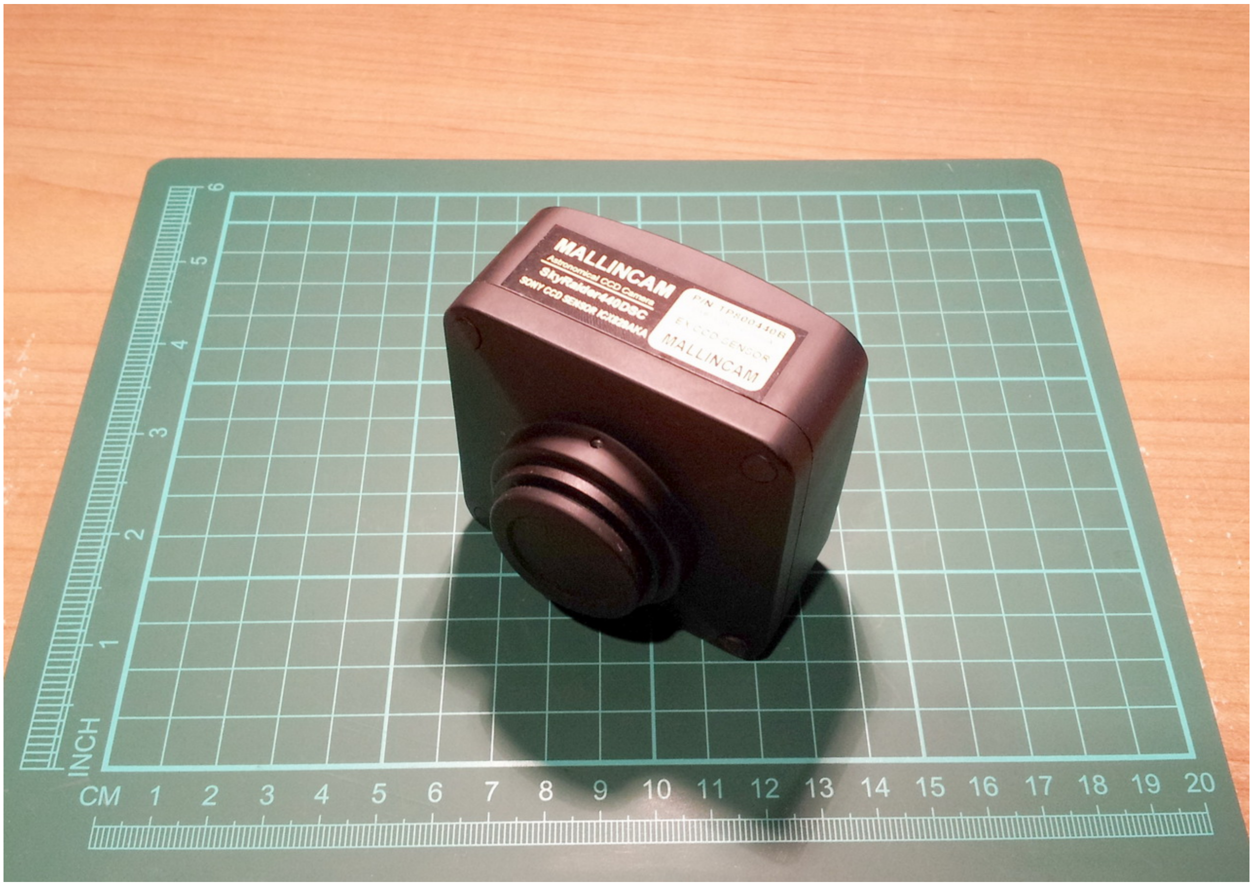
Cam #14: Micro EX



Cam #15: Micro Super

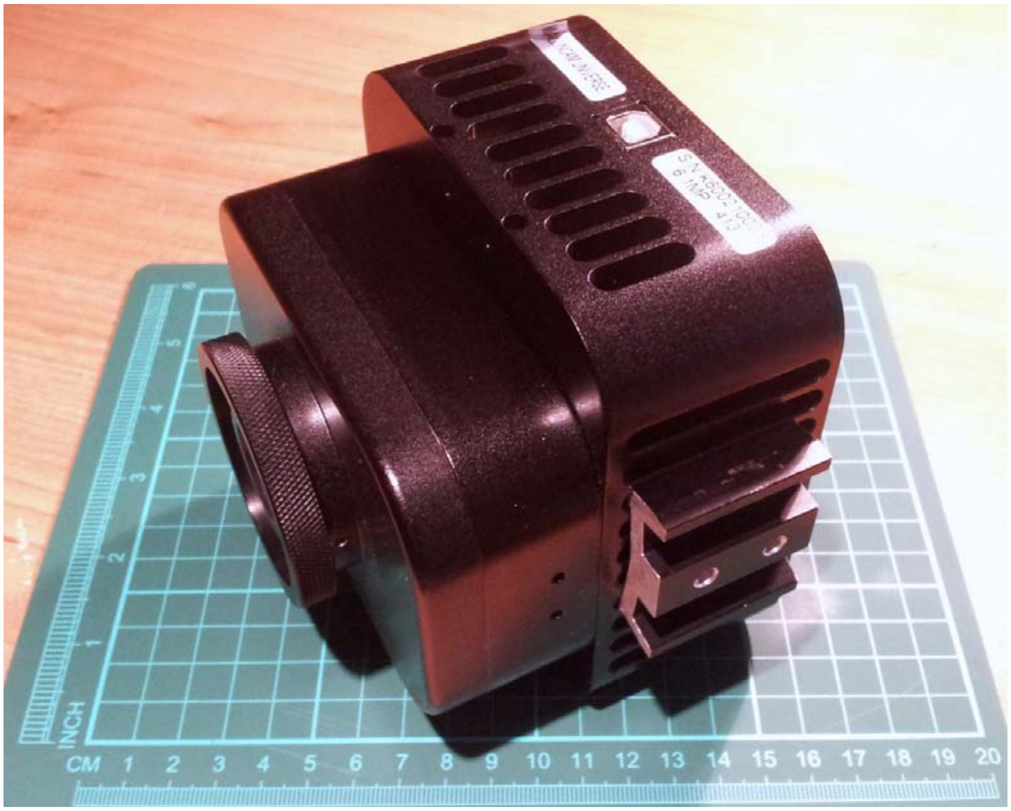
Cam #16: Xterminator

Cam #17: SkyRaider AGc

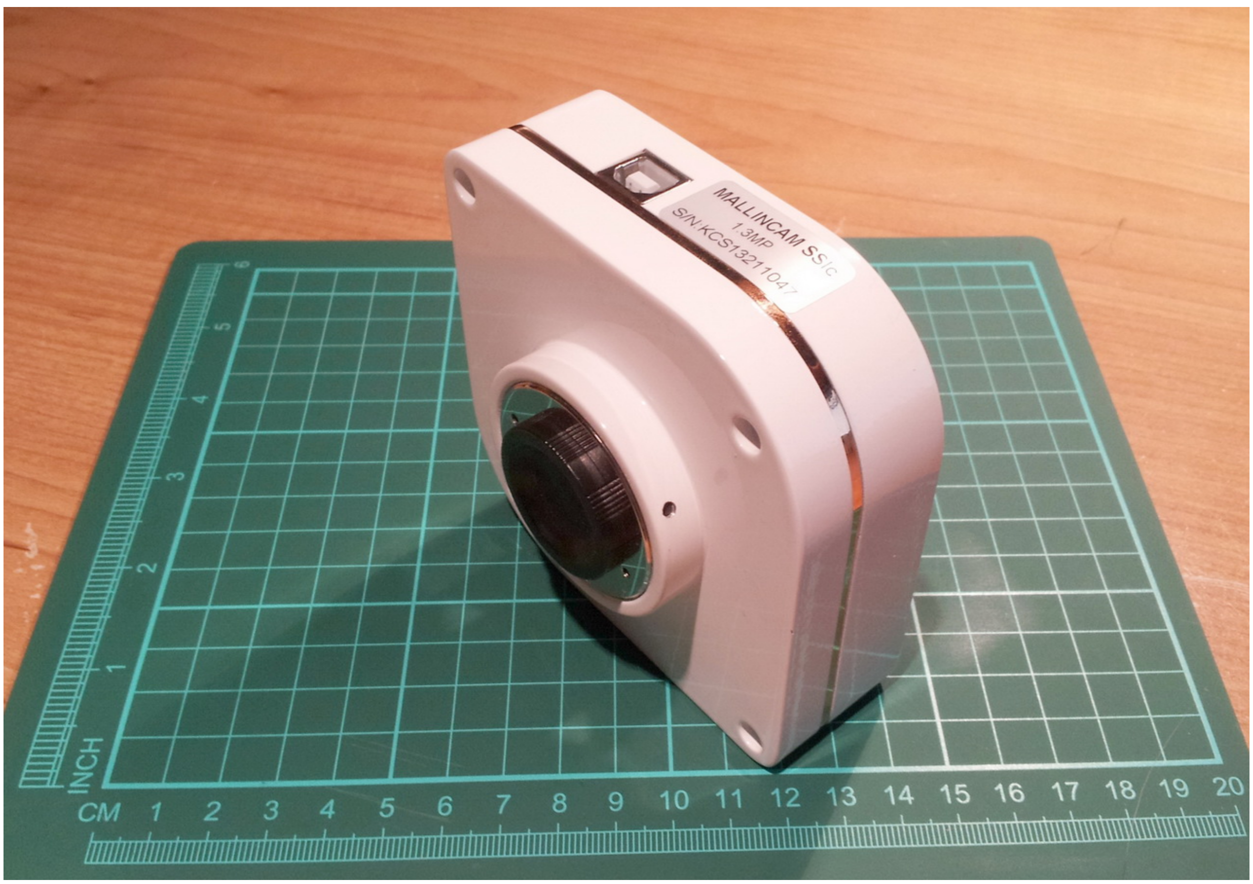


Cam #18: SkyRaider DSc

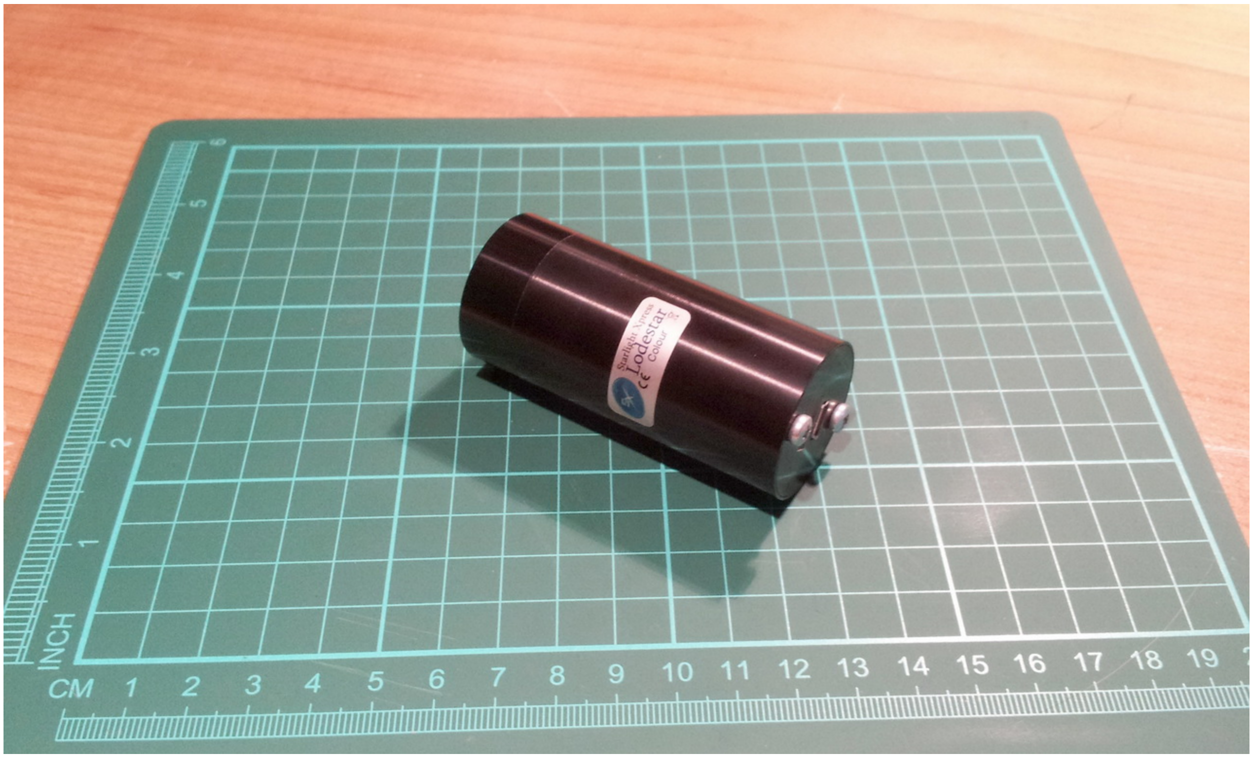
Cam #19: SkyRaider DS2.3



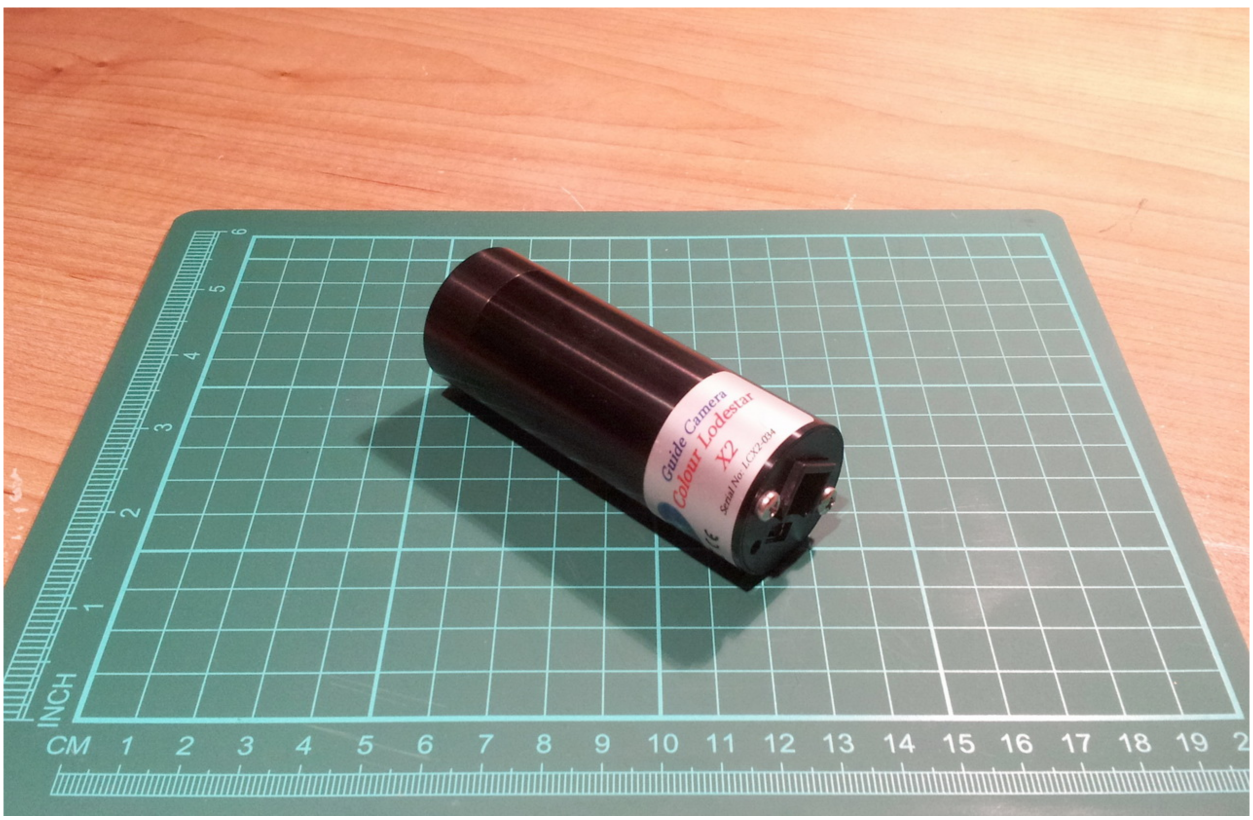
Cam #20: Universe



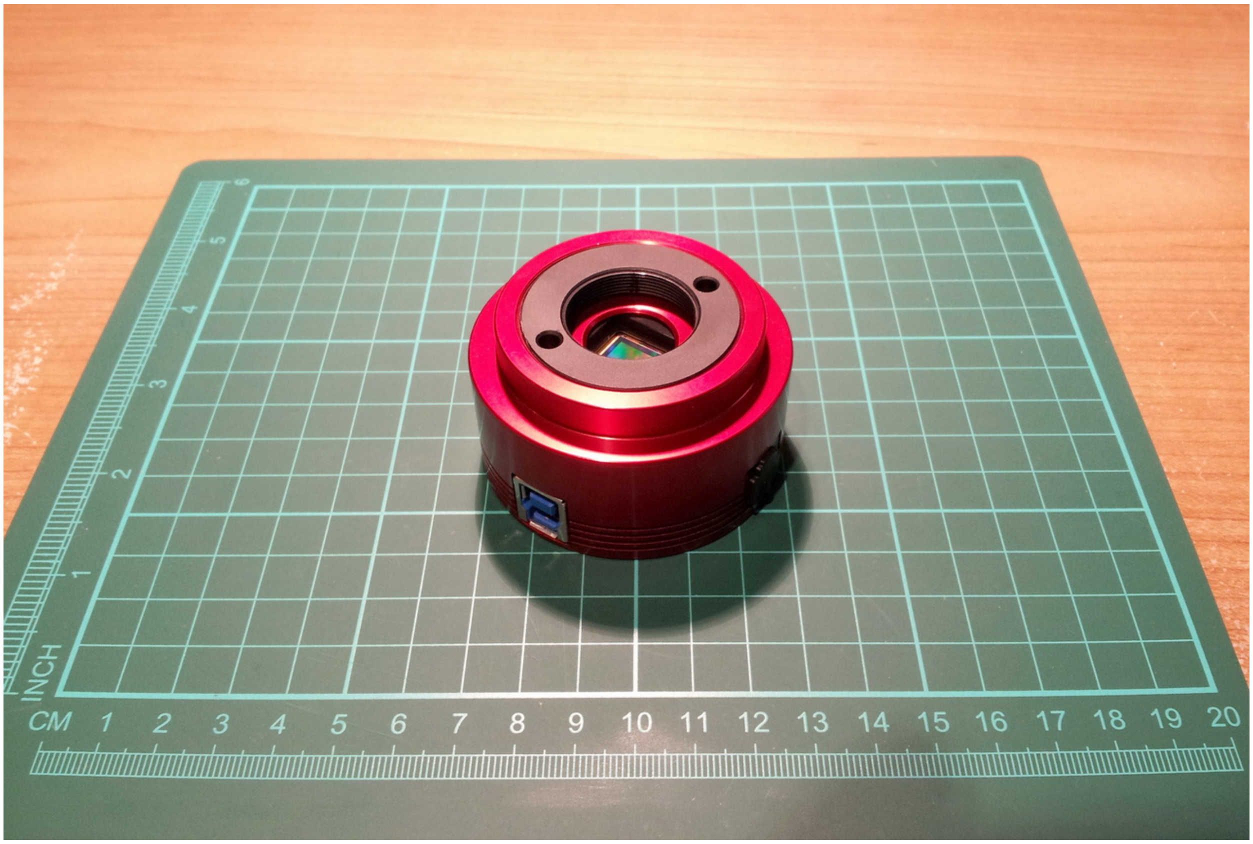
Cam #21: SSI-c



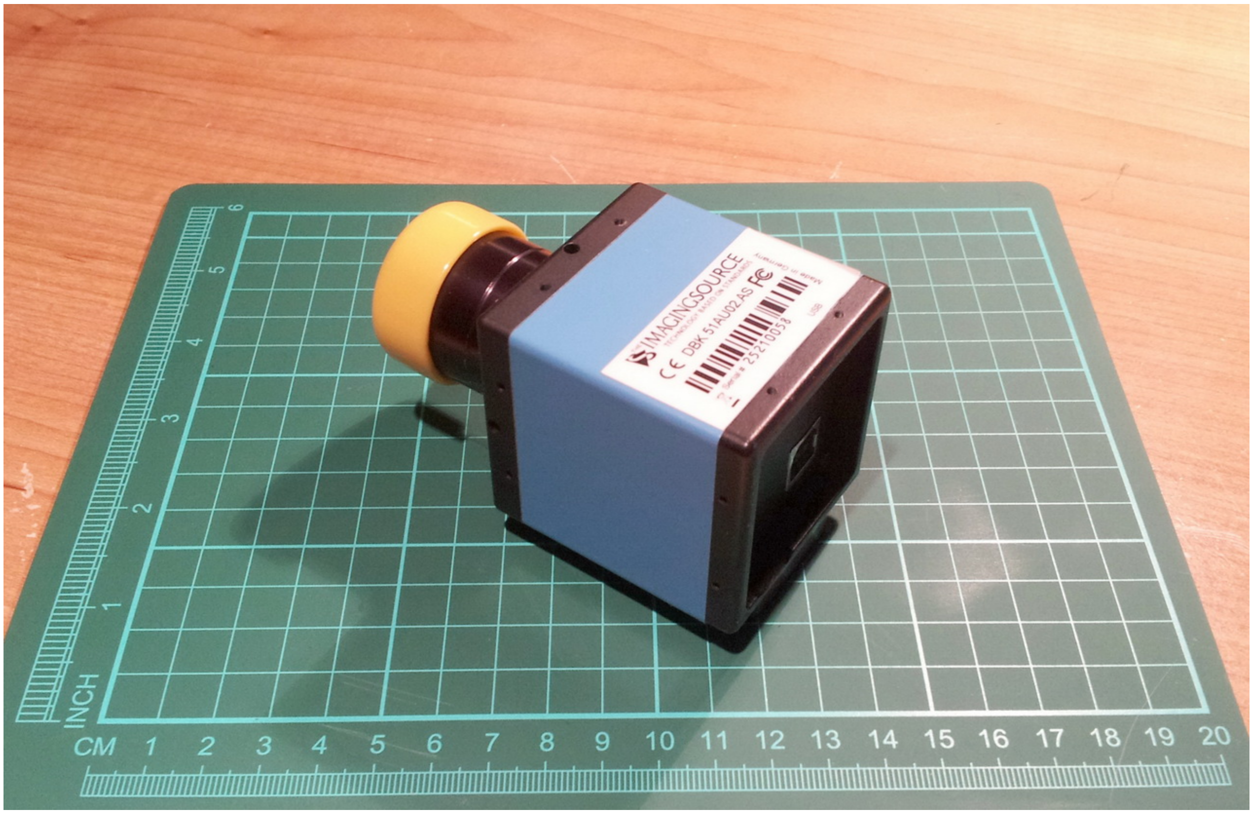
Cam #22: Lodestar-C



Cam #23: Lodestar-X2C



Cam #24: ASI 185MC



Cam #25: DBK 51AU02.AS