G0 and G1 CCD Camera

User's Guide

moravian instruments

Version 3.0

Modified on December 15th, 2015

Moravian Instruments

Masarykova 1148

763 02 Zlín

Czech Republic

tel./fax: +420 577 107 171

internet: http://www.gcxxd.com/

e-mail: info@gxccd.com

Table of Contents

Introduction

Thank you for choosing the Moravian Instruments CCD camera. These cameras were developed to be small, lightweight and easily operated. Despite their compactness and simplicity, they are very sensitive for use in low-light imaging applications in astronomy, microscopy and similar areas.

G0 and G1 cameras digitize image with 16 bit precision to fully exploit CCD chip dynamic range. Still the pixel digitization rate reaches 8 Mpx/s in fast read mode – downloading of image containing hundreds thousands pixels takes only a small fraction of a second. Slow read mode on the other hand ensures very low read noise, approaching the read noise limit of the CCD chip itself, and still provides more than 2.5 Mpx/s digitization speed.

Also important design goal of G0 and G1 cameras was USB-powered operation. Camera is attached to the host computer only via single USB cable, which provides both camera-to-host communication and camera power. No separate power supply is used with G1 cameras.

Both G0 and G1 series of CCD cameras provide also the RJ-12 connector beside the USB-B connector, which allows direct connection of the camera head and the telescope mount equipped with the standard “autoguider” port. This connector (together with other camera features like very fast download, compact and lightweight construction, USB powered operation etc.) makes using of these cameras for guiding of telescope mount very simple. Using of G0 or G1 CCD for guiding is described later in this manual.

Simplicity, compactness and quick image download took precedence to some other features, so G0 and G1 series of CCD cameras lack mechanical shutter and filter wheel. Also power provided by USB cable is not sufficient for power-hungry thermoelectric (Peltier) coolers. This is why the CCD chip in these cameras cannot be cooled below ambient temperature. However, G1 cameras employ a small fan, which forces air flow inside the camera head and removes the heat generated by camera electronics. The CCD temperature can be lowered by many degrees Celsius compared to sealed designs, which results to lowering of CCD thermal noise by a factor of two or more.

Please note the G0 and G1 CCD cameras are designed to work in cooperation with a host Personal Computer (PC). Computer is necessary for operation control, image download, processing and storage as well as for guiding. To operate G0 or G1 CCD camera, you need a computer which:

1. Is compatible with a PC standard.
2. Runs a modern 32 or 64-bit Windows operating system.

   Drivers for 32-bit and 64-bit Linux systems are also provided, but camera control and image processing software, supplied with the camera, requires Windows operating system.

3. Provides at last one free USB port.

   The G0 and G1 CCD cameras are designed to operate with USB 2.0 high-speed (480 Mbps) hosts. Although they are fully backward compatible with USB 1.1 full-speed (12 Mbps) hosts, image download time can be significantly longer if USB 1.1 connection is used.

   A simple and cheap device called USB hub can expand number of available USB port. Typical USB hub occupies one computer USB port and offers four free ports. Make sure the USB hub is USB 2.0 high-speed compatible.

   But keep on mind that if more USB devices connected to one hub need to communicate with a host PC, USB hub shares its single up-link line to the host PC. Although G0 and G1 CCD cameras can operate through a USB hub, it can negatively affect the camera performance, like download time etc. It is recommended to connect other USB devices through USB hub (e.g. the mouse) and to provide the camera a direct USB connection to the host PC.

   Also note the G0 and G1 cameras are powered from the host PC through the USB cable. Unpowered USB hub may not provide enough current to operate the camera. Always use USB hub with its own power supply to connect the camera. G0 and G1 camera power considerations are described later.

4. Alternatively it is possible to use the Gx Camera Ethernet Adapter. This device can connect up to four Gx cameras of any type (not only G0 and G1, but also G2, G3 and G4) and offers 1 Gbps and 10/100 Mbps Ethernet interface for direct connection to the host

PC. Because the PC then uses TCP/IP protocol to communicate with the cameras, it is possible to insert e.g. WiFi bridge or other networking device to the communication path.

The G0 or G1 CCD camera must be connected to some optical system (e.g. the telescope) to capture images.

G1 cameras are equipped with CS-thread adapter, which allows usage of CCTV lens with C/CS thread with the camera (it is necessary to use 5 mm distance ring for C-mount lenses). Adapter for 1.25” telescope focuser is screwed into the CS-thread adapter adapter.

G0 cameras are designed to be attached to the 1.25” telescope focuser only and CCTV lenses cannot be directly used.

Camera Technical Specifications

The G0 series of CCD cameras comprises of the following models:

Model	G0-0300	G0-0300C	G0-0800	G0-0800C
CCD chip	ICX424AL	ICX424AQ	ICX204AL	ICX204AK
Resolution	656×494	656×494	1032×778	1032×778
Pixel size	7.4×7.4 µm	7.4×7.4 µm	4.65×4.65 µm	4.65×4.65 µm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	4.9×3.7 mm	4.9×3.7 mm	4.8×3.6 mm	4.8×3.6 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

Model	G0-2000	G0-2000C
CCD chip	ICX274AL	ICX274AQ
Resolution	1628×1236	1628×1236
Pixel size	4.4×4.4 µm	4.4×4.4 µm
Read mode	Progressive	Progressive
Dimension	7.2×5.4 mm	7.2×5.4 mm
Color mask	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0

The G1 series of CCD cameras comprises of the following models:

Model	**G1-0300**	**G1-0300C**	**G1-0301**	**G1-0301C**
CCD chip	ICX424AL	ICX424AQ	ICX414AL	ICX414AQ
Resolution	656×494	656×494	656×494	656×494
Pixel size	7.4×7.4 µm	7.4×7.4 µm	9.9×9.9 µm	9.9×9.9 µm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	4.9×3.7 mm	4.9×3.7 mm	6.5×4.9 mm	6.5×4.9 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

Model	**G1-0800**	**G1-0800C**	**G1-1200**	**G1-1200C**
CCD chip	ICX204AL	ICX204AK	ICX445ALA	ICX445AQA
Resolution	1032×778	1032×778	1296×966	1296×966
Pixel size	4.65×4.65 µm	4.65×4.65 µm	3.75×3.75 µm	3.75×3.75 µm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	4.8×3.6 mm	4.8×3.6 mm	4.9×3.6 mm	4.9×3.6 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

Model	**G1-1400**	**G1-1400C**	**G1-2000**	**G1-2000C**
CCD chip	ICX285AL	ICX285AQ	ICX274AL	ICX274AQ
Resolution	1392×1040	1392×1040	1628×1236	1628×1236
Pixel size	6.45×6.45 µm	6.45×6.45 µm	4.4×4.4 µm	4.4×4.4 µm
Read mode	Progressive	Progressive	Progressive	Progressive
Dimension	9.0×6.7 mm	9.0×6.7 mm	7.2×5.4 mm	7.2×5.4 mm
Color mask	Not present	RGB (Bayer)	Not present	RGB (Bayer)
Interface	USB 2.0	USB 2.0	USB 2.0	USB 2.0

CCD Chip

Sensitivity is an important feature of any CCD camera, no matter if it is used as an imaging camera or automatic guider. Imaging camera must not waste light gathered by the optical system to provide images with as good signal/noise ratio as possible. Achieving of sufficient S/N ratio in rather short time is also important to allow perfect guiding – the necessity to accumulate light for many minutes is often unacceptable for high quality guider. This is why the G1 cameras utilize sensitive Sony CCDs.

- The CCD quantum efficiency exceeds 50%.
- The CCD read noise is very low and reaches 5 to 10 electrons RMS.
- G1 cameras support 16-bit digitization, significantly enhancing the dynamic range compared to 8-bit cameras.
- Strong anti-blooming protection keeps even bright stars round, without blooming streaks.
- G1 cameras also provide very fas readout – pixel digitization speed is 8 Mpx/s in fast read mode.

Model G0-0300 and G1-0300

G0/G1-0300 model uses progressive-scan VGA (640×480 pixels) Sony ICX424AL CCD chip.

Resolution	656 × 494 pixels
Pixel size	7.4 × 7.4 μm
Imaging area	4.9 × 3.7 mm
Color mask	Not present

Model G0-0300C and G1-0300C

G0/G1-0300C model uses progressive-scan VGA (640×480 pixels) Sony ICX424AQ CCD chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	656 × 494 pixels

Pixel size	7.4 × 7.4 µm
Imaging area	4.9 × 3.7 mm
Color mask	RGBG (Bayer mask)

Model G1-0301

G0/G1-0300 model uses progressive-scan VGA (640×480 pixels) Sony ICX424AL CCD chip.

Resolution	656 × 494 pixels
Pixel size	9.9×9.9 µm
Imaging area	6.5×4.9 mm
Color mask	Not present

Model G1-0301C

G0/G1-0300C model uses progressive-scan VGA (640×480 pixels) Sony ICX424AQ CCD chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	656 × 494 pixels
Pixel size	9.9×9.9 µm
Imaging area	6.5×4.9 mm
Color mask	RGBG (Bayer mask)

Model G0-0800 and G1-0800

G0/G1-0800 model uses progressive-scan XGA (1024×768 pixels) Sony ICX204AL CCD chip.

Resolution	1032 × 778 pixels
Pixel size	4.65 × 4.65 µm
Imaging area	4.8 × 3.6 mm
Color mask	Not present

Model G0-0800C and G1-0800C

G0/G1-0800C uses progressive-scan XGA (1024×768 pixels) Sony Super HAD ICX204AK chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	1032 × 778 pixels
Pixel size	4.65 × 4.65 µm
Imaging area	4.8 × 3.6 mm
Color mask	RGBG (Bayer mask)

Model G0-2000 and G1-2000

G0/G1-2000 model uses progressive-scan UXGA (1600×1200 pixels) Sony ICX274AL CCD chip.

Resolution	1628 × 1236 pixels
Pixel size	4.4 × 4.4 µm
Imaging area	7.2 × 5.4 mm
Color mask	Not present

Model G0-2000C and G1-2000C

G0/G1-2000C uses progressive-scan UXGA (1600×1200 pixels) Sony Super HAD ICX274AQ chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure.

Resolution	1628 × 1236 pixels
Pixel size	4.4 × 4.4 µm
Imaging area	7.2 × 5.4 mm
Color mask	RGBG (Bayer mask)

Model G1-1200

G1-1200 model uses progressive-scan HD (1280×960 pixels) Sony ICX445ALA chip. The ICX445 detector is manufactured using so-called ExView HAD technology, which enhances its sensitivity especially in red and near infra-red portion of the spectrum. Also absolute quantum

efficiency of this CCD chip very high, comparable to ICX285 based models.

Resolution	1296 × 966 pixels
Pixel size	3.75 × 3.75 µm
Imaging area	4.9 × 3.6 mm
Color mask	Not present

Model G1-1200C

G1-1200C model uses progressive-scan HD (1280×960 pixels) Sony ICX445AQA chip with Red, Green and Blue color mask (Bayer mask) applied directly on the CCD, which allows capturing of color images by single exposure. The ICX445 detector is manufactured using so-called ExView HAD technology with absolute absolute quantum efficiency comparable to ICX285 based models.

Resolution	1296 × 966 pixels
Pixel size	3.75 × 3.75 µm
Imaging area	4.9 × 3.6 mm
Color mask	RGBG (Bayer mask)

Model G1-1400

G1-1400 model uses progressive-scan SXGA (1280×1024 pixels) Sony ICX285AL chip. The ICX285 detector is manufactured using so-called ExView HAD technology, which enhances its sensitivity especially in red and near infra-red portion of the spectrum. Also absolute quantum efficiency of this CCD chip is highest from all detectors used in other G1 camera models.

Resolution	1392 × 1040 pixels
Pixel size	6.45 × 6.45 µm
Imaging area	9.0 × 6.7 mm
Color mask	Not present

Model G1-1400C

G1-1400C model uses progressive-scan SXGA (1280×1024 pixels) Sony ICX285AQ chip with Red, Green and Blue color mask (Bayer mask)

applied directly on the CCD, which allows capturing of color images by single exposure. The ICX285 detector is manufactured using so-called ExView HAD technology, which enhances its sensitivity especially in read and near infra-red portion of the spectrum.

Resolution	1392 × 1040 pixels
Pixel size	6.45 × 6.45 µm
Imaging area	9.0 × 6.7 mm
Color mask	RGBG (Bayer mask)

Camera Electronics

16-bit A/D converter with correlated double sampling ensures high dynamic range, in fact exceeding the pixel well capacity of the used CCD. Fast USB interface ensures image download time within a small fraction of second.

Maximum length of single USB cable is 5 m. This length can be extended to 10 m by using single USB hub or active USB extender cable. Up to 5 hubs or active extenders can be used in one connection.

Gx Camera Ethernet Adapter device allows connection of up to four Gx cameras of any type through Ethernet interface and TCP/IP network. Because TCP/IP protocol can be routed, the distance between camera and host PC can be virtually unlimited.

ADC resolution	16 bits
Sampling method	Correlated double sampling
Read modes	Fast (8 Mpx/s)
	Slow (2.5 Mpx/s)
Computer interface	USB 2.0 high-speed
	USB 1.1 full-speed compatible

1. Camera driver allows arbitrary software binning up to 4×4 pixels of downloaded images.

Image download time and system read noise depends on the CCD chip used in particular camera model and on the read mode.

Camera model	G0/G1-0300	G0/G1-0800	G0/G1-2000	G1-1400
Download time (fast mode)	0.05 s	0.1 s	0.25 s	0.18 s
Download time (slow mode)	0.15 s	0.32 s	0.8 s	0.58 s

1. Download times are valid for USB 2.0 host and may vary depending on host PC. Times stated here were measured on 1.5 GHz Pentium M based laptop computer.
2. Download times can be significantly longer when connected to USB 1.1 host.

Some electronics characteristics like system gain or system read noise cannot be determined without knowledge of some CCD parameters (e.g. output node sensitivity), which are not published by Sony.

CCD Chip Cooling

The G0 and G1 series of CCD cameras does not use active cooling with Peltier TEC modules, so the CCD cannot be cooled below ambient temperature.

Working electronics (including the CCD chip itself) produce quite amount of heat, which rise the camera internal temperature many degrees above ambient temperature. Because the CCD thermal noise typically doubles every 5 or 7 °C, the thermal noise can be significantly higher after some time of camera operation.

The G1 series of CCD cameras contain small fan, which efficiently removes the heat from the camera body and keeps the CCD temperature as close to ambient temperature as possible. The fan operation can be controlled from the software.

G0 and G1 cameras also include the embedded temperature sensor, which measures the current CCD temperature. This feature enables controlling of the CCD temperature and ensuring the used dark frame was taken in the same or similar temperature as the light exposure etc.

Power Supply

G0 and G1 cameras are powered from the USB cable. No external power supply is necessary.

The current limit for single USB device is 500 mA from 5 V supply. The current required by G1 CCD cameras varies depending on the camera operation mode. The following table summarizes camera consumption. Either way, G1 cameras do not reach the allowed 500 mA limit, defined in USB specification.

Camera operation mode	Required current
Idle, fan off	185 mA
Idle, fan on	260 mA
Image digitization, fan off	285 mA
Image digitization, fan on	360 mA

G0 cameras are not equipped with fan, so their power consumption equals to power consumption of G1 cameras with fan off.

1. If the camera is connected through non-powered USB hub, the current available for the connected devices can be as low as 100 mA, which is insufficient. Always use powered USB hubs when using G1 cameras.
2. Note the so-called “active USB extender cable” is in fact nothing more than standard USB cable with a hub with single USB connector on the far side. Such hub consumes some energy and may not work with G1 cameras.
3. Some USB cables incorporate very thin power lines with relatively high resistance. If the USB device consumes several hundreds milliamperes, the voltage drop on such cable can be around one volt. Although the G1 camera should work, some features (e.g. temperature measurement) may be negatively affected. Always make sure the used USB cable is as short as possible and with low-resistance power lines.

G0 Camera Mechanical Specifications

G0 camera head has just 40 mm diameter (approx. 1.6 inch) and 85 mm length (approx. 3.3 inch), including the 18 mm long 1.25” nose in the front part of the camera. All connectors (USB and autoguider) are placed on the rear side of the camera.

G0 cameras are designed to be attached directly to standard 1.25” telescope focusers. There is no C/CS thread available, so the G0 camera cannot be used with common CCTV lenses.

Illustration 1: G0 camera head

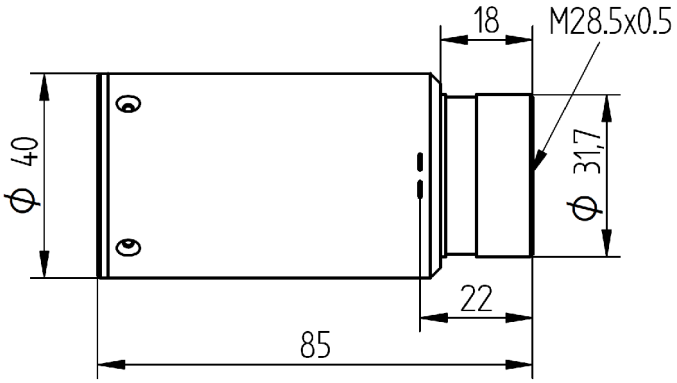


Illustration 2: G0 camera dimensions

The G0 cameras use Interline Transfer CCDs allowing electronic exposure control, so they do not contain mechanical shutter. But it is necessary to cover the telescope manually to take dark or bias frame.

Internal mechanical shutter	No
Shortest exposure time	0.000125 s
Longest exposure time	Limited by chip saturation only
Head dimensions	40 mm (diameter) × 85 mm (length)
Camera head weight	0.1 kg

G1 Camera Mechanical Specifications

Compact and robust camera head measures only 83 × 76 × 26 mm (approx. 3.25 × 3 × 1 inch). The head is CNC-machined from high-quality aluminum and black anodized.

The camera is supplied with CS adapter for connecting various CS compatible lenses. The C-thread to 1.25" adapter can be screwed into the head to attach the camera to any telescope focuser accepting standard 1.25" eyepieces.

Both C and CS standards use the same thread specification (C-thread with 1 inch diameter, 32 threads per inch). The difference between them is in the back focal distance – while the standard C-thread back focal distance is 17.5 mm, the CS back focal distance is 12.5 mm. Both variants are available for G1 CCD cameras.

Illustration 3: G1 camera head

The G1 cameras use Interline Transfer CCDs allowing electronic exposure control, so they do not contain mechanical shutter. But it is necessary to cover the telescope manually to take dark or bias frame.

Internal mechanical shutter	No
Shortest exposure time	0.000125 s
Longest exposure time	Limited by chip saturation only
Head dimensions	83 mm × 76 mm × 26 mm
Back focal distance	12.5 mm (CS standard)
	17.5 mm (C standard)
Camera head weight	0.2 kg

1. Camera dimensions do not include the CS-thread adapter. This adapter depth is 6.4 mm, so the camera depth including the CS-thread adapter is 32.4 mm.

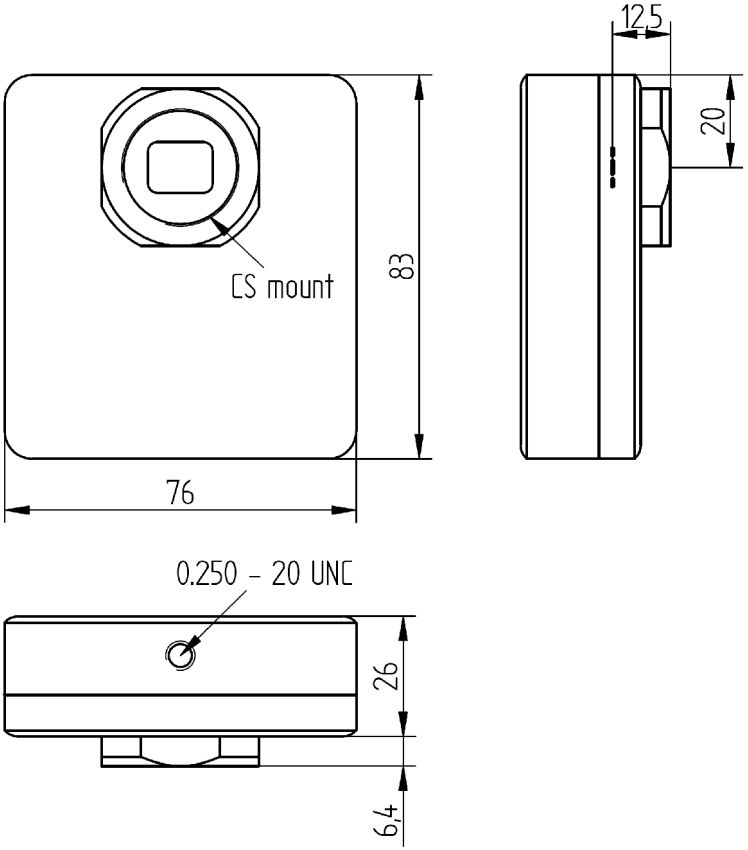


Illustration 4: G1 camera dimensions

Guiding

A lot of astronomical telescope mounts (especially the mass-manufactured ones) are not precise enough to keep the star images perfectly round during long exposures without small corrections. Astronomical CCD cameras and digital SLR cameras allow perfectly sharp and high-resolution images, so even a small irregularity in mount tracking appears as star image deformations. G0 and G1 CCD cameras were designed especially with automatic mount guiding on mind.

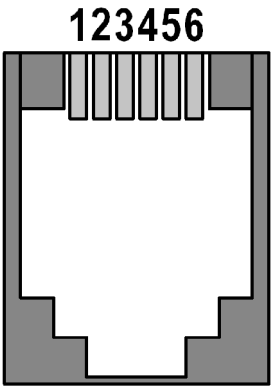
The G0 and G1 cameras were designed to operate without any mechanically moving parts (with the exception of magnetically levitating fan used in G1 cameras). Electronic shutter allows extremely short exposures and also obtaining thousands of images in a short time, which is necessary for quality guiding. CCD chips used in G0 and G1 cameras are sensitive enough to capture even a faint stars within few seconds. The limiting magnitude of G0 and G1 cameras is much higher compared to the most sensitive TV or Web cameras.

G0 and G1 cameras work in connection with a host computer (PC). Guiding corrections are not calculated in the camera itself, it only sends acquired images to the PC. The software running on the PC calculates the difference from required state and sends appropriate corrections to the telescope mount. The plus side of using a host PC CPU to process images is the fact, that current PCs provide overwhelming computational power compared to any embedded processor inside the guiding camera. Guiding algorithms then can determine star position with sub-pixel precision, can match multiple stars to calculate average difference, which limits the effects of seeing, etc.

Calculated corrections can be sent back to mount using PC-to-mount link, but more accurate guiding can be achieved using so called “Autoguider” port. It is enough to connect the G0 or G1 camera and the mount using 6-wire cable and guide the mount through the camera.

Illustration 5: Bottom side of the G0 and G1 camera heads with USB and Autoguider connectors

The Autoguider port follows the de-facto standard introduced by SBIG ST-4 autoguider. The pins have the following functions:



1. R.A. + (Right)
2. Dec + (Up)
3. Dec – (Down)
4. R.A.– (Left)
5. Common (Ground)
6. Not connected

The maximum sinking current of each pin of the G0 or G1 camera is 100 mA. If the mount does not treat the autoguider port as logical input only, but switches the guiding motors directly by these signals, a relay box must be inserted between the camera and the mount. The relay box ensures switching of currents required by the mount.

Camera Maintenance

The G0 and G1 cameras require no special maintenance. However, it is a precision optical and mechanical instrument so it should be handled with care. Camera should be protected from moisture and dust. Always cover the telescope adapter when the camera is removed from the telescope or put the whole camera into protective plastic bag.

Changing the Telescope Adapter of the G1 Camera

The 1.25" telescope adapter is screwed into the camera CS adapter. If you intend to use the camera with some CS compatible lens or microscope with C-thread adapter, simply unscrew the 1.25" adapter.

There are two standards using the C-thread (C-thread has 1 inch diameter and 32 threads per inch), differentiated by the back focal distance. The C standard has 17.5 mm back focal distance while the CS standard has 12.5 mm back focal distance.

G1 CCD cameras can be supplied with either C or CS adapter. This usually has no importance if the camera is used with the telescope, because the telescope focuser can easily compensate the difference. But certain lenses are designed either for C or CS standard.

While it is possible to use the distance ring to prolong the CS adapter to C standard, it is not possible to use the CS lens with full length C adapter. The C and CS adapters used on G1 cameras can be replaced, but camera mus be returned to manufacturer for such exchange.