QHY IMAGING

Distributed by Gama Electronics Pty. Ltd Australia

QHY-8
6 Mega Pixel
Cooled astronomical CCD Camera
User's guide

Thank you for purchasing a QHY Camera. I'm sure that it will give you hours of pleasure doing what its supposed to do, and that's image.
Please take the time to read this manual so you can familiarise yourself with some basic understanding of how the CCD camera works, and how to get the most from your camera.

1) <u>How to connect your camera</u>

When you first open your package, please check to make sure everything you ordered is there.

If you find your package is damaged please contact your dealer immediately.

Parts description.

1 – QHY-8

2 – Filter/nose piece

3 – Regulator

4 – Air sealed carry case

5 – Silicone Gel heater

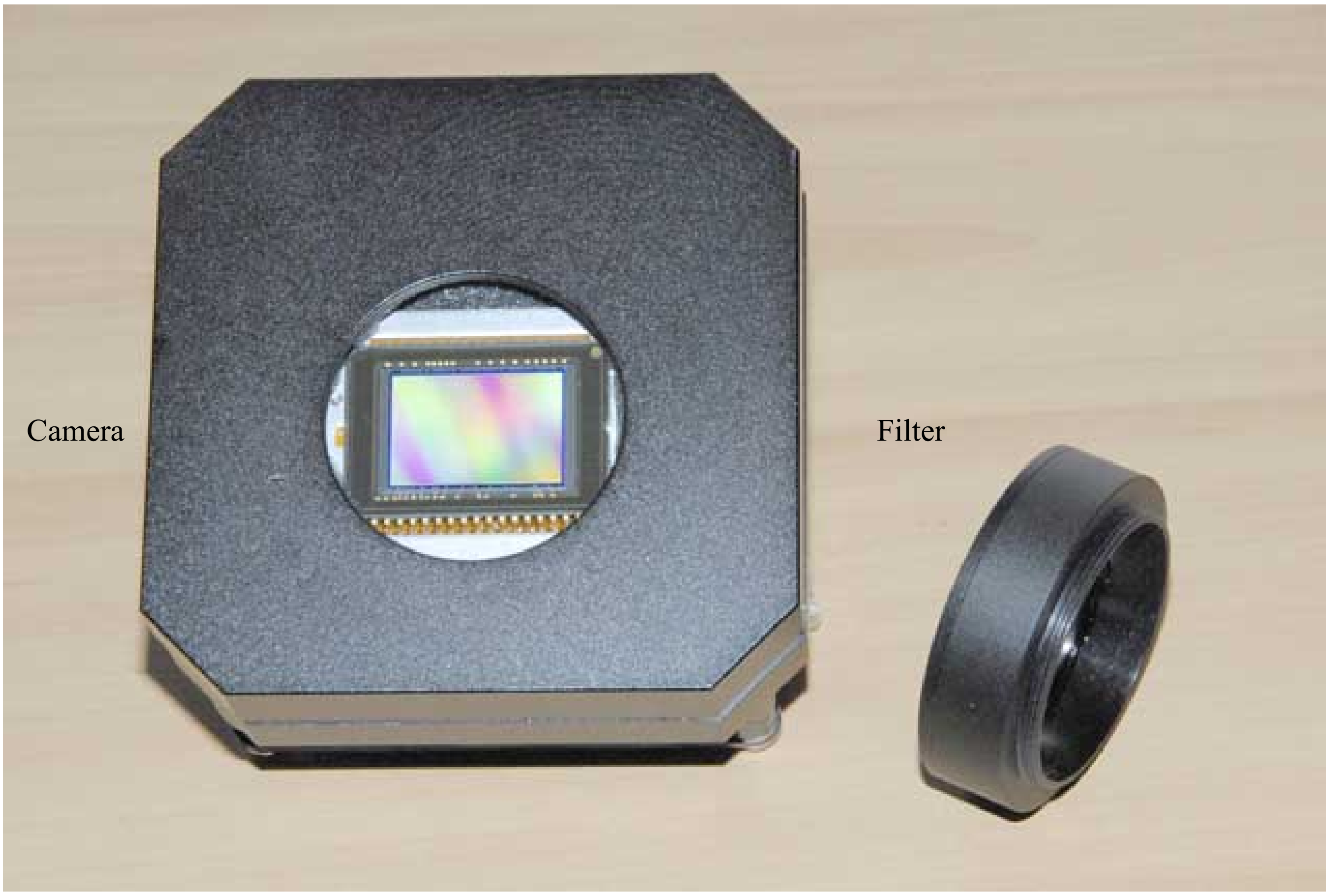
6 – Svideo cable

7 – DC Power cable

8 – *Plug pack supply

* *Model and power rating may vary.*

Removing the Filter/nose piece.



Just remove the filter like any other filter by unscrewing the nose piece anticlockwise

<u>**CAUTION :**</u>

Remove power to the TEC and wait **<u>5 minutes</u>** before removing the filter/nose piece.
Re connect power to TEC ***<u>ONLY</u>*** when filter is re fitted.

Never remove the filter/nose piece when camera has been on for more than 5 minutes.
This will cause moisture to accumulate inside the camera which may lead to CCD icing/frosting or may even cause camera failure in time.

2) <u>The connections :</u>

Connect Svideo leads from the Camera to the Regulator. The Sockets are both 4 pin.

Next connect the DC cable from the TEC cooler socket of the camera to the Regulator. The sockets are both 1 pin.

You should now have a similar image as this one on the right.

The USB socket accepts only USB2.0 interface and cables, as the camera operates at very high speeds and requires the right type of interface and cables

Lastly, connect the power supply to the “Input” of the Regulator..

The camera is ready for imaging

3) **How does a CCD camera work :**

Before we look at how to operate the camera, lets look at some basic theory of the CCD camera.
What is a CCD camera ?, well, its similar to your DSLR or pocket digital camera, except that its been designed specifically to do only one function.
The astronomical camera is a specialized instrument that is specifically made to collect as much photons as possible while at the same time maintain the lowest temperature it can for the CCD sensor to obtain the lowest noise possible.

The CCD image sensors can be implemented in several different architectures. The most common are full-frame, frame-transfer and interline. The distinguishing characteristic of each of these architectures is their approach to the problem of shuttering.
In a full-frame device, all of the image area is active and there is no electronic shutter. A mechanical shutter must be added to this type of sensor or the image will smear as the device is clocked or read out.

With a frame transfer CCD, half of the silicon area is covered by an opaque mask (typically aluminium). The image can be quickly transferred from the image area to the opaque area or storage region with acceptable smear of a few percent. That image can then be read out slowly from the storage region while a new image is integrating or exposing in the active area. Frame-transfer devices typically do not require a mechanical shutter and were a common architecture for early solid-state broadcast cameras. The downside to the frame-transfer architecture is that it requires twice the silicon real estate of an equivalent full-frame device; hence, it costs roughly twice as much.

The interline architecture extends this concept one step further and masks every other column of the image sensor for storage. In this device, only one pixel shift has to occur to transfer from image area to storage area; thus, shutter times can be less than a microsecond and smear is essentially eliminated. The advantage is not free, however, as the imaging area is now covered by opaque strips dropping the fill factor to approximately 50% and the effective quantum efficiency by an equivalent amount. Modern designs have addressed this deleterious characteristic by adding microlenses on the surface of the device to direct light away from the opaque regions and on the active area. Microlenses can bring the fill factor back up to 90% or more depending on pixel size and the overall system's optical design.

The choice of architecture comes down to one of utility. If the application cannot tolerate an expensive, failure prone, power hungry mechanical shutter, then an interline device is the right choice. Consumer snap-shot cameras have used interline devices. On the other hand, for those applications that require the best possible light collection and issues of money, power and time are less important, the full-frame device will be the right choice. Astronomers tend to prefer full-frame devices. The frame-transfer falls in between and was a common choice before the fill-factor issue of interline devices was addressed. Today, the choice of frame-transfer is usually made when an interline architecture is not available, such as in a back-illuminated device.

CCD's containing grids of pixels are used in digital cameras, optical scanners and video cameras as light-sensing devices. They commonly respond to 70% of the incident light (meaning a quantum efficiency of about 70%) making them far more efficient than photographic film, which captures only about 2% of the incident light.
Most common types of CCD's are sensitive to infrared light, which allows infrared photography, night-vision devices, and zero lux (or near zero lux) video-recording/photography.

Because of their sensitivity to infrared, CCD's used in astronomy are usually cooled to liquid nitrogen temperatures, because infrared black body radiation is emitted from room-temperature sources. One other consequence of their sensitivity

to infrared is that infrared from remote controls will often appear on CCD-based digital cameras or camcorders if they don't have infrared blockers. Cooling also reduces the array's dark current, improving the sensitivity of the CCD to low light intensities, even for ultraviolet and visible wavelengths.
Due to the high quantum efficiencies of CCD’s, linearity of their outputs (one count for one photon of light), ease of use compared to photographic plates, and a variety of other reasons, CCD’s were very rapidly adopted by astronomers for nearly all UV-to-infrared applications.

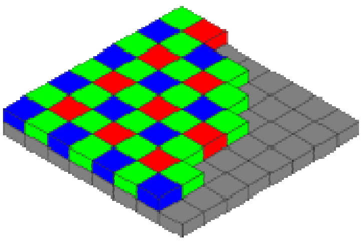
Thermal noise, dark current, and cosmic rays may alter the pixels in the CCD array. To counter such effects, astronomers take an average of several exposures with the CCD shutter closed and opened. The average of images taken with the shutter closed is necessary to lower the random noise. Once developed, the “dark frame” average image is then subtracted from the open-shutter image to remove the dark current and other systematic defects in the CCD (dead pixels, hot pixels, etc.). The Hubble Space Telescope, in particular, has a highly developed series of steps (“data reduction pipeline”) used to convert the raw CCD data to useful images.

CCD cameras used in astrophotography often require sturdy mounts to cope with vibrations and breezes, along with the tremendous weight of most imaging platforms. To take long exposures of galaxies and nebulae, many astronomers use a technique known as auto-guiding. Most autoguiders use a second CCD chip to monitor deviations during imaging. This chip can rapidly detect errors in tracking and command the mount's motors to correct for them.

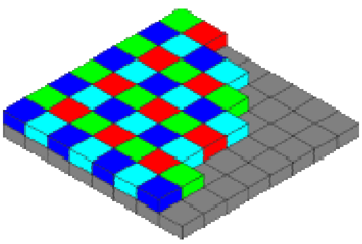
An interesting and unusual astronomical application for CCD’s, is called "drift-scanning", where you use a CCD to make a fixed telescope behave like a tracking telescope and follow the motion of the sky. The charges in the CCD are transferred and read in a direction parallel to the motion of the sky, and at the same speed. In this way, the telescope can image a larger region of the sky than its normal field of view. The Sloan Digital Sky Survey is the most famous example of this, using the technique to produce the largest uniform survey of the sky yet.

Colour Sensors
Digital colour cameras generally use a Bayer mask over the CCD. Each square of four pixels has one filtered red, one blue, and two green (the human eye is more sensitive to green than either red or blue). The result of this is that luminance information is collected at every pixel, but the colour resolution is lower than the luminance resolution.

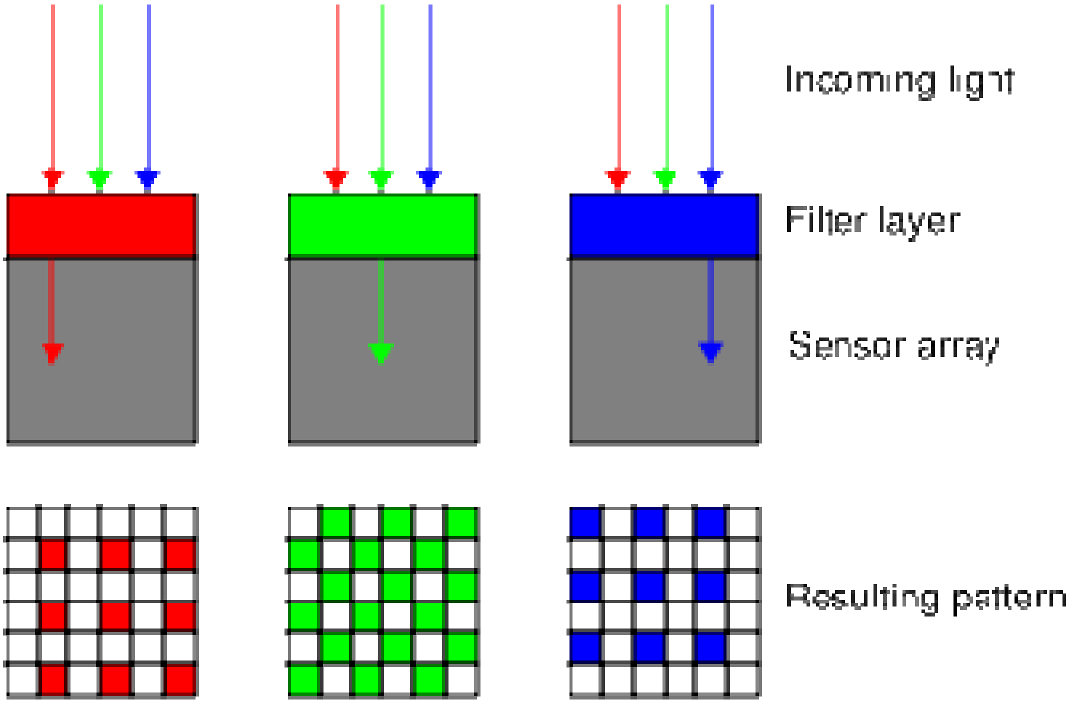
A Bayer filter mosaic is a colour filter array (CFA) for arranging RGB colour filters on a square grid of photo sensors. Its particular arrangement of colour filters is used in most single-chip digital image sensors used in digital cameras, camcorders, and scanners to create a colour image. The filter pattern is 50% green, 25% red and 25% blue, hence is also called GRGB or other permutation such as RGGB.
It is named after its inventor, Dr. Bryce E. Bayer of Eastman Kodak. Bayer is also known for his recursively defined matrix used in ordered dithering.



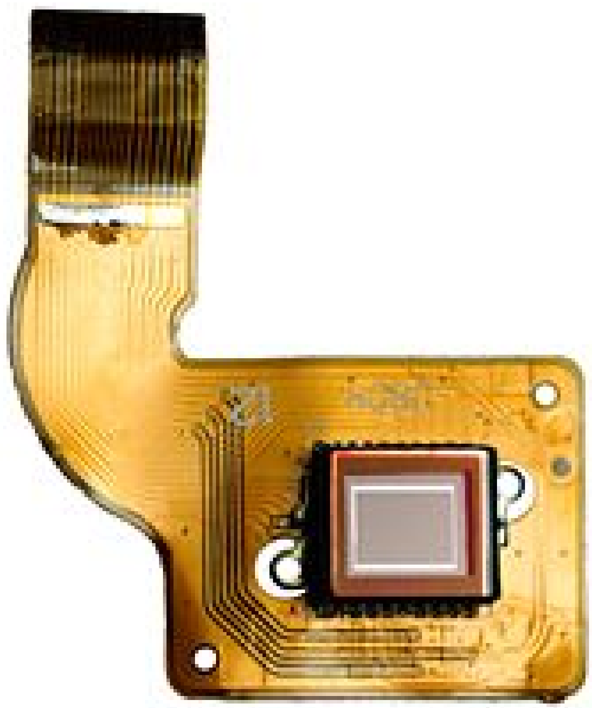
A Bayer filter on a CCD



An RGBE filter on a CCD



Bayer pattern on CCD sensor showing only the constituant colors passing thru.



An Basic CCD Color sensor.

CCD Sensor sizes

Sensors (CCD / CMOS) are often referred to with an imperial fraction designation such as 1/1.8" or 2/3", this measurement actually originates back in the 1950's and the time of Vidicon tubes. Compact digital cameras and Digicams typically have much smaller sensors than a Digital SLR and are thus less sensitive to light and inherently more prone to noise.

Type	Aspect Ratio	Width mm	Height mm	Diagonal mm	Area mm^2	Relative Area
1/6"	4:3	2.300	1.730	2.878	3.979	1.000
1/4"	4:3	3.200	2.400	4.000	7.680	1.930
1/3.6"	4:3	4.000	3.000	5.000	12.000	3.016
1/3.2"	4:3	4.536	3.416	5.678	15.495	3.894
1/3"	4:3	4.800	3.600	6.000	17.280	4.343
1/2.7"	4:3	5.270	3.960	6.592	20.869	5.245
1/2"	4:3	6.400	4.800	8.000	30.720	7.721
1/1.8"	4:3	7.176	5.319	8.932	38.169	9.593
2/3"	4:3	8.800	6.600	11.000	58.080	14.597
1"	4:3	12.800	9.600	16.000	122.880	30.882
4/3"	4:3	22.500	18.000	28.814	405.000	101.784
Other image sizes as a comparison						
APS-C	3:2	25.100	16.700	30.148	419.170	105.346
35mm	3:2	36.000	24.000	43.267	864.000	217.140
645	4:3	56.000	41.500	69.701	2324.000	584.066

4) **Taking your first image.**

First you need to connect the camera to the telescope by either sliding the nose/filter of the camera into the focuser and tightning the focuser locking screw(s), or by attaching it directly to a T thread adapter to your telescope.

Next point the telescope to a bright star or object and take a short exposure, say 2 seconds using your softwares focus function. You should see some sort of image appear, and you will now need to make adjustments in focus to get a sharp image. Once you have a semi good focus, you will need to decrease the exposure time in order to create a smaller star image, so that its easier to see if fine focusing is required. The addition of a Hartman Mask is a great tool to have when focusing, or any other focusing tools that may be available, like using FWHM for focusing. It is a good idea to zoom in on your star image, as you will see finer detail which will allow you to in turn, produce a better focus.

Once focus is obtained, move the telescope to the object you wish to image. Take an initial image so you can place the object in the centre of the CCD frame by moving the telescope in the direction required.
Once you have focus, and alignment, we are ready to take an image. Setup your exposure times, Gain and Offsett and start your session.

What is Offset and Gain that is used to setup the camera ?.

Gain is used to increase the levels sent from the CCD before its read be the A/D converter to preserve very small and minute levels. For example, lets say the data 0.1, 0.3, 1 and 1.2 is being sent. Well, if no gain was used, the A/D converter will only see 0, 0, 1, 1 because it cannot do fractions. So the end result is the same intensity being displayed, and you loose the subtle changes. But by using gain, we increase the values to a point where the A/D converter does recognise them, e.g. from 0.1, 0.3, 1 to 1, 3, 10, 12 etc.

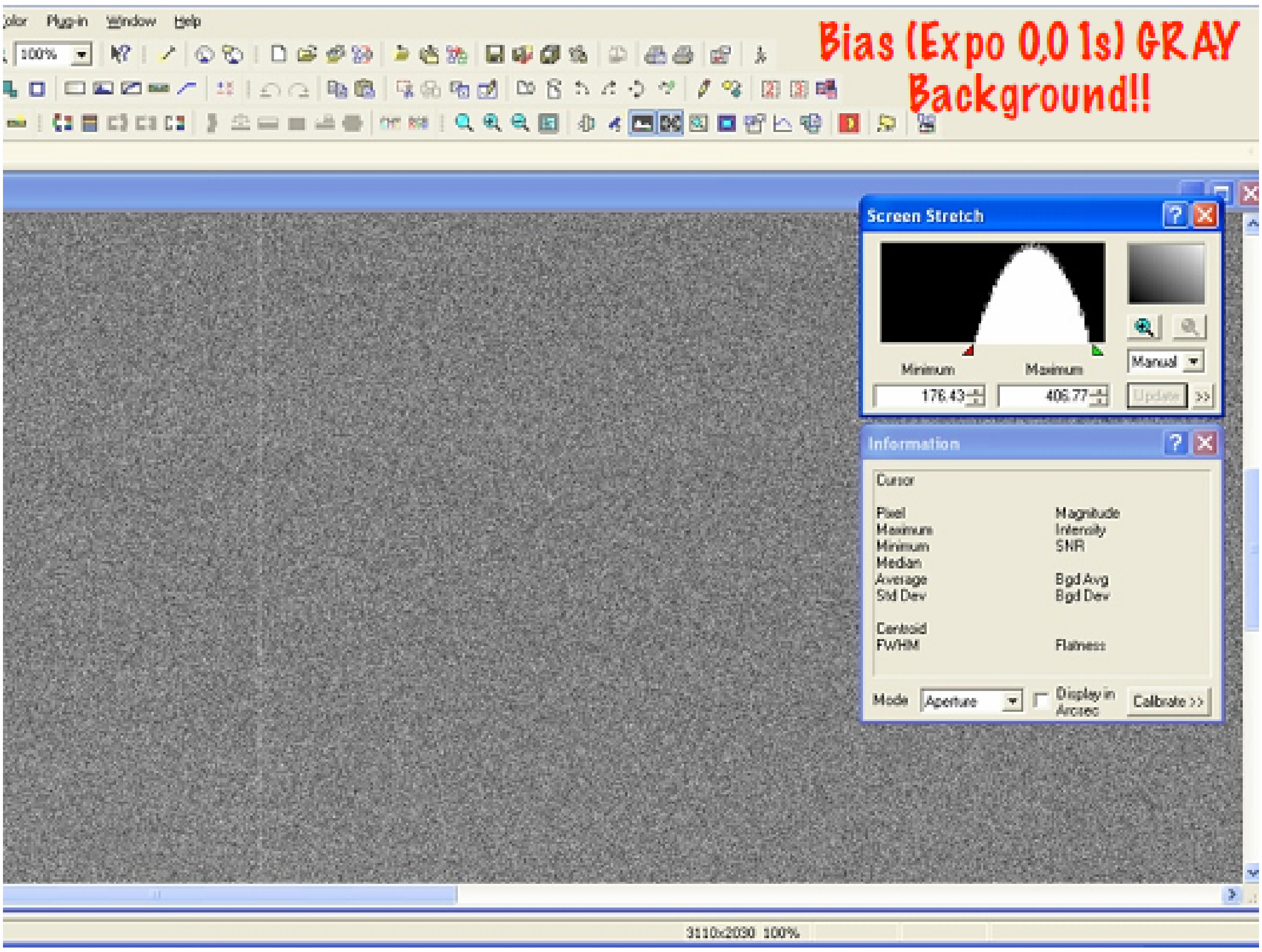
Offsett is used to help and setup the right point so the A/D converter is able to convert the data so as to avoid any values lower than 1. It does this by providing a DC voltage in the data path.
But be aware, an increase of gain has an effect on Dynamic range and the steps between subtle changes is decreased.

Finding your Offset/Gain

Connect your camera to your PC and allow the camera to cool down for 10 minutes. Make sure you have the lens cap on the front of the camera.

A setting of, Gain 50 and Offset to 125 is a good default to start with. Also make sure to use "Low" download speed for downloading to your PC.

Take a Bias Frame (With the shortest possible time in your exposure settings) by selecting "Bias frame" from your camera control software menu.
You should have an image as shown below when finished.



Thanks to CS Christoph for this image

If your image appears black, you will need to change your Offset by adding a small number. Say, from 125 to 130
Redo another Bias frame and re check the image again. If its still black, add a further value and re test again, etc.
You will want a value between 400 to 1000 as a Maximum Pixel Value, before your good to go.
In time you will be able estimate your values and just enter an offsett and gain with experience.
Now with the Gain and Offsett taken care of, you can proceed to take your image.

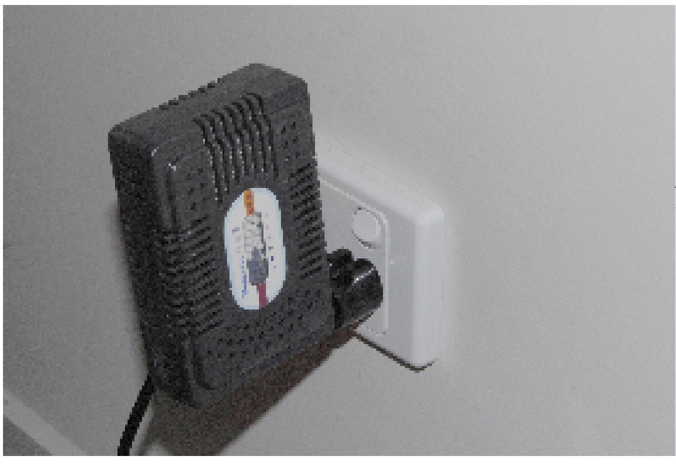
Please refer to your Processing software to process your images.

5) How to use the Silicone Gel heater for removing moisture from the camera.

After using your QHY-8, you may either, leave the filter on and just pack the camera away or if you used various filters during your imaging session, and you have opened the camera seal by removing the filter/nose piece, then you may use the Silicone Gel heater because you may have some moisture within the camera cavity that must be removed before the next imaging session.

This can be easily be done by first releasing the AC socket prongs by sliding the button on the side of the Gel heater.
Depending on your country, you may need a socket changer to fit your power point socket.

Optional Socket converter



Next, just plug in the heater and allow to heat at least one hour.

When the unit is ready, just remove from the wall socket and place inside the Air sealed case along with the camera.

Make sure you remove either the filter, or rubber grommet found on the side of the camera before placing it in the case.

You may now close the case and store it away. The camera will now be dry and ready for its next imaging session.

6) Cleaning

Cleaning the camera is easy and straight forward. Please try to minimise sensor cleaning to a minimum.

1) Make sure power has been removed and has been removed for at least 1 hour before removing the filter and proceeding to clean the sensor.
2) Unscrew and remove the filter attached to the camera by firmly gripping the filter and gently rotating it Anti clockwise.
3) Using a very soft cloth, place a drop of Methylated Spirits (Or similar) on to the cloth, and gently clean the CCD surface of any dust or residue that may be evident.
4) Hold the camera with the CCD sensor facing down and use a blower bulb to blow out any dust or fibres that may have been left behind.
5) Repeat the steps for the filter if it needs it.
6) If you have the heated gel pack and sealed box, then place the camera inside with the heated gel pack, and when finished, re fit the filter to once again seal the camera. If you don't have the gel pack, just re tighten filter and you're done.

7) Camera Features

A Proven and documented High performance multi-function electronic design, and a built in USB2.0, assures high speed data transfer rates yet provides a very small footprint that produces very little noise, this is due to component count being kept to a bare necessity, and in turn reducing heat and noise. Many tests have been conducted by many amateurs, with great rock solid results

Double Correlated Sampling along with the ultra low kTC noise gives the product a very smooth image output.

The TEC used in the QHY-8 is a large 40mm x 40mm 2 stage Peltier (2 Peltier's sand witched together), unlike other cameras that use the smaller 20mm x 20mm or 10mm x 10mm single or dual stage TEC's.
This allows the sensor to cool faster and maintain a better stability due to changes in component temperatures inside the camera.
Those cameras struggle to cool the sensor due to the current/power rating of the TEC, there is no problem with the QHY-8 cooling down in this area.

The fan mounted on the back is a low vibration and low noise 80mm unit. It provides plenty of cooling to the heatsink and produces no vibration to your system. Compare this with many cameras using the smaller 20mm and 40mm fans. Without proper cooling it will lead to excess heat within the camera, which in turn affects noise levels to the CCD sensor. The QHY series do not suffer from excess heat within the camera.

Other cameras try to lower heat by reducing the power to the TEC so the cooling fan/heatsinks can cope, which in turn drops the efficiency of the cooling system during warm or hot nights.

Ultra low noise Preamp Readout, noise is 8 -12e

Programmable Gain Amplifier with analog and digital stages allows gain to be controlled by the user.

16 bit AD converter allowing 65535 contrast levels.

By having the power supply and regulation (DC-101) externally and away from the camera electronics, we remove all unwanted noise and heat away from the heat sensitive components inside.

This effectively lowers the thermal and electrical noise further within the camera and allows for higher sensitivity overall.

Exposure steps are adjustable down to as low as 1ms increments.

High speed transfer data rate by using the USB2.0 interface. Normal download is at 600 KPixels/s. Fast preview mode is 6 Mpixels/s (Allowing fast focus, or object alignment).
This speed allows you to download the whole 6 Mpixel image within 2 seconds.

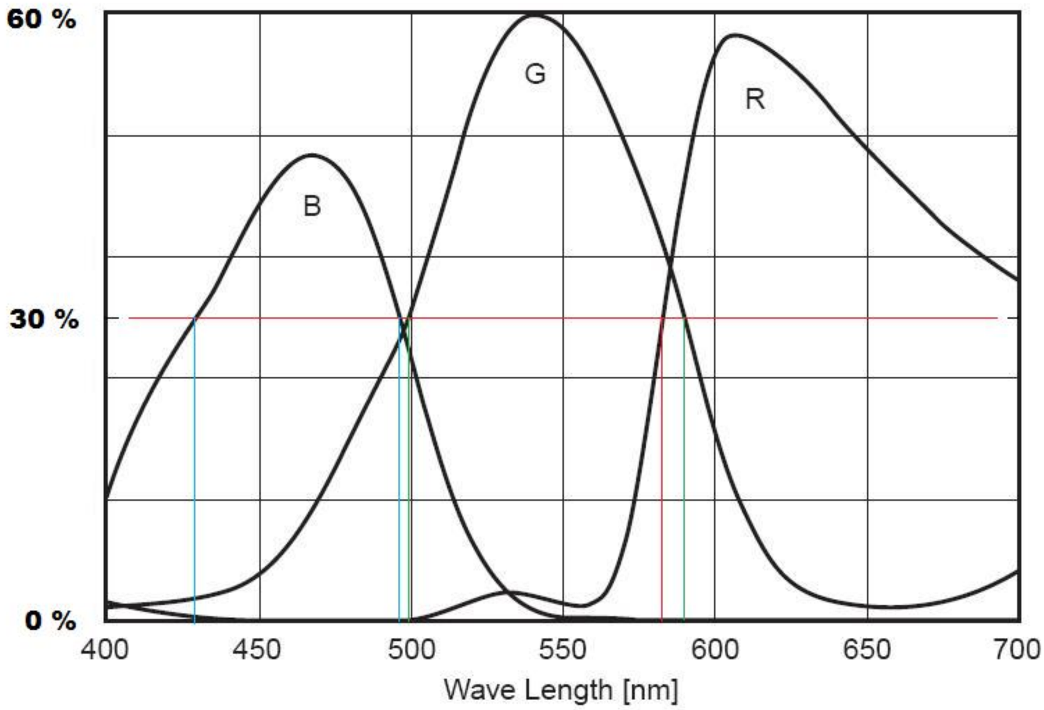
The Progressive CCD is the preferred choice for the CCD sensor. Progressive CCD scan design produces less noise and temperature within the camera, plus the exposures are evenly illuminated, even for short exposures.

Interlaced sensors distort the exposure by unevenly exposing the odd and even fields of the CCD sensor during short exposures.
This may directly affect your Flat frames and Bias frames, because while the data is read from the odd field, the even field is STILL being exposed, with up to 30 seconds with some slower PC's, resulting in an uneven exposure.
This is why mechanical shutters are required by manufacturers.

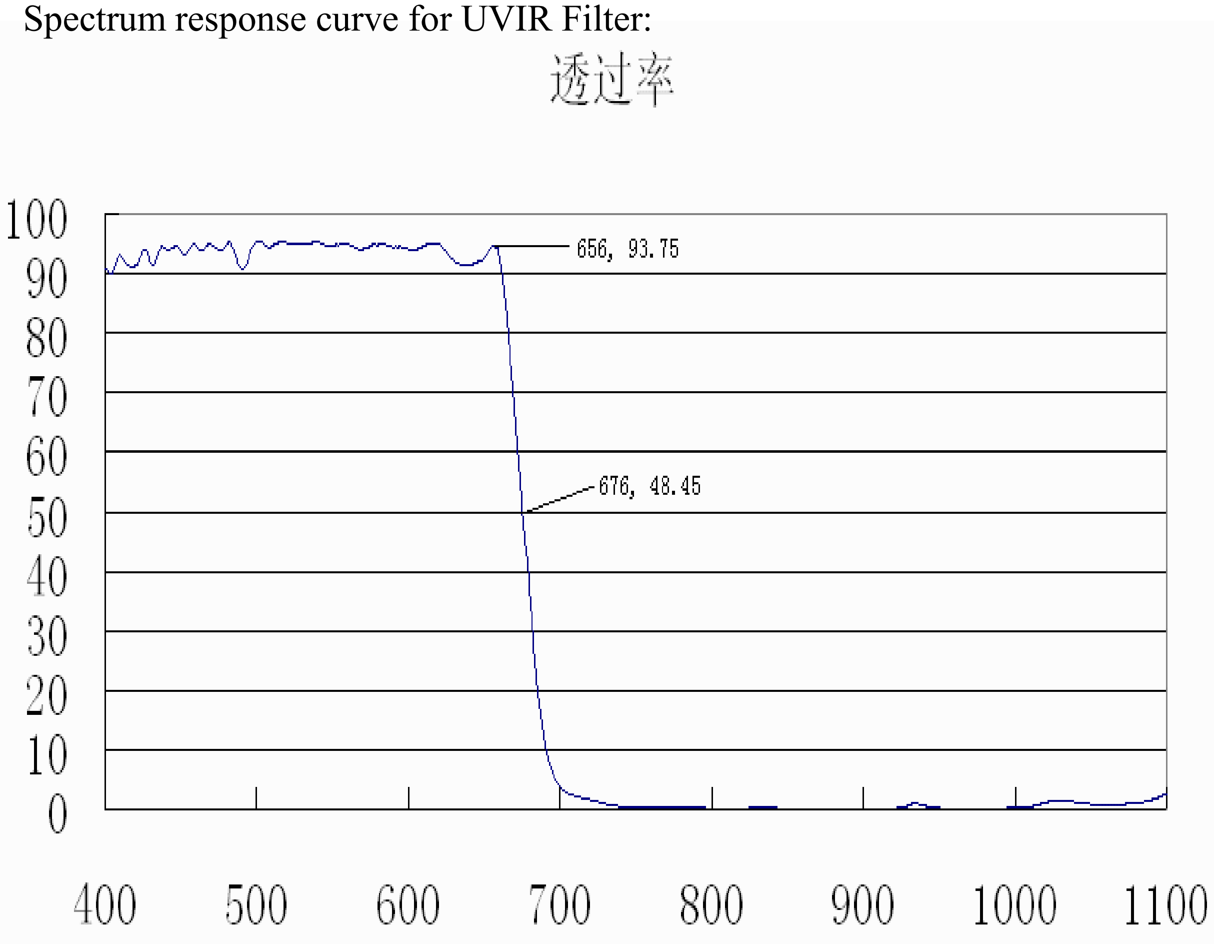
8) Specifications: QHY-8

CCD Sensor:	Sony ICX-453
Total pixel:	3110 x 2030
Active pixels:	3032 x 2016
Pixel Size:	7.8um x 7.8um square
Colour method:	RGB BAYER film on CCD
Effective sensor area:	28.4 mm diagonal
Readout noise:	8 -12 e @600Kpixel/s
QE:	60% at Green (Peak) , 50% at Blue and H.a
QE Boost:	Microlensing on chip
Scanning method:	Progressive Scan
NABG:	-110dB
Cooling System:	2-Stage TEC (Up to -45C below ambient)
Power consumption:	12V 3.3A
Additional Cooling:	Built in 12V low noise FAN
Mounting Threads:	M42, 0.75 pitch

Quantum Efficiency ICX-453 Sony Sensor



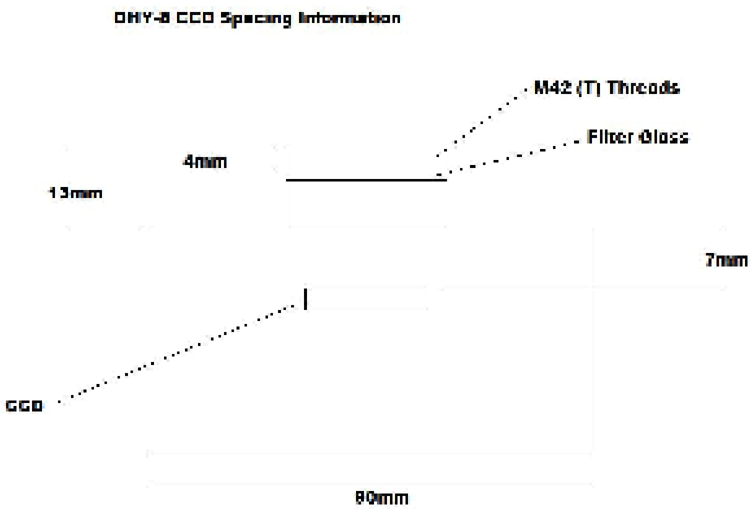
Spectrum response curve for UVIR Filter:



Wavelength in [nm]

9) <u>Camera measurements :</u>

CCD Offset Dimensions:



Dimensions 90 x 90 x 55 mm

From CCD to M42 Threads, 7mm + 13mm = 20mm +/- 2mm

10) Problems and fixes

Q: Why does my sensor fog up?

A: This will NOT occur if the filter is firmly attached to the camera, but when the sealed chamber has been opened by removing the Filter, you allow the local air around you that contains a higher % of humidity inside the chamber then what was originally sealed.

But it is easily rectified by simply re sealing the camera by re fitting the filter back on firmly in a dry environment, like near a heater, or other dry hot air.

Q: My sensor forms Ice crystals on it why ?.

A: This is caused by residue left on the sensor either after a poor Sensor clean, or by some other residue that may have formed after many hours of use during high humidity.

To rectify, open the CCD chamber by removing the filter/nose piece, then apply a small drop of alcohol or similar cleaning fluid to the CCD glass surface, and gently wipe the whole sensor, even the corners. If you leave anything behind, then this will freeze and create the ice pattern on your sensor.

Once you have cleaned and re fitted the filter back on (Using the dry hot air method), the camera is again ready for action. Just a note, it is important to understand if the sensor is clean and the chamber is sealed correctly, the CCD will never fog or ice up.

Q: The back of the camera is very hot, yet the front is cold, why?

A: The QHY-8 is fitted with a dual stage Peltier device. This device is able to change temperature of anything it is attached too, a further -40 degrees C from ambient temperature. So by placing directly behind the CCD, we cool it down a further 40 degrees

and enjoy the benefits of low noise as a consequence. But, what it cools on one side, the Peltier heats +40 deg C on the other side of itself. Here is where we place the heat sink and fan, and this is where all the heat is dissipated and released to atmosphere.

Q: I use my camera remotely, can I conserve battery power and still run my QHY-8 for hours?

A: Yes, by reducing the amount of voltage/current to the TEC (Peltier), you increase your operating time. The only difference you will notice is that it will take a little longer to reach its operating temperature of around -40 Deg C Delta.

Q: Is the cable that supplies power to the camera a Svideo cable as used in TV’s?.

A: Yes, so if you ever lose, break, or just want to extend the length, you can use a standard Svideo lead.

11) Glossary:

Charge Amplifier:

Charge amplifier is a circuit whose equivalent input impedance is capacitance so that it provides a very high value of impedance at low frequencies. Thus contrary to what its name may suggest, a charge amplifier does not amplify the electric charge present at its input. Its function is actually to obtain a voltage, proportional to that charge and yield a low output impedance. Thus, it is a charge-to-voltage converter. Charge amplifiers are often found in the readout circuitry of CCD imagers. In read-out circuits the objective is usually to measure the very small charge stored within an in-pixel capacitor, despite the capacitance of the circuit-track to the readout circuit being a couple of orders of magnitude greater than the in-pixel capacitor.

Frame transfer CCD is a specialized CCD, often used in astronomy, designed for high exposure efficiency and correctness.
The normal functioning of a CCD, astronomical or otherwise, can be divided into two phases: exposure and readout. During the first phase, the CCD passively collects incoming photons, storing electrons in its cells. After the exposure time is passed, the cells are read out one line at a time.
During the readout phase, cells are shifted down the entire area of the CCD. While they are shifted, they continue to collect light. Thus, if the shifting is not fast enough, errors can result from light that falls on a cell holding charge during the transfer. These errors are referred to as "vertical smear" and cause a strong light source to create a vertical line above and below its exact location. In addition, the CCD cannot be used to collect light while it is being read out. Unfortunately, a faster shifting requires a faster readout, and a faster readout can introduce errors in the cell charge measurement, leading to a higher noise level.
A frame transfer CCD solves both problems: it has a hidden, not normally used, area containing as many cells as the area exposed to light. Typically, this area is covered by a reflective material such as aluminium. When the exposure time is up, the cells are transferred very rapidly to the hidden area.

Here, safe from any incoming light, cells can be read out at any speed one deems necessary to correctly measure the cells' charge. At the same time, the exposed part of the CCD is collecting light again, so no delay occurs between successive exposures.
The downside of such a CCD is the higher cost: the cell area is basically doubled, and more complex control electronics are needed.

Quantum Efficiency (QE) is a quantity defined for a photosensitive device such as photographic film or a charge-coupled device (CCD) as the percentage of photons hitting the photo reactive surface that will produce an electron–hole pair. It is an accurate measurement of the device's electrical sensitivity to light. Since the energy of a photon depends on (more precisely, is inversely proportional to) its wavelength, QE is often measured over a range of different wavelengths to characterize a device's efficiency at each photon energy. Photographic film typically has a QE of much less than 10%, while CCD's can have a QE of well over 90% at some wavelengths.

Dark current is the relatively small electric current that flows through a photosensitive device such as a photomultiplier tube, photodiode, or charge-coupled device even when no photons are entering the device. It is referred to as reverse bias leakage current in non optical devices and is present in all diodes. Physically, dark current is due to the random generation of electrons and holes within the depletion region of the device that are then swept by the high electric field.

Dynamic Range of a CCD is its ability to measure and differintiate between light and dark (Contrast range).

dynamic range of a CCD image sensor

The dynamic range (DR) is defined as the ratio of the maximum possible signal (full well capacity), versus the total noise signal (in the dark). The data is expressed in decibels [dB] or is dimensionless:

$$DR_{CCD} = \frac{\text{full well capacity}}{\text{rms noise}_{dark}}$$

$$DR_{CCD} = 20 \cdot \log\left(\frac{\text{full well capacity}}{\text{rms noise}_{dark}}\right) \text{ [dB]}$$

Full Well Capacity is the largest charge a pixel can hold before saturation, which results in degradation of the signal. When the charge in a pixel exceeds the saturation level, the charge starts to fill adjacent pixels (Over flows), a process known as Blooming. The camera also starts to deviate from a linear response and hence compromises the quantitative performance of the camera. Larger pixels have lower spatial resolution (Blocky image) but their greater well capacity offers higher dynamic range which can be important for some applications.

Bias Frame is an image made with an integration of zero seconds and shutter closed. It contains the amplifier zero-point offset, the random readout noise from the amplifier and the noise from camera electronics

Dark Frame is a technique used to identify and remove noise in a CCD imaging device. This is done by recording without exposing the CCD, usually by leaving the shutter closed and putting the CCD in a dark room. These "dark frames" are then subtracted from subsequent images to correct for extraneous noise in the CCD. The noise is often caused by hot pixels. Hot pixels are sensors on the CCD with higher than normal charge leakage. On long exposure, they can appear as bright pixels.
Sensors on the CCD that always appears as brighter pixels are called stuck pixels while sensors that only brighten up after long exposure are called hot pixels.

Image byGerhard Bachmayer