Point Grey Research Grasshopper 2 Camera Review by Milton Aupperle

Introduction

In mid January 2012, I had a six week opportunity to test the Point Grey Research Grasshopper 2 Monochrome camera (Model GS2-FW-14S5). A new firmware load provides the ability to do exposure times of up to 90 minutes without needing to make the camera self triggering via the GPIO pins and Bulb trigger mode, as is currently done in Astro IIDC. PGR also offers a color version of the Camera too, but it was not tested. It should have similar characteristics as the Mono camera as far as noise goes though.

Testing was performed on my Mac Book Pro 17" dual core i7, G5 Mac Desktop PowerPC 2.5 Giga Hertz dual core, Mac Mini dual core 2.0 Giga Hertz x86 and my G4 Mac BookPowerPC single core 1.25 Giga Hertz G4 under OSX 10.4 to 10.7. Astro IIDC 4.08.00 Alpha was used for all camera control, capture, stacking, processing and photometric measurements. Some data analysis was done using spreadsheets in AppleWorks and with "Plot".

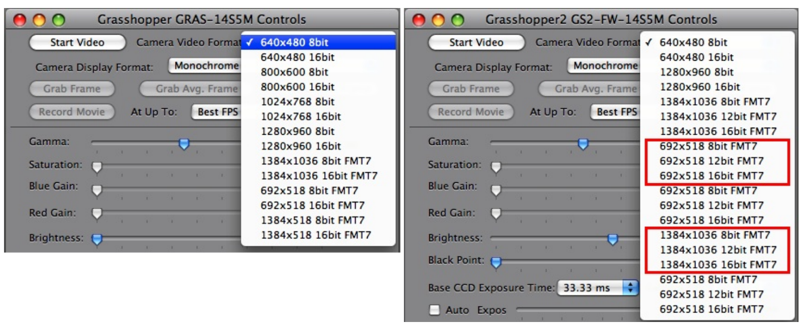
Due to unusually poor weather conditions for this time of year, I only had a hand full of nights to test on astronomical targets. I had hoped to have a "head to head" comparison of the GS2 versus GS1 for the same Deeps Space Objects (DSO), but the weather did not co-operate. Indoors, I did characterize the noise versus gain curves of the GS2 as compared to my two year old Grasshopper 1 Monochrome camera (Model GRAS-14S5M-C).

Camera Properties

Externally the GS2 and GS1 cameras are nearly identical in size (44 mm x 29 mm x 58 mm or 1.7" x 1.1" x 2.3"), weight (~100 grams or ~ 3 ounces), ports (two FireWire 800 ports and a single 8 pin Hirose HR25 port) and CCD type (Sony EXView HAD Mono ICX 285 2/3"progressive scan 6.45 micron square).

However under the hood there have been numerous changes made which keeps the GS2 camera at cooler temperatures, reduces power draw (by 0.5 watts), reduced image noise, eliminates amplifier glow, increases out of the box exposure time and runs at higher frame rates too.

The first major internal difference is the GS2 cameras supports the IIDC 1.3.2 specification, where as the GS1 supports IIDC 1.3.1. The updated IIDC 1.3.2 specification required changes to Astro IIDC to accommodate an additional twenty four Format 7 modes, support for 12 bit packed Monochrome or Bayer video and some additional changes to the ISO Start command. Point Grey Research's support was very helpful in sorting this out and the Astro IIDC 4.08.00 Beta application now supports IIDC 1.3.2 cameras. The difference between supported Video sizes for the GS1 and GS2 cameras are shown below.



For the GS2 camera, the special formats what have lower temperature, long exposure and reduced noise modes have been marked by Red boxes and correspond to Format 7 Mode 3 (692x518 8 ,12 and 16 bit) and Format 7 Mode 8 (1384x1036 8, 12 and 16 bit). Note that the special low noise - lower temperature modes run at slower frame rates (maximum 6.9 fps) so they are not much use for non DSO targets.

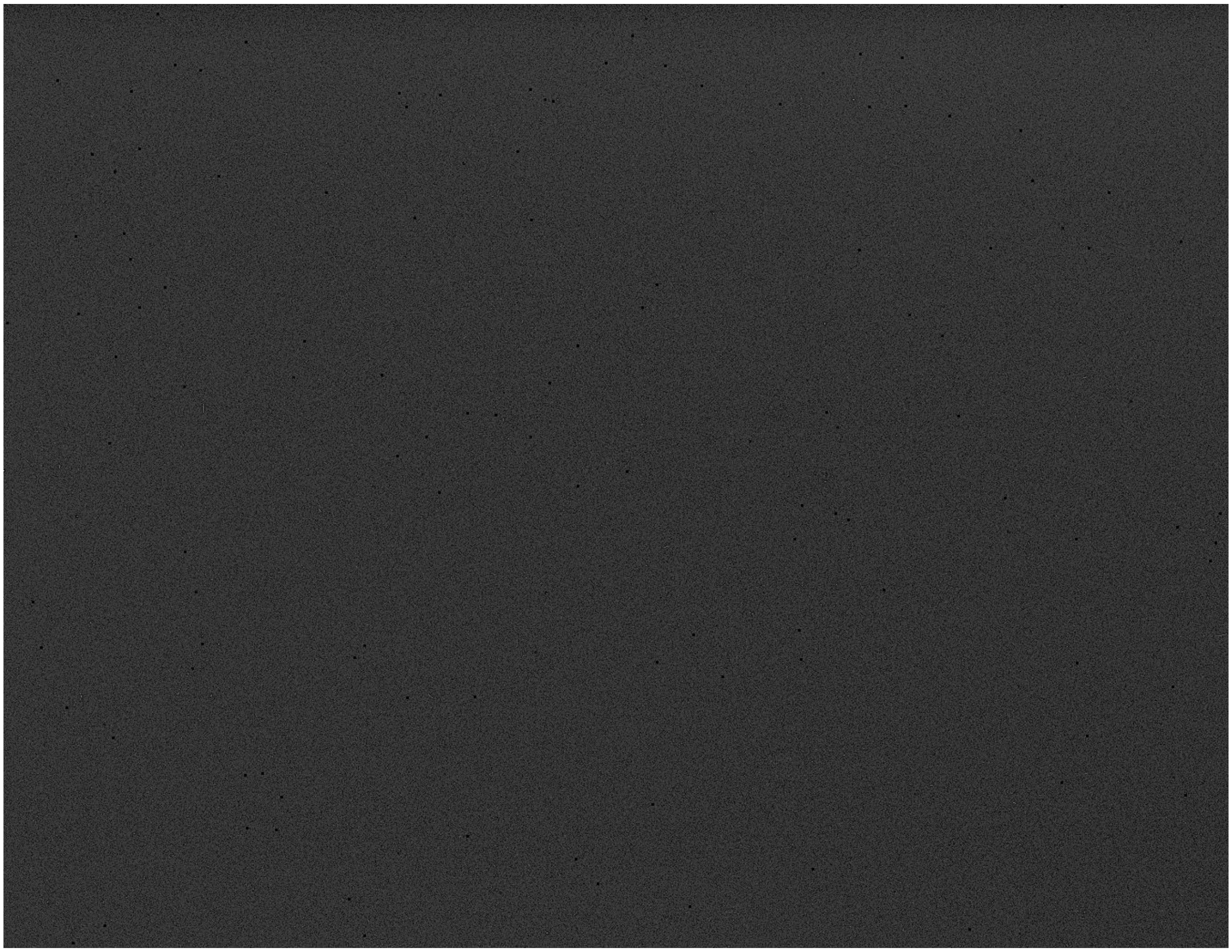
Frame rate wise, the GS2 camera runs up to 2 times as fast as the GS1 camera does. Maximum frame rate achieved for the GS2 using 640 x480 ROI for Format 7 was 48.3 fps and for the GS1 camera peak frame rate was 29.4 fps. For video at 1384x1028 in 16 bit modes, the GS2 runs at 29.4 fps (that's 80.4 megabytes per second streamed to disk) and the GS1 tops out at 14.6 fps.

Temperature measurements show the GS2 runs about 4 to 6°C cooler than the GS1 camera does, which does help with reducing thermal noise.

Outdoor and Indoor Noise Characterization

My first test was to examine the cameras noise levels with dark frames to determine how much amplifier glow or other irregularities there are. To create a dark frame, you completely block any light from reaching the CCD and then shoot a series of frames which contain total noise from the camera for that gain setting and exposure time. Astro IIDC's "Grab Avg. Frames.." button will do this on the fly and can capture a user defined number of frames (6 frames in my testing), average them together and creating a resulting Mono 16 bit tiff averaged frame. I shot 30 second, 3 minute, 10 minute and 16 minute dark frames outdoors with an ambient temperature of -9.0 to -11.5°C and the Camera's internal sensor measured temperatures of 6.4 to 4.4°C. The GS2 camera was not actively cooled during the test.

The GS2 camera produced uniform dark frames with pixels values in the range of 40 to 50 values out of 65,535 maximum (0.015% variance) across the 1384x1036 unstretched frame. The stretched image below shows how uniform and flat the original is, with no amplifier glow or irregularities at all.



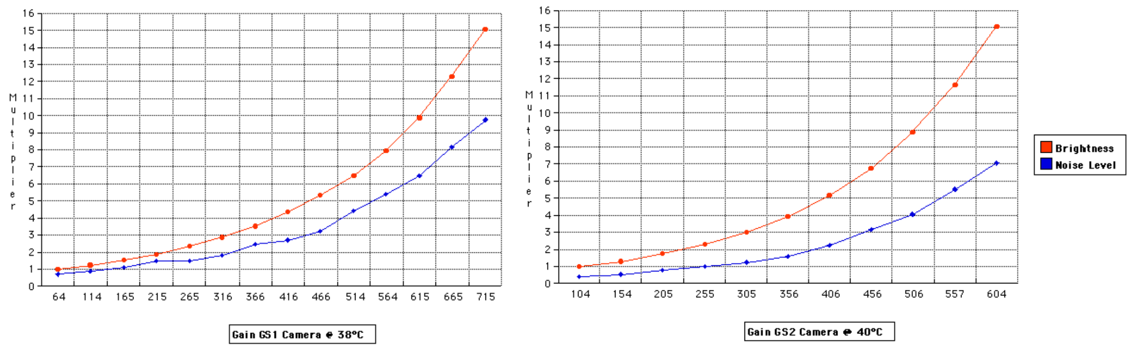
For comparison, here is a 16 minute dark frame taken with the GS1 camera cooled to -14°C (internal temperature):

and stretched version using the same stretch settings as the GS2 image.

The GS1 pixel values range from 0 to 4,500 out of 65,535 (6.87% variation) across the unstretched image. You can see the broad hot spot from the amplifier glow in the upper left corner, uneven vertical and horizontal line noise too. So it's pretty clear that the GS2 camera improvements have solved one of my major noise and unevenness issues for doing DSO imaging with the Grasshopper cameras.

The second test performed indoors measured the intra frame noise of a cluster of 1024 pixels at different gain settings. This indicates the amount of variance between the same pixels in each frame. If there was no noise and variance in pixel values, then the difference between frames would be zero. Higher gain exacerbates the amount of noise you have.

Essentially the camera running at 1384x1036 in 16 bit mono mode is pointed at a constant DC powered light source (AC lights have flicker) and the total brightness of central 32x32 block of pixels are measured for 200+ frames. Then the change in brightness between each frame is calculated and the Standard Deviation (at 68% confidence interval) is then computed. This is a time consuming process where the gain is advanced by 50 increments from minimum to maximum and after each increase, 200+ frames are shot and analyzed. For these tests the cameras were uncooled and running at approximately 39°C internally over the several hours it takes to acquire all the data.



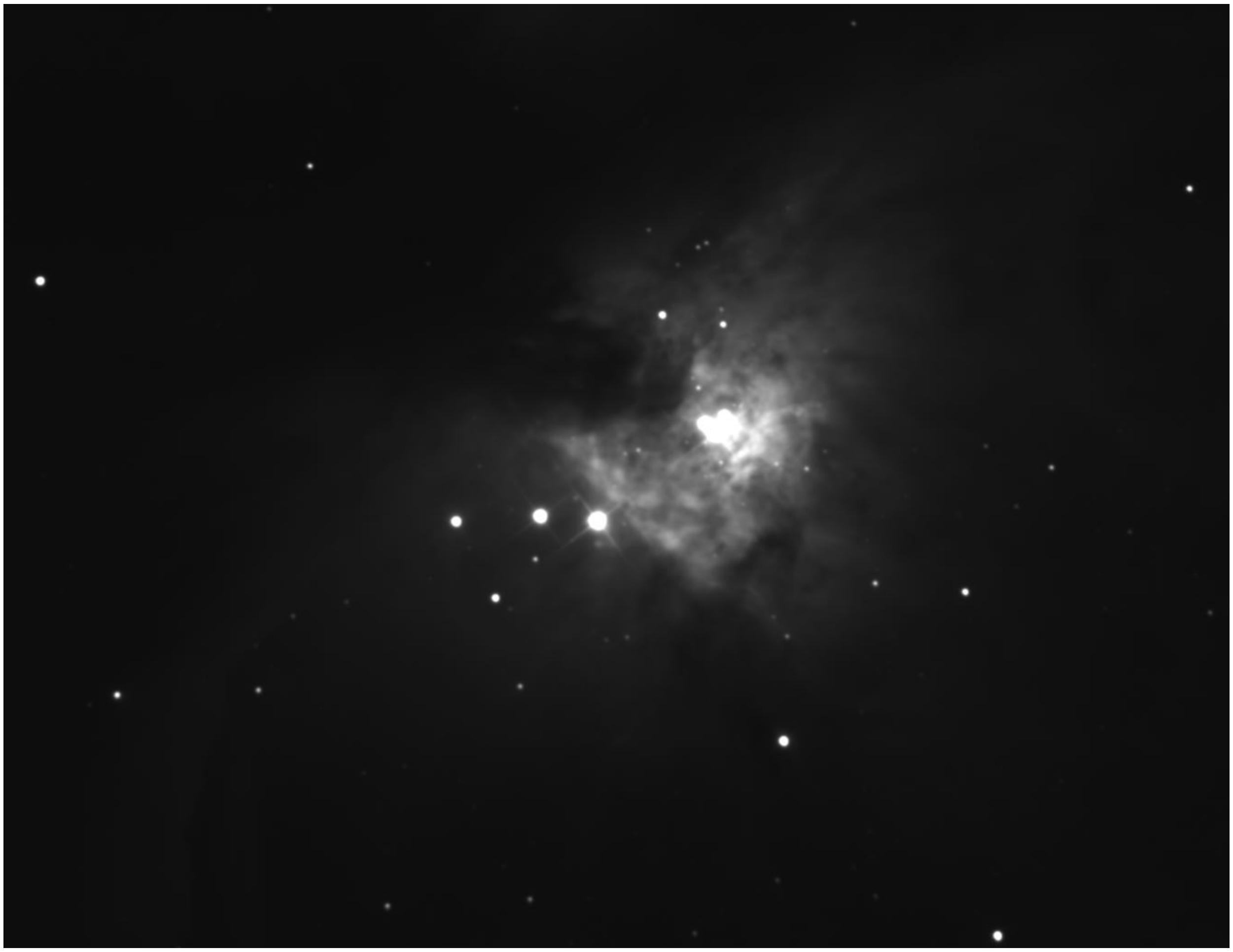
The graph on the left is for the GS1 camera and the graph on the right is GS2 camera. You can see that the GS2 camera has approximately 40% lower noise than the GS1 camera for the same amount of gain induced brightness.

Astronomy Imaging and Photometric Tests

I had 3 nights of typical mediocre seeing (measured star FWHM in the 4 to 8 arc seconds range) to test the camera on Astronomical targets. In all cases, I was shooting with AstroDon Series 2 "I" LRGB Filters using the AstroTech 8" RC scope at 1625 mm focal length on the HEQ5 mount. Active guiding was done with a Celestron Radial Guider and a Flea 640x480 color camera, which controlled the mount movements using the GPIO To ST4 Guider board. The Flea camera was daisy chained to the GS2 camera via the second FireWire port, so that I had one FireWire 800 cable coming from the Mac Book Pro laptop to run 2 cameras and control the mount, including power for all devices which vastly simplifies cabling over USB 2 or 3. No Flat frame correction or Dark frame subtraction were applied to the movies recorded. Since both the GS1 and GS2 cameras use the same CCD, I used the G2 star calibrated exposure times that I had already determined with the GS1 camera for all exposure. WITHOUT the Hutech IDAS LPR filter being used, my color balanced exposure ratios are Luma 1.00 : Red 0.97: Green 1.00 : Blue 1.18. WITH the Hutech IDAS LPR filter in place, my color balanced exposure ratios would be Luma 1.00 : Red 1.30 : Green 1.00 : Blue 0.91.

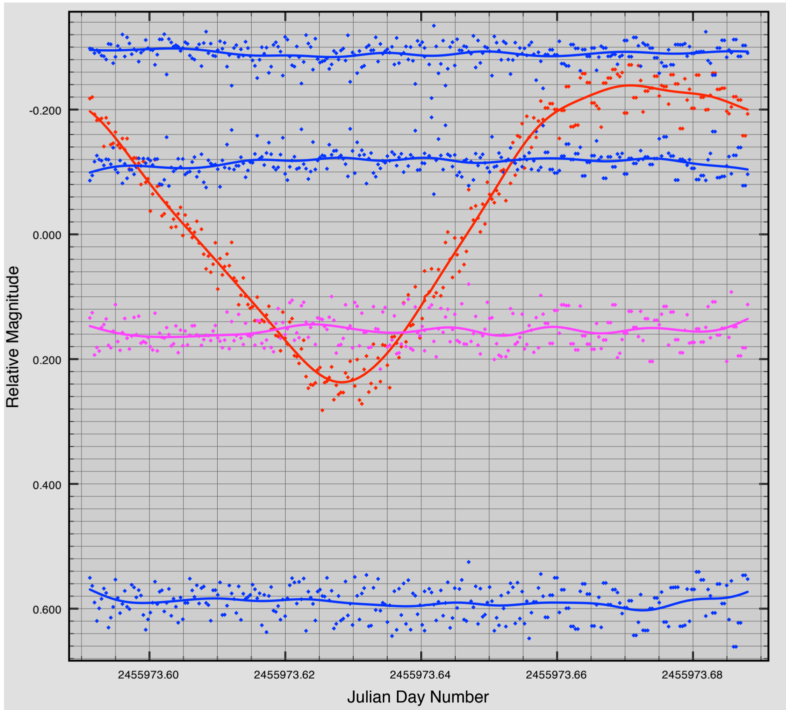
The first target I selected to image on February 3, 2012 was the heart of Messier 42, the Orion Nebula. The Camera was uncooled and at an internal temperature of 3 to 4°C. Guiding was done on a mag 6.7 star at 7.5 fps with the Flea camera, which helped reduce the erratic turbulence I was getting that night. I shot 30 seconds luma, 30 seconds Red, 30 seconds Green and 35 seconds Blue all binned 1x1. I chose to underexpose and then stretch the stacks afterwards to bring out the faint arms without completely blowing out the core around the trapezium.

This first image is the unprocessed luma stacked frame showing the M42 core area:



The second image is the LRGB Combined stacks, which have been stretch image processed, balanced and sharpened in Astro IIDC:

My second session on February 15, 2012 was a photometric test of asteroid #22 Kalliope (magnitude 11.1 visual, rotational period of 4.148 hours, approximately 166 km diameter, M class Metal rich) for a period of 2.475 hours which is a bit more than half a rotation, before being clouded out. The Camera was uncooled at an internal temperature ~ -1°C and I used 30 second exposures with just a Luma filter. The change in brightness of the asteroid due to rotation (Red points and smoothed curve line with +0.28 to -0.24 magnitude change is for Kalliope) is shown below:



The curve is asymmetric and suggest that one side of the Kalliope is broader (or brighter) than the other (see http://www.imcce.fr/langues/en/observateur/campagnes_obs/kalliope/ for shape confirmation). Measured signal to noise ratio for Kalliope and the comparison stars is in the ± 0.0017 to 0.0022 magnitude range, which means that instrument noise will not be a singifcant factor for detecting exoplanet transits.

My third imaging opportunity was on February 17th when I targeted the open star cluster M37 and the Eskimo Nebula NGC 2392. For M37 I used exposures of Luma 5 minute binned 1x1, Red 1.25 minutes binned 2x2, Green 1.25 minutes binned 2x2 and Blue 1.5 minutes binned 2x2, as shown below:

With 5 minute exposures on my RC 8" scope, you can just detect Mag 17.2 stars. The sky background due to light pollution was 10,700 out of 65,535 (16% of the light collected is light pollution) and under dark sky conditions, one could probably detect Mag 19 stars.

For the Eskimo Nebula NGC 2392 I used exposures of Luma 1.25 minutes, Red 1.25 minutes, Green 1.25 minutes and Blue 1.5 minutes all binned 1x1, as shown below:

Turbulence had increased and seeing became worse than the M37 imaging, so fine detail levels are not great for the Eskimo Nebula. Still you can make out the bluish green hood surrounding the white face of the eskimo.

<u>Conclusions</u>

The Grasshopper 2 is a superb general purpose camera for doing both bright field fast imaging of lunar, solar or planetary and long exposure faint DSO targets. Even 5 minute exposures uncooled produce good imaging results and could reach magnitude 19 under dark skies with smaller aperture scopes. The low noise and uniform image characteristics should also make it a very good camera for doing astrometry and photometry on exoplanets, variable stars, asteroid, novae and cometary targets.

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