C0 and C1 Series CMOS Cameras

The C0 and C1 series cameras with **global shutter** CMOS sensors were designed to be small, lightweight imagers for Moon and planets and for automatic telescope guiding. With proper image calibration, these cameras provide surprisingly good results also in entry-level deep-sky imaging. The used CMOS sensors response to light is linear up to very close to saturation point. So, the C0 and C1 cameras can be used for some entry-level scientific applications for instance in the variable star research etc.

The C0 and C1 cameras share majority of features, like the used sensors, USB interface, autoguider port, etc. At the first view, the only difference is the size of camera body.

C0 camera

But greater dimensions of the C1 models allowed adding of some features, not available on the C0 cameras, like cooling fan and mounting threaded holes.

C1 camera

Feature	**C0**	**C1**
Dimensions	50 × 50 × 40.4 mm	57 × 57 × 46.4 mm
Weight	115 g	170 g
Cooling fan	No	Yes
Tripod and metric threads	No	Yes

The C1 dimensions and weight are valid for C1 cameras version 3. Earlier C1 versions 1 and 2 are slightly thicker and heavier. More details are in the Mechanical Specification chapter.

Comparing the C0 (left) and C1 (right) cameras

C0 and C1 camera models are equipped with Sony IMX **global shutter** CMOS detectors with 3.45 × 3.45 μm square pixels. Individual models differ in resolution only.

All used sensors utilize global electronic shutter. This means every pixel within the image is exposed in the same time, as opposed to rolling shutter sensors, which exposes individual lines one after another. There is no difference for long exposures of static objects, but imaging of moving objects using short exposure time using rolling shutter leads to image shape distortions.

Two lines of C1 cameras are available depending on the available dynamic range (bit-depth of the digitized pixels):

- **C1 cameras with Sony IMX sensors supporting 8- and 12-bit digitization.** Because every 12-bit pixel occupies two bytes when transferred to host PC, 12-bit image download time is longer compared to 8-bit image. Maximal FPS in 8-bit mode is then significantly higher.
- **C1 cameras with Sony IMX sensors supporting 12-bit digitization only.** As the 12-bit read mode is always used for long-exposure applications (astronomical photography, scientific research) either way, lower theoretical download time in 8-bit mode brings no limitations for real-world scenarios. All other parameters being same (sensor size, resolution, pixels size, noise, …), lower price of these cameras may be then very attractive.

C1 camera models with 8- and 12-bit digitization:

Model	CMOS sensor	Resolution	Pixel size	Image area
C0/C1-1500	IMX273	1456 × 1088 pixels	3.45 × 3.45 μm	5.02 × 3.75 mm
C0/C1-3000	IMX252	2064 × 1544 pixels	3.45 × 3.45 μm	7.12 × 5.33 mm
C0/C1-5000	IMX250	2464 × 2056 pixels	3.45 × 3.45 μm	8.50 × 7.09 mm

C0/C1-12000	IMX253	4112 × 3008 pixels	3.45 × 3.45 μm	14.19 × 10.38 mm

C1 camera models with 12-bit digitization only:

Model	CMOS sensor	Resolution	Pixel size	Image area
C0/C1-3000A	IMX265	2064 × 1544 pixels	3.45 × 3.45 μm	7.12 × 5.33 mm
C0/C1-5000A	IMX264	2464 × 2056 pixels	3.45 × 3.45 μm	8.50 × 7.09 mm
C0/C1-12000A	IMX304	4112 × 3008 pixels	3.45 × 3.45 μm	14.19 × 10.38 mm

mark:

Cameras limited to 12-bit read mode are marked with letter A, following the model number. For instance, if C1-3000 marks camera with both 8- and 12-bit read modes, C1-3000A denotes camera model with only 12-bit read mode. All other parameters (sensor size, pixel resolution) are equal.

The C0 and C1 cameras are designed to work in cooperation with a host Personal Computer (PC). As opposite to digital still cameras, which are operated independently on the computer, the scientific cameras usually require computer for operation control, image download, processing and storage etc. To operate the camera, you need a computer which:

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

   Remark:

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

3. Support for x64 based Apple Macintosh computers is also included.

   Remark:

   Only certain software packages are currently supported on Mac.

C1 cameras are designed to be connected with the host PC through USB 3.0 interface, operating at 5 Gbps. Cameras are also compatible with USB 2.0 port to communicate with a host PC.
Alternatively, it is possible to use the **Moravian Camera Ethernet Adapter** device. This device can connect up to four Cx (with CMOS sensors) or Gx (with CCD sensors) cameras of any type 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 WiFi adapter or other networking device to the communication path.

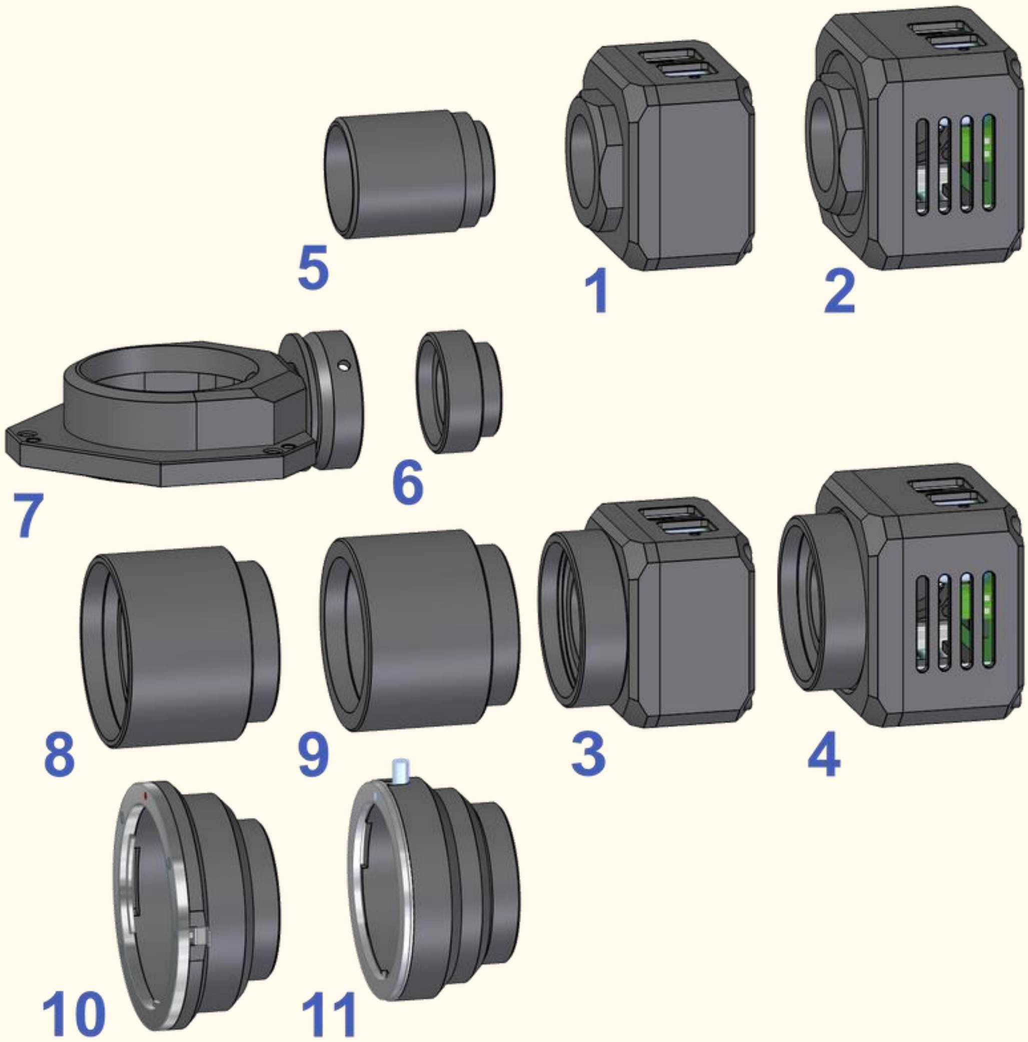
nt:

Please note that the USB standard allows usage of cable no longer than approx. 5 meters and USB 3.0 cables are even shorter to achieve very fast transfer speeds. On the other side, the TCP/IP communication protocol used to connect the camera over the Ethernet adapter is routable, so the distance between camera setup and the host PC is virtually unlimited.

The C0 and C1 cameras do not need an external power supply to operate, they are powered through the USB connection from the host PC.

Note the camera must be connected to some optical system (e.g. the telescope) to capture images. The camera is capable of long exposures, necessary to acquire the light from faint objects. If you plan to use the camera with the telescope, make sure the whole telescope/mount setup is capable to track the target object smoothly during long exposures.

C0 and C1 Camera System



Components of the C0 and C1 Camera system include:

1. C0 camera head with CS-mount adapter
2. C1 camera head with CS-mount adapter

3. C0 camera head with combined T-thread (M42×0.75) and CS-mount adapter
4. C1 camera head with combined T-thread (M42×0.75) and CS-mount adapter
5. C/CS-mount to 1.25” barrel adapter
6. Short (10 mm) variant of C/CS-mount to 1.25” barrel adapter, intended for usage with OAG
7. Off-Axis Guider adapter (OAG) for cooled C1+ and C2 cameras

Remark:

OAG shown here is not exactly part of the C0/C1 camera system. It is intended for large cameras and only accommodates C0 and C1 camera for guiding.

To allow the C0 or C1 camera to work with OAG, it is necessary to use the CS-mount adapter. C0 or C1 camera with T-thread adapter is not compatible with OAG.

The C0 and C1 cameras are also compatible with larger OAGs for C3/C4 and C5 cameras, not shown here.

8. Extension tube with M48 × 0.75 thread and 55 mm back focal distance
9. Extension tube with M42 × 0.75 thread and 55 mm back focal distance (standard T-thread adapter)
10. Adapter for Canon EOS bayonet lens
11. Adapter for Nikon bayonet lens

C1 camera versions

The C1 cameras underwent several innovation cycles through its lifetime. Versions 1 and 2 differ only internally and they are indistinguishable from the user point of view. The 3rd iteration of the C1 camera design allowed to make the camera head 7 mm thinner and 45 g lighter. Beside the smaller and lighter body, all other features (used sensors, USB and autoguider interfaces, download time, …) are the same.

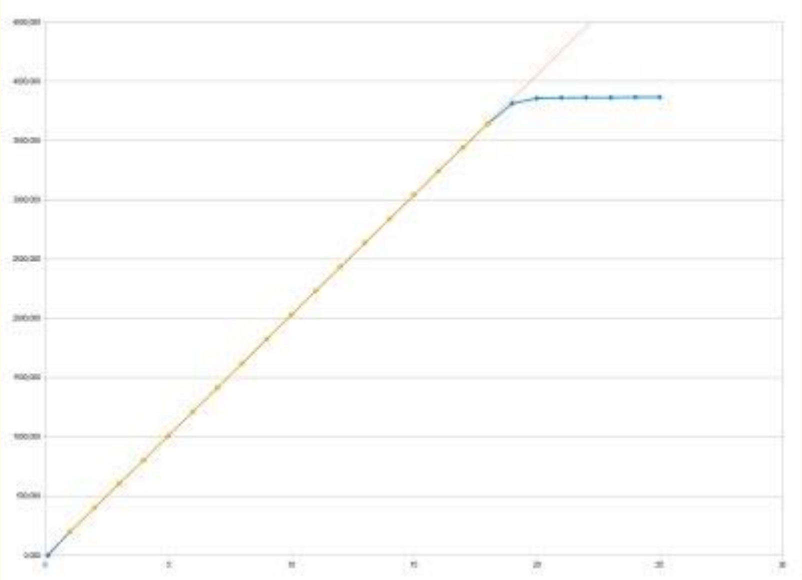
Comparison of the C1 v3 (left) and v1/v2 (right) models shows the difference in camera thickness

Camera Electronics

CMOS camera electronics primary role, beside the sensor initialization and some auxiliary functions, is to transfer data from the CMOS detector to the host PC for storage and processing. So, as opposite to CCD cameras, CMOS camera design cannot influence number of important camera features, like the dynamic range (bit-depth of the digitized pixels).

Sensor linearity

The sensors used in C1 cameras shows very good linearity in response to light. This means the camera can be used also for entry-level research projects, like for instance photometry or brighter variable stars etc.



C1-3000 (IMX252) response to light

Download speed

As already noted, there are two lines of C0 and C1 camera series, differing in the used sensor. The first series offers four different read modes:

- **8-bit slow** mode with ~132 MPx/s digitization speed
- **12-bit slow** mode with ~72 MPx/s digitization speed
- **8-bit fast** mode with ~263 MPx/s digitization speed
- **12-bit fast** mode with ~132 MPx/s digitization speed

mark:

The slow variant of both read modes can be used to slightly lower the amount of heat generated by the sensor, as the communication interface operates at half speed compared to fast mode. Also, when the camera is connected using USB 2.0 interface, fast read mode provides data at higher speed than the USB 2.0 can handle and thus causes more interruptions of image digitization process.

The "A" version of C0 and C1 cameras offers only single read mode:

- **12-bit fast** mode with ~132 MPx/s digitization speed

The digitization speeds mentioned above are valid for USB 3.0 connection. Also please note the digitization speeds do not necessarily lead to corresponding FPS, because every image downloaded has to be processed and displayed, which also consumes time. This time is negligible, if slow-scan camera needs many seconds for image download, but in the case of fast CMOS cameras, time for image processing in the PC (e.g. calculation of image standard deviation etc.) can be longer than image download itself.

mark:

Despite one byte per pixels is transferred from camera to PC in the 8-bit read mode, many astronomical processing software packages work with 16-bit or 32-bit images only (e.g. SIPS). So, images occupy the same space in the computer memory regardless of the read mode.

Also, standard format for image storage in astronomy is FITS. While this format supports 8-bit per pixel, this variant is rather unusual and 16 or 32-bit integer or 32-bit floating-point pixels are typically stored to disk files to achieve as wide compatibility as possible.

Camera gain

Sensors used in C0 and C1 cameras offer programmable gain from 0 to 24 dB, which translates to the output signal multiplication from 1× to 15.9×. Gain can be set with 0.1 dB step.

mark:

Note the C0 and C1 camera firmware supports only **analog gain**, which means real amplification of the signal prior to its digitization. The used sensors support also **digital gain** control, which is only numerical operation, bringing no real benefit for astronomical camera. Any such operation can be performed later during image processing if desired.

Conversion factors and read noise

Generally, many sensor characteristics depend on the used gain. Hence, we provide two lists of parameters for both minimal and maximal gain.

Digitization resolution	12-bit	12-bit	8-bit	8-bit
Sensor gain	0 dB	24 dB	0 dB	24 dB
Full well capacity	11000 e^-	1100 e^-	2600 e^-	1100 e^-
Conversion factor	2.8 e^-/ADU	0.3 e^-/ADU	10.0 e^-/ADU	4.4 e^-/ADU
Read noise	2.2 e^- RMS	2.0 e^- RMS	4.2 e^- RMS	9.7 e^- RMS

mark:

Please note the values stated above are not published by sensor manufacturer, but determined from acquired images using the SIPS software package. Results may slightly vary depending on the test run, on the particular sensor and other factors (e.g. sensor temperature, sensor illumination conditions etc.), but also on the software used to determine these values, as the method is based on statistical analysis of sensor response to light.

Exposure control

C0 and C1 cameras are capable of very short exposures. The shortest exposure time is 125 μs (1/8000 of second). This is also the step, by which the exposure time is expressed. So, the second shortest exposure is 250 μs etc.

Long exposure timing is controlled by the host PC and there is no upper limit on exposure time. In reality the longest exposures are limited by saturation of the sensor either by incoming light or by dark current (see the following sub-chapter).

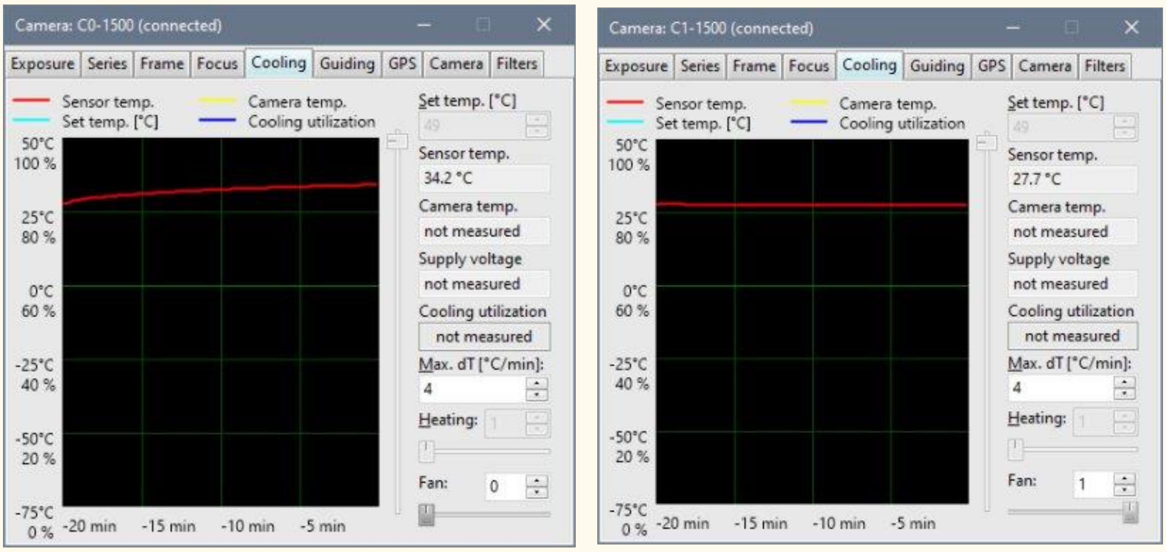
Sensor Cooling

Dark current is an inherent feature of all silicone circuits. It is called "dark", because it is generated regardless if the sensor is exposed to light or not. Dark current, injected into individual pixels, appear in image as noise. The longer exposure, the greater amount of noise is present in every image. As it is generated by random movement of particles, it depends on the temperature exponentially (this is why the noise generated by dark current is also denoted "thermal noise"). Typically, lowering the sensor temperature by 6 or 7 °C halves the dark current.

While neither C0 nor C1 cameras are equipped with active thermo-electric (Peltier) cooling, the C1 models employ a small fan, exchanging air inside the camera body. What is more, a small heat sink is located directly on the sensor to remove as much heat as possible (with the exception of C1-1500, which sensor is too small to be equipped with a heat sink). So, the C1 sensor cannot be cooled below the ambient temperature, but its temperature is kept as close to environment as possible. Compared to closed designs of C0 and other cameras, the sensor temperature in the C1 can be between 7 and 10°C lower and resulting dark current may be less than a half.

Cooling air intake is on the right side of the camera (left), while the output vents are on the opposite side (right)

The fan operation can be controlled from the software. SIPS directly offers a slider controlling fan in the “Cooling” tab of the imaging camera tool window. Camera drivers for other software must rely on driver configuration dialog box to control fan.



Without fan, the sensor in the C0-1500 camera reaches temperature approx. 7°C above ambient (left), while the sensor in the C1-1500 camera with running fan is kept very close the ambient temperature

Autoguider port

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. Cooled astronomical 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. C0 and C1 cameras were designed especially with automatic mount guiding on mind.

The C0 and C1 cameras were designed to operate without any mechanically moving parts (with the exception of magnetically levitating fan). Electronic shutter allows extremely short exposures and also obtaining thousands of images in a short time, which is necessary for quality guiding.

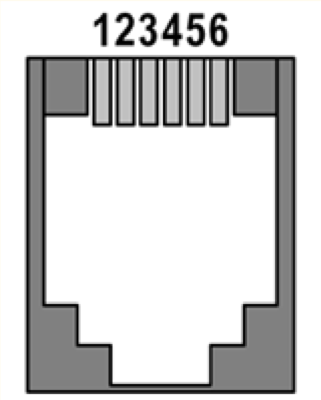
The C0 and C1 cameras work in connection with a host computer (PC). Guiding corrections are not calculated in the camera itself, it only sends acquired images to the PC. The software running on the PC calculates the difference from required state and sends appropriate corrections to the telescope mount. 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. If the mount controller does not support so-called "Pulse Guide" commands, it is possible to use "Autoguider" port. It is enough to connect the C0 or C1 camera and the mount using standard 6-wire cable and guide the mount through the camera.

The maximum sinking current of each pin of the C0 and C1 camera is 400 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.

Standard 6-pin Autoguider Port is located beside the USB3 port on the top side of C1 (left) and C0 (right) cameras

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

Mechanical Specifications

C1 camera head is designed to be lightweight and compact to be easily attached even to small telescopes or finders. Compact and robust camera head measures only 57 × 57 × 48 mm not including the lens adapter.

The head is CNC-machined from high-quality aluminum and black anodized. The head itself contains USB-B 3.0 (device) connector and standard 6-pin “autoguider” connector.

Internal mechanical shutter	No
Shortest exposure time	125 μs
Longest exposure time	Limited by chip saturation only
C0 head dimensions	50 mm × 50 mm × 40.4 mm (including CS-mount adapter)
C1 head dimensions	57 mm × 57 mm × 47.4 mm (including CS-mount adapter)
Back focal distance	12.5 mm for 1/32 UN thread (CS-mount compatible)
	18.5 mm for M42 × 0.75 thread (T-mount)
C0 head weight	115 g
C1 head weight	170 g

mark:

The C1 dimension 47.4 mm is valid for C1 v3, version 1 and 2 thickness is 54.4 mm. C1 camera weight 170 g is valid for C1 v3, version 1 and 2 weight is 215 g.

Telescope/lens adapters

C0 and C1 cameras are supplied with two types of telescope/lens adapters:

- Adapter with 1/32 UN thread and 12.5 mm Back Focal Distance (CS-mount).

- Adapter with M42 × 0.75 thread (T-thread) and 18.5 mm Back Focal Distance. This adapter also contains inner thread 1/32 UN with 12.5 mm BFD (CS-mount).

Comparison of C1 camera with CS- mount only adapter (left) and C1 camera with combined T-thread (M42 × 0.75) and CS-mount adapter (right)

CS-mount it compatible with vast number of CCTV lenses. If C-mount lens has to be used (with 17.5 mm Back Focal Distance), simple 5 mm thick adapter ring can be used.

If the C0 or C1 camera should be used with OAG for cooled Cx cameras, short 10 mm C-to-1.25” barrel adapter has to be used. This adapter, shipped with respective OAG, is fully compatible with C0 and C1 camera.

Note the C0 and C1 cameras with M42 × 0.75 (T-thread) adapter cannot be used with OAG, despite the short CS-to-1.25" barrel adapter can be attached to it. The large-diameter M42 adapter interferes with screws fixing the camera in the OAG guider port. This is why C0 and C1 variant with CS-mount only adapter are still supplied.

C-to-1.25” barrel adapter, compatible with standard 1.25” eyepieces, is included into camera package. So, the C0 or C1 camera can be easily mounted into virtually every astronomical telescope instead of an eyepiece.

The T-mount interface (also known as T-thread adapter) is defined by thread dimensions M42 × 0.75 as well as by 55 mm Back focal Distance. T-thread adapter for C1 cameras does not comply to the second parameter, its BFD is only 18.5 mm. The 55 mm BFD is not required in all applications and keeping such relatively large BFD would make the adapter quite bulky.

Still, an extension tube with male M42 × 0.75 thread is available. This extension tube converts the C0 or C1 camera BFD to 55 mm, required by numerous focal-reducers, field-flatteners, coma-correctors and other optical elements.

There are two variants of the 55 mm BFD extension tubes available:

- Extension tube with M42 × 0.75 (T-thread) on the telescope side.
- Extension tube with larger M48 × 0.75 thread on the telescope side.

C1 camera (left), 55 mm BFD extension tube with M42 × 0.75 thread (center) and with M48 × 0.75 thread (right)

Also, extension tubes with bayonet interfaces for standard photographic lenses are available:

- Extension tube with Nikon bayonet adapter.
- Extension tube with Canon EOS bayonet adapter.

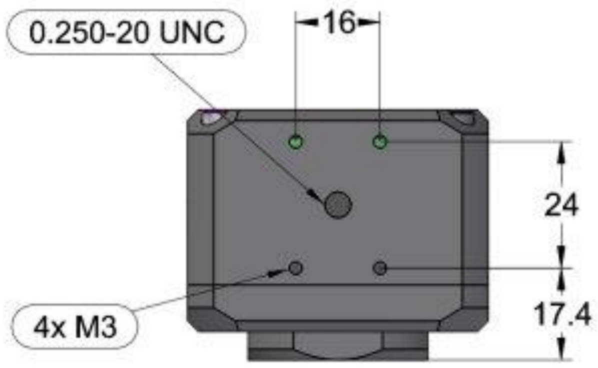
The extension tube outer diameter is exactly 2 inches (50.8 mm), so it can allow using of the C0 or C1 camera with any 2" focuser instead of 2" eyepiece.

C1 camera with Canon EOS lens attached

Tripod and metric threads

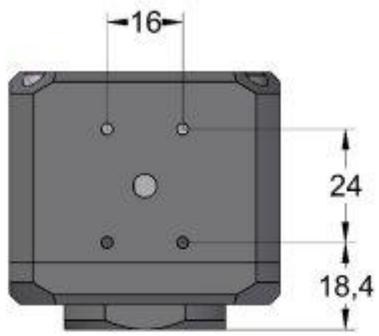
C1 camera bottom contains standard 0.25" (tripod) thread and 4 metric M3 threaded holes

If the C1 camera is not attached to the telescope focuser through its telescope/lens adapter, it can be attached to standard photographic tripod using 0.25” thread. Another possibility is to use 4 metric M3 threaded holes, also located on the bottom side of the camera head.



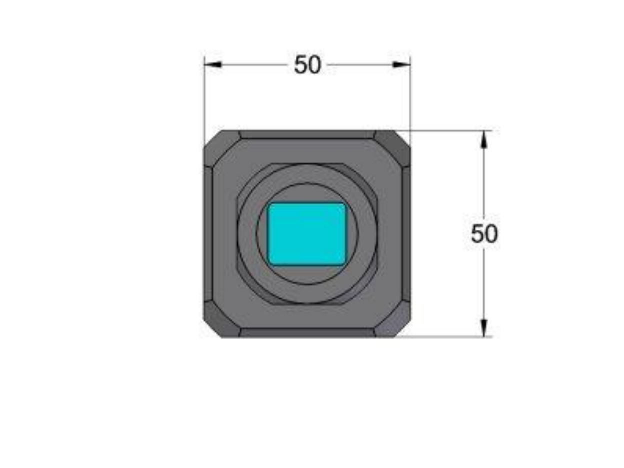
Position of the four M3 threaded holes on the bottom of C1 v3 camera head

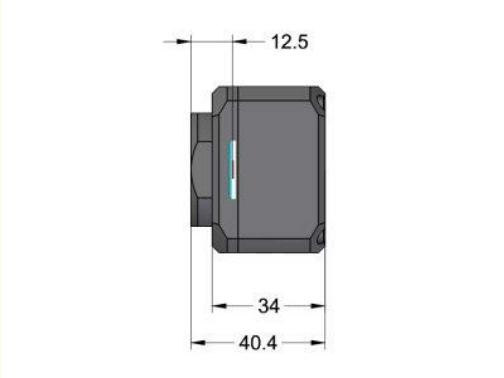
The threaded hole pattern (thread diameter as well as hole mutual distances) is the same for all versions of C1 cameras. Only the holes were 1 mm further from the camera front side on C1 cameras version 1 and 2.



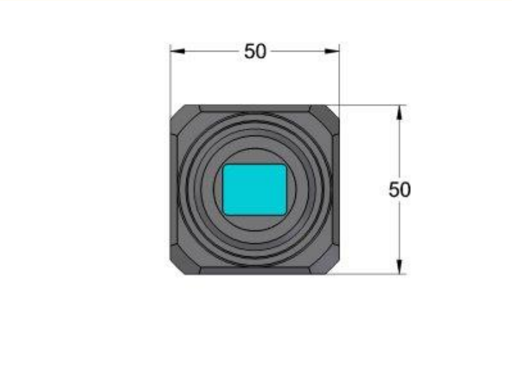
Position of the four M3 threaded holes on the bottom of C1 camera head

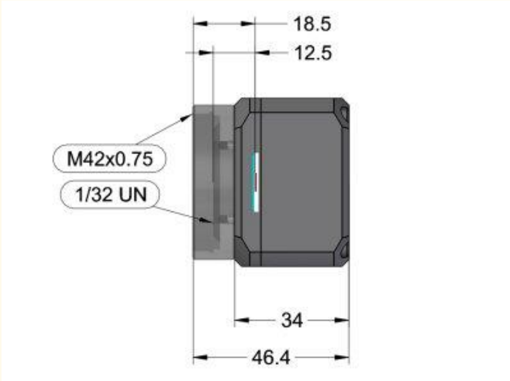
C0 Camera Dimensions





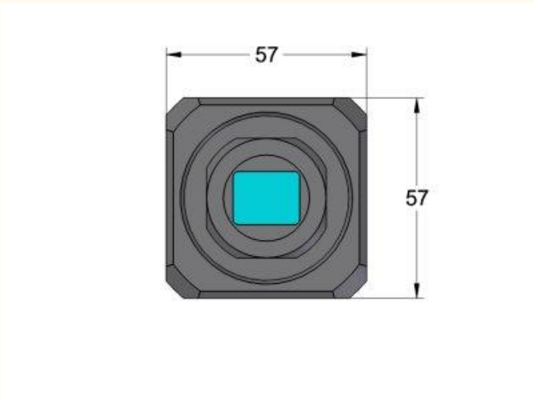
C0 camera head with CS-mount adapter front view dimensions (left) and side view dimensions and Back Focal Distance (right)

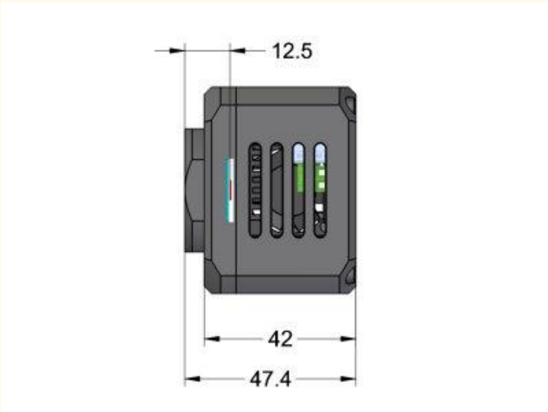




C0 camera head with M42 × 0.75 adapter front view dimensions (left) and side view dimensions and Back Focal Distance (right)

C1 Camera Dimensions

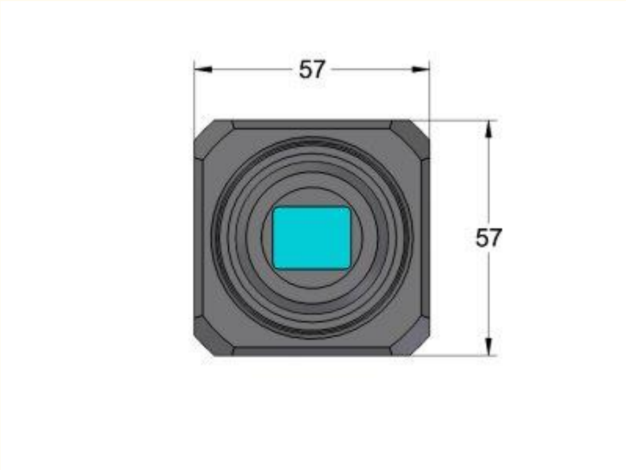


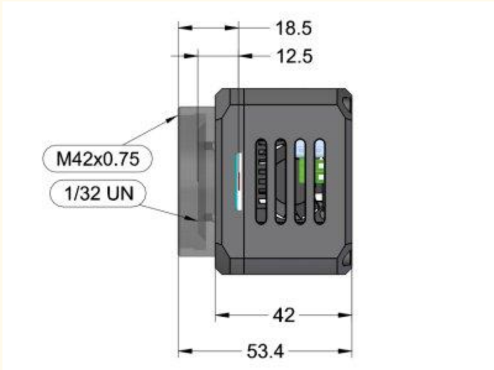


C1 camera head with CS-mount adapter front view dimensions (left) and C1 v3 side view dimensions and Back Focal Distance (right)

mark:

The C1 camera v1 and v2 total length is 54.4 mm.





C1 camera head with M42 × 0.75 adapter front view dimensions (left) and C1 v3 side view dimensions and Back Focal Distance (right)

mark:

The C1 camera v1 and v2 total length is 60.4 mm.

Software support

Always use the latest versions of the system driver package for both Windows and Linux system. Older versions of drivers may not support new camera models (like C0) or latest versions or existing series (like C1 version 3).
If the camera is controlled through the **Moravian Camera Ethernet Adapter**, make sure the device firmware is updated to the latest version available.
Also, always use the latest version of the SIPS software package, older versions may not support latest cameras correctly. If a driver for 3rd party software package is used (e.g. ASCOM or INDI drivers), always update the driver to the latest available version.

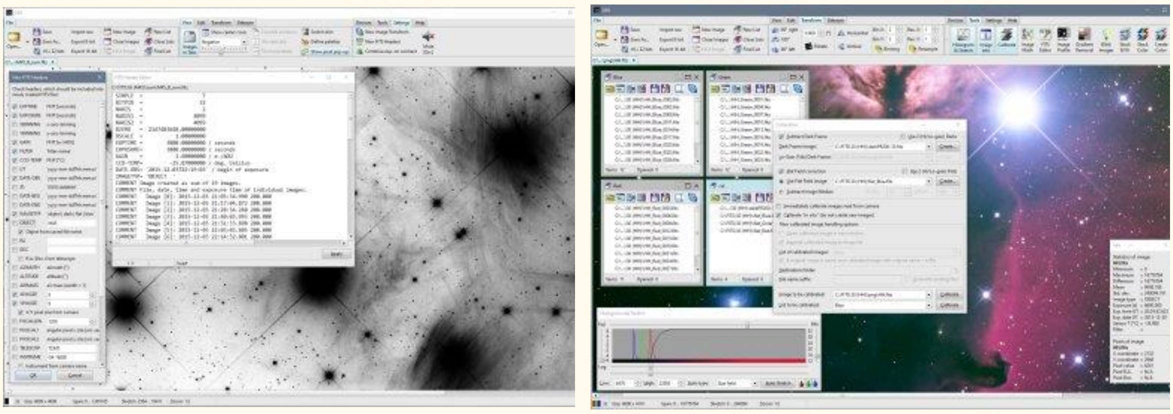
SIPS

Powerful **SIPS** (Scientific Image Processing System) software, supplied with the camera, allows complete camera control (exposures, cooling, filter selection etc.). Also automatic sequences of images with different filters, different binning etc. are supported. With full ASCOM standard support, SIPS can be also used to control other observatory equipment. Specifically the telescope mounts, but also other devices (focusers, dome or roof controllers, GPS receivers etc.).

SIPS also supports automatic guiding, including image dithering. Both “autoguider” port hardware interface (6-wire cable) and mount “Pulse-Guide API” guiding methods are supported. For hi-quality mounts, capable to track without the necessity to guide at last during one exposure, inter-image guiding using the main camera only is available.

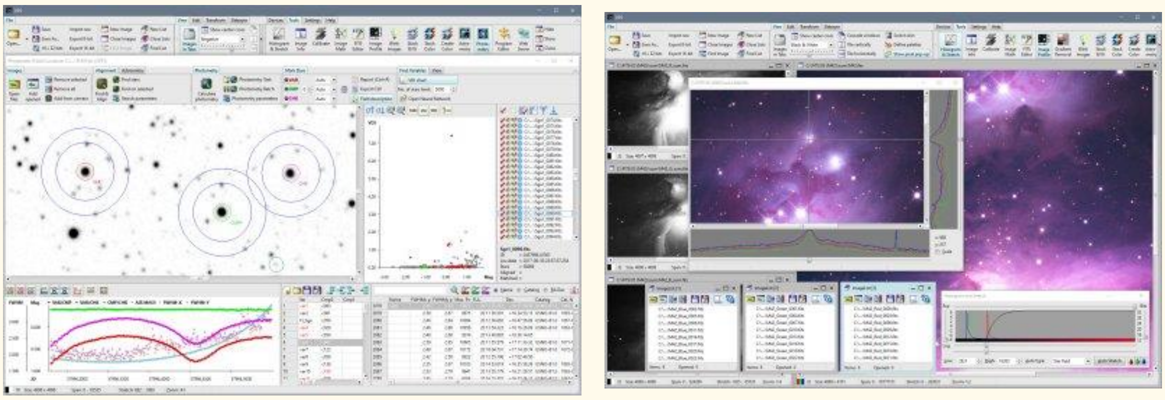
SIPS controlling whole observatory (shown in optional dark skin)

But SIPS is capable to do much more than just camera and observatory control. Many tools for image calibration, 16 and 32 bit FITS file handling, image set processing (e.g. median combine), image transformation, image export etc. are available.



SIPS handles FITS files, supports image calibration and processing

As the first “S” in the abbreviation SIPS means Scientific, the software supports astrometric image reduction as well as photometric processing of image series.

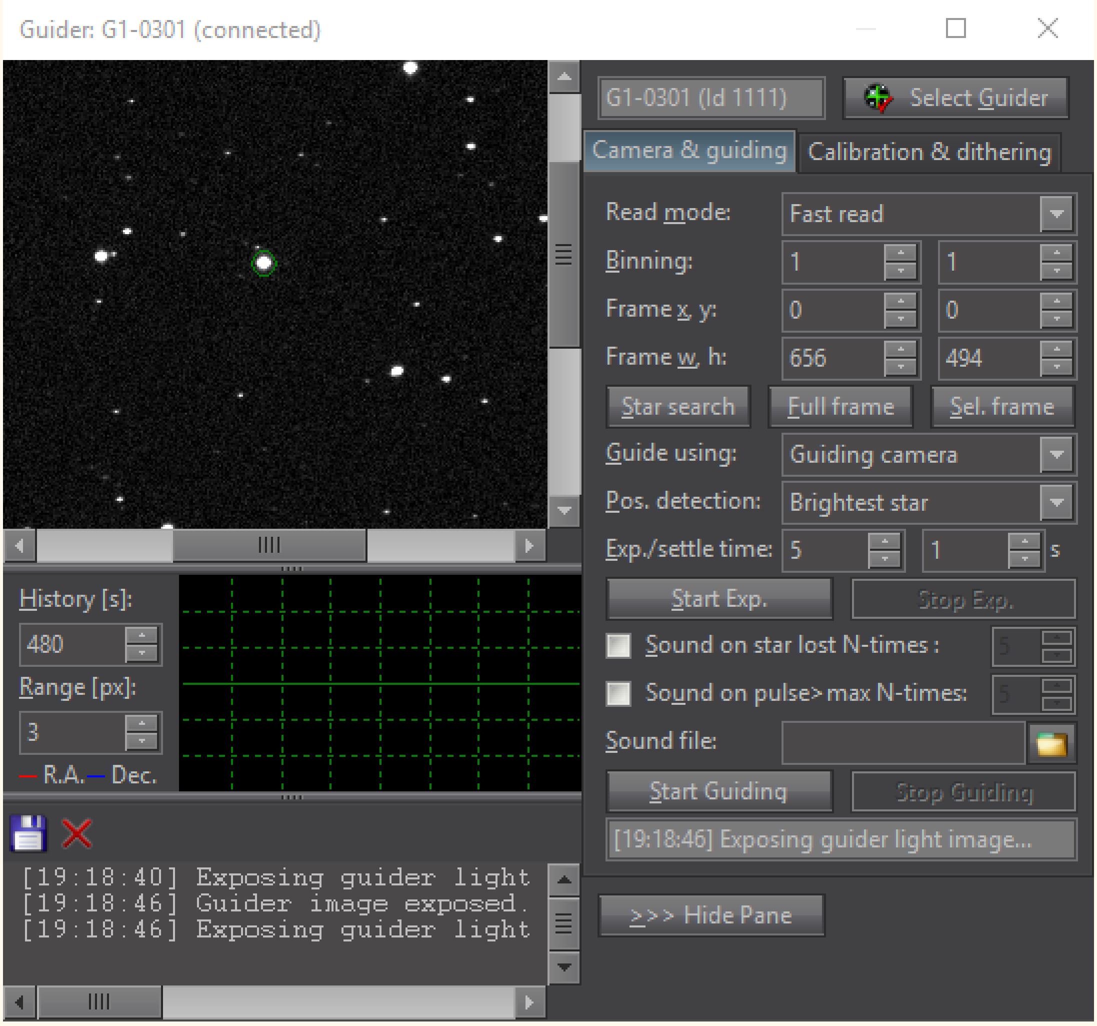


SIPS focuses to advanced astrometric and photometric image reduction, but also provides some very basic astro-photography processing

SIPS software package is freely available for download from this www site. All functions are thoroughly described in the SIPS User's Manual, installed with every copy of the software.

Automatic guiding

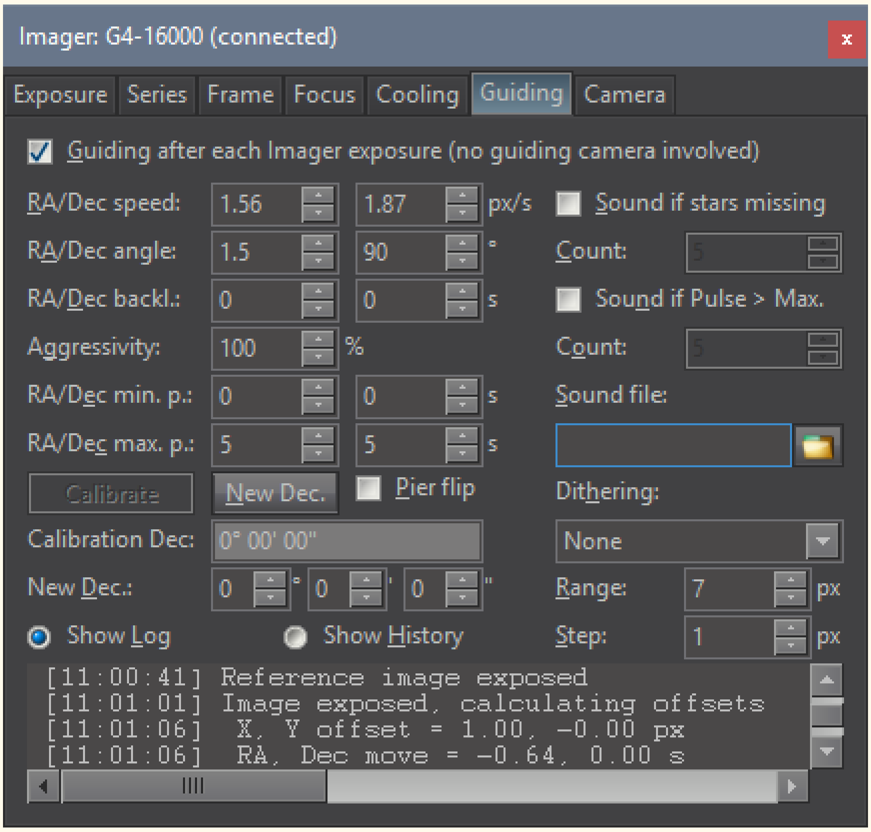
SIPS software package allows automatic guiding of the astronomical telescope mounts using separate guiding camera. Proper and reliable automatic guiding utilizing the computational power of Personal Computer (e.g. calculation of star centroid allows guiding with sub-pixel precision) is not simple task. Guiding complexity corresponds to number of parameters, which must be entered (or automatically measured).



The SIPS "Guider" tool window

The "Guiding" tool allows switching of autoguiding on and off, starting of the automatic calibration procedure and recalculation of autoguiding parameters when the telescope changes declination without the necessity of new calibration. Also swapping of the German Equatorial mount no longer requires new autoguider calibration. There is also a graph showing time history of guide star offsets from reference position in both axes. The length of graph history as well as the graph range can be freely defined, so the graph can be adjusted according to particular mount errors and periodic error period length. Complete log of calibration procedure, detected offsets, correction pulses etc. is also shown in this tool. The log can by anytime saved to log file.

An alternative to classic autoguiding is the inter-image guiding, designed for modern mounts, which are precise enough to keep tracking with sub-pixel precision through the single exposure, and irregularities only appear on the multiple-exposure time-span. Inter-image guiding then performs slight mount position fixes between individual exposures of the main camera, which eliminates “traveling” of the observed objects through the detector area during observing session. This guiding method uses main imaging camera, it does not use another guiding camera and naturally does not need neither OAG nor separate guiding telescope to feed the light into it.



Inter-image guiding controls in the *Guiding* tab of the Imager Camera tool window

Advanced reconstruction of color information of single-shot-color cameras

Color sensors have red, green and blue filters applied directly on individual pixels (so-called Bayer mask).

Every pixel registers light of particular color only (red, green or blue). But color image should contain all three colors for every pixel. So it is necessary to calculate missing information from values of neighboring pixels.

There are many ways how to calculate missing color values — from simple extending of colors to neighboring pixels (this method leads to coarse images with visible color errors) to methods based on bi-linear or bi-cubic interpolation to even more advanced multi-pass methods etc.

Bi-linear interpolation provides significantly better results than simple extending of color information to neighboring pixels and still it is fast enough. But if the telescope/lens resolution is close to the size of individual pixels, color artifacts appear close to fine details, as demonstrated by the image below left.

The above raw image with colors calculated using bi-linear interpolation (left) and the same raw image, but now processed by the multi-pass de-mosaic algorithm (right)

Multi-pass algorithm is significantly slower compared to single-pass bi-linear interpolation, but the resulting image is much better, especially in fine details. This method allows using of color camera resolution to its limits.

SIPS offers choosing of color image interpolation method in both “Image Transform” and “New Image Transform” tools. For fast image previews or if the smallest details are significantly bigger than is the pixel size (be it due to seeing or resolution of the used telescope/lens) the fast bi-linear interpolation is good enough. But the best results can be achieved using multi-pass method.

Drivers for 3rd party programs

Regularly updated Sofware Development Kit for Windows allows to control all cameras from arbitrary applications, as well as from Python scripts etc. There are ASCOM standard drivers available together with native drivers for some 3rd party programs (for instance, TheSkyX, AstroArt, etc.). Visit the download page of this server to see a list of all supported drivers. Libraries and INDI standard drivers for 32-bit and 64-bit Linux working on x86 and ARM processors are available as well. Also drivers for TheSkyX running on macOS are supplied with all cameras.

First light images

The very first prototype of **C1-3000** camera was used by renowned astro-photographer Martin Myslivec. He used the Borg 77ED refractor telescope on the EQ6 mount co capture several unguided exposures. Despite we understand Martin is highly skilled and experienced astro-photographer, the performance of C1 camera is very good also for deep-sky imaging.

C1-3000 first light: M31 Great Andromeda galaxy (left), M42 Great Orion nebula (center) and nebulosity around stars in M45 Pleiades open cluster (right)

The **M31 Great Andromeda galaxy** is a stack of 197 exposures 20 s long (approximately 1 hour and 5 minutes of total exposure time). No image processing was performed beside individual frame calibration and slightly non-linear stretching.
The **M42 Great Orion nebula** image was combined from two sets of exposures (kind of HDR image processing). Faint nebulosity, far from the image center, was acquired using 100 exposures 20 s long (approximately 33 minutes of total exposure time). The very bright central part of the nebula was captured with only 2 s long exposures (again 100 of them), which leads to approximately 3 minutes of total exposure time. The very short exposures allowed to perfectly capture the 4 central stars (called Trapezium) without over-exposing them.
The image of **M45 Pleiades** is a combination of 218 exposures 20 s long (approximately 1 hour and 12 minutes of total exposure time). Again, no image processing was performed, only the calibration and slight non-linearly stretch was performed.

Sun in the Hα spectral line

Martin Myslivec used his global-shutter **C1-5000** based camera to acquire the Sun in the Hα line. See what the C1 camera can achieve on the Sun.