C1+ Series

Cooled CMOS Cameras

User's Guide

moravian instruments

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Introduction

Thank you for choosing the Moravian Instruments camera. C1+ camera models are designed to fulfil the gap between small and lightweight C1 models, intended as Moon and planetary cameras and auto-guiders, and C2 cameras, equipped with active sensor cooling and mechanical shutter and thus intended for more serious astronomical imaging and research. C1+ cameras are able to work as C1 ones, only being somewhat heavier and bulkier, and at the same time C1+ can replace the cooled C2 models, only with slightly less cooling performance and lack of mechanical shutter.

C1+ cameras are designed to operate from USB power lines only. However, some functions are available only if external 12 V DC power supply is connected. C1+ functions equal to C1 cameras when **powered from USB** only:

- Image acquisition.
- Mount guiding through standard “autoguider” 6-pin connector.

When a **12 V DC power** is plugged in, C1 camera functions extend with:

- Active and regulated sensor cooling with Peltier cooler.
- Ability to control external filter wheel.

Still, C1+ capabilities lack some functionality, available in larger and heavier C2 cameras only:

- C1+ have no mechanical shutter, necessary for automatic dark and bias frame acquisition in remote or robotic setups.
- C1+ lack the possibility to use internal filter wheel.
- C1+ cooling performance is slightly lower than in the case of C2, but the sensor temperature difference is only a few degrees Celsius.

Mechanical design of this series makes it fully compatible with vast range of telescope adapters, off-axis guider adapters, internal or external filter wheels, Camera Ethernet adapters, guiding cameras etc.

Rich software and driver support allows usage of C1+ camera without necessity to invest into any 3rd party software package thanks to included free SIPS software package. However, ASCOM (for Windows) and INDI (for Linux) drivers, shipped with the camera, provide the way to integrate C1+ camera with broad variety of camera control programs.

The 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 slow-scan, cooled 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.

   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.

   Only certain software packages are currently supported on Mac.

C1+ cameras are designed to be attached to host PC through very fast USB 3.0 port. While C1+ cameras remain compatible with older (and slower) USB 2.0 interface, image download time is significantly longer.

Alternatively, it is possible to use the “Moravian Camera Ethernet Adapter” device. This device can connect up to four Cx (and Gx) cameras of any type (not only C1+, but also C1, C2, C3 and C4) 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.

Please note while the USB standard allows usage of cable no longer than approx. 5 meters, 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.

Download speed is naturally significantly slower when camera is attached over Ethernet adapter, especially when compared with direct USB 3 connection.

Note the camera must be connected to some optical system (e.g. the telescope) to capture images. The camera is designed for 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.

Figure 1: Comparison of the C1+ camera head (middle) with C1 camera (left) and C2 camera (right)

C1+ Camera Overview

C1+ camera head is designed to be as small and compact as a cooled camera with rich features and compatible with broad set of accessories can be.

C1+ cameras are equipped with tiltable telescope interface and tripod mounting threaded holes. They are also compatible with external filter wheels designed for larger C2 cameras – camera head contains connector to control filter wheel. If the external filter wheel is used, the tiltable mechanism on the camera head is inactive and tiltable adapters for external filter wheels are used instead. Therefore, C1+ cameras can utilize vast range of telescope and lens adapters including off-axis guider adapters.

Figure 2: C1+ Camera without filter wheel (left) and with attached External filter wheel (right)

There are two sizes of the External filter wheels, each capable to accept two sizes of filters, available for the C1+ cameras:

- Extra small “XS” size wheel for 8 unmounted filters D31 mm or filters in 1.25” threaded cells.
- Extra small “XS” size wheel for 7 unmounted filters D36 mm.
- Small “S” size wheel for 12 unmounted filters D31 mm or filters in 1.25” threaded cells.
- Small “S” size wheel for 10 unmounted filters D36 mm.

C1+ Camera System

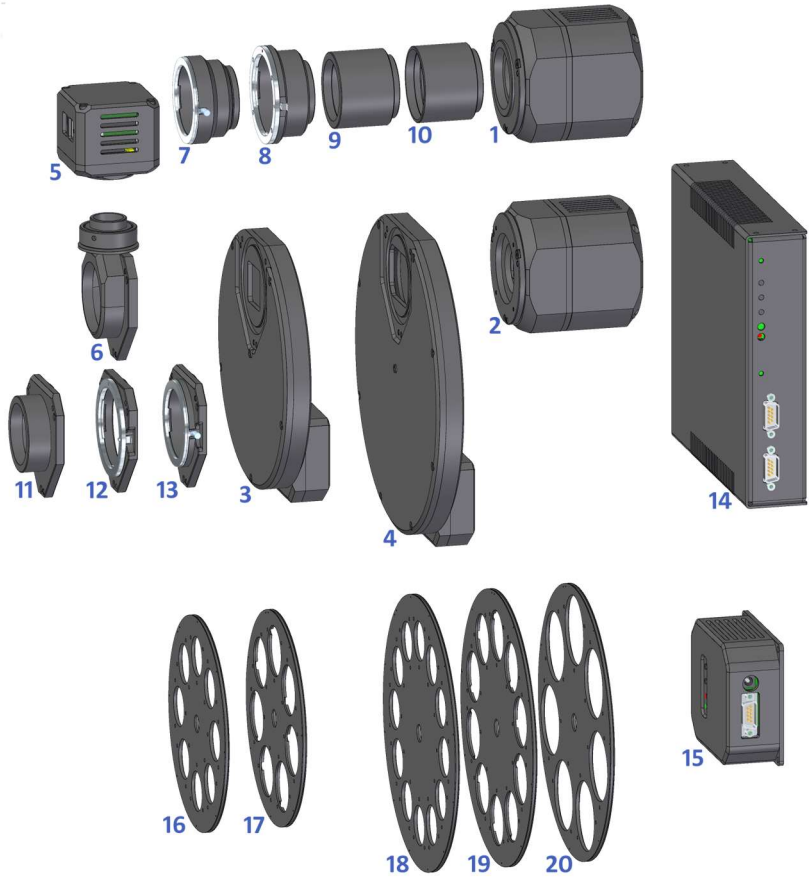


Figure 3: Schematic diagram of C1+ camera system components

Components of the C1+ Camera system include:

1. C1+ camera with C1 compatible adapter
2. C1+ camera with C2 compatible adapter

   When used without spring and pushing screws, this adapter also works as base for External filter wheels.

3. External Filter Wheel “XS” size (7 or 8 positions)
4. External Filter Wheel “S” size (10 or 12 positions)
5. C1 guider camera

   C1 cameras are completely independent devices with their own USB connection to the host PC. They can be used either on OAG or on standalone guiding telescope.

6. Off-Axis Guider with M48×0.75 thread
7. C1 compatible Nikon bayonet adapter
8. C1 compatible Canon EOS bayonet adapter
9. C1 compatible M42×0.75 (T-thread) adapter, 55 mm BFD
10. C1 compatible M48×0.75 adapter, 55 mm BFD
11. C2 compatible M42×0.75 (T-thread) or M48×0.75 threaded adapter, 55 mm BFD
12. C2 compatible Canon EOS bayonet adapter
13. C2 compatible Nikon bayonet adapter
14. Camera Ethernet Adapter (x86 CPU)
15. Camera Ethernet Adapter (ARM CPU)

    Moravian Camera Ethernet Adapter allows connection of up to four Cx cameras of any type on the one side and 1 Gbps Ethernet on the other side. This adapter allows access to connected Cx cameras using routable TCP/IP protocol over unlimited distance.

16. 8-positions external filter wheel “XS” for 1.25”/D31 mm filters
17. 7-positions external filter wheel “XS” for D36 mm filters
18. 12-positions external filter wheel “S” for 1.25”/D31 mm filters
19. 10-positions external filter wheel “S” for D36 mm filters
20. 7-positions external filter wheel “S” for 2”/D50 mm filters

CMOS Sensors and Camera Electronics

C1+ series of CMOS cameras are equipped with Sony IMX **global shutter** CMOS detectors with 3.45 × 3.45 µm or 4.50 × 4.50 µm square pixels.

All used sensors utilize global electronic shutter, which means every pixel within the image is exposed in the same time, as opposed to rolling shutter, 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.

Three lines of C1+ cameras are available depending on the available dynamic range (bit-depth of the digitized pixels) and pixel size:

- **C1+ cameras with Sony IMX sensors with 3.45 × 3.45 µm pixels, 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 with 3.45 × 3.45 µm pixels, 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 speed 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 “A” cameras may be then very attractive.
- **C1+ cameras with Sony IMX sensors with 4.50 × 4.50 µm pixels and 12-bit digitization only.** Greater pixels mean higher dynamic range (more electrons can be stored in each pixel before it saturates), but also higher read noise. Still the theoretical S/N is almost the same because of higher signal camera can accumulate. This camera is more suitable for longer focal length telescopes, where small pixels provide oversampled images, and also for research applications, where dynamic range is important.

C1+ camera models with 3.45 × 3.45 µm pixels and 8- and 12-bit digitization:

Model	C1+3000	C1+5000	C1+12000
CMOS sensor	IMX252	IMX250	IMX253
Resolution	2064 × 1544	2464 × 2056	4112 × 3008
Pixel size	3.45 × 3.45 µm	3.45 × 3.45 µm	3.45 × 3.45 µm
Sensor size	7.12 × 5.33 mm	8.50 × 7.09 mm	14.19 × 10.38 mm

C1+ camera models with 3.45 × 3.45 µm pixels and 12-bit digitization only:

Model	C1+3000A	C1+5000A	C1+12000A
CMOS sensor	IMX265	IMX246	IMX304
Resolution	2064 × 1544	2464 × 2056	4112 × 3008
Pixel size	3.45 × 3.45 µm	3.45 × 3.45 µm	3.45 × 3.45 µm
Sensor size	7.12 × 5.33 mm	8.50 × 7.09 mm	14.19 × 10.38 mm

C1+ camera models with 4.50 × 4.50 µm pixels and 12-bit digitization only:

Model	C1+7000A
CMOS sensor	IMX428
Resolution	3216 × 2208
Pixel size	4.50 × 4.50 µm
Sensor size	14.47 × 9.94 mm

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.

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 show 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.

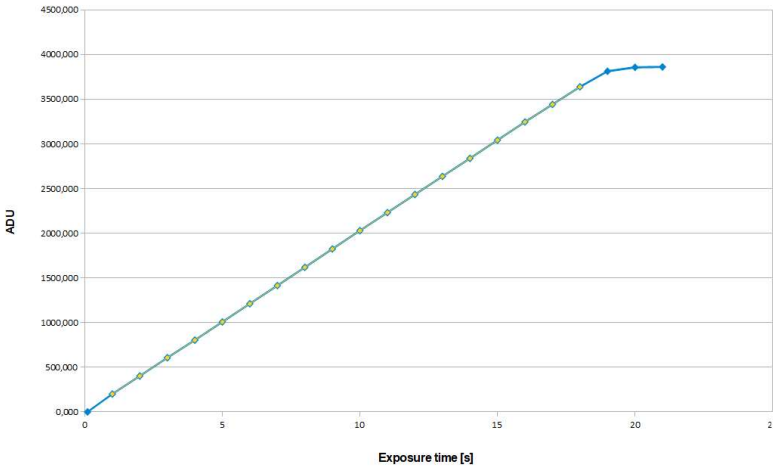


Figure 4: Response of the Sony IMX sensors with 3.45 × 3.45 µm pixels (IMX252)

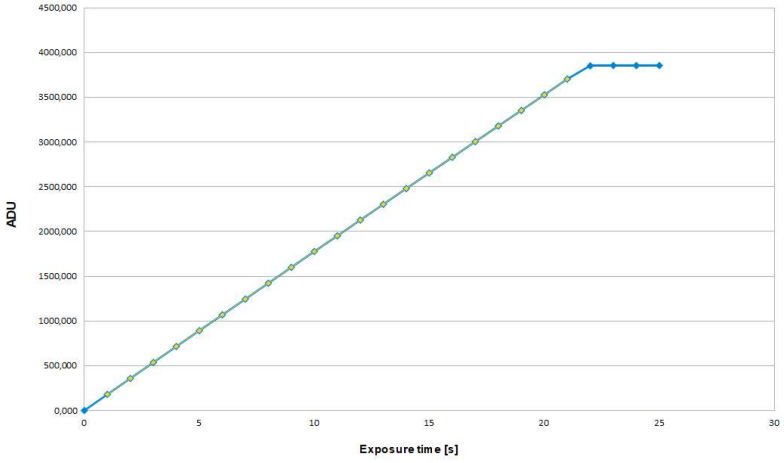


Figure 5: Response of the Sony IMX sensors with 4.50 × 4.50 µm pixels (IMX428)

Download speed

As already noted, there are two lines of C1+ camera series, differing in the used sensor. The first series with 3.45 × 3.45 µm pixels 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

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 C1+ cameras with 3.45 × 3.45 µm pixels offers only single read mode:

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

And the "A" version of C1+ cameras with 4.50 × 4.50 µm pixels offers also only one read mode:

- **12-bit fast** mode with ~151 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.

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 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.

Note the 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, all sensor characteristics depend on the used gain. So, we provide two list of parameters for both minimal and maximal gain.

Camera/sensor parameters for sensors with 3.45 × 3.45 µm pixels:

Digitization	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

Camera/sensor parameters for sensors with 4.50 × 4.50 µm pixels:

Digitization	12-bit	12-bit
Sensor gain	0 dB	24 dB
Full well capacity	26000 e-	2100 -e
Conversion factor	6.3 e-/ADU	0.5 e-/ADU
Read noise	5.3 e- RMS	3.9 e- RMS

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

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).

Internal mechanical shutter	No
Shortest exposure time	0.000125 s (electronic shutter)
Longest exposure time	Limited by chip saturation only

Cooling and power supply

As mentioned in the introduction, C1+ cameras can operate only with USB power. Camera is then capable to acquire images and to control (guide) telescope mount via “autoguider” port. However, active sensor cooling (as well as filter wheel operation) is available only if external 12 V DC power supply is connected.

> Camera fan operates even without 12 V DC power attached, only with lower fan speed. This helps to keep the camera electronics temperature close to environment temperature. When the 12 V DC power is plugged in, the fan turns to full speed to remove the heat generated by the Peltier thermo-electric cooler.

Regulated thermoelectric cooling is capable to cool the CMOS sensor more than 40 °C below ambient temperature. The Peltier hot side is cooled by fan. The sensor temperature is regulated with ±0.1 °C precision. High temperature drop and precision regulation ensure very low dark current for long exposures and allow proper image calibration.

Figure 6: C1+ air inlet with fan is on the bottom side of the camera head (left), air outlet vents are on the camera top side (right)

The camera head contains two temperature sensors – the first thermometer measures directly the temperature of the CMOS sensor. The second one measures the temperature inside the camera shell.

The cooling performance depends on the environmental conditions and also on the power supply. If the power supply voltage drops below 12 V, the maximum temperature drop is lower.

CMOS sensor cooling	Thermoelectric (Peltier modules)
Maximal cooling ΔT	~45 °C below ambient
Regulated cooling ΔT	40 °C below ambient (~90% cooling)
Regulation precision	±0.1 °C
Hot side cooling	Forced air cooling (fan)

Maximum temperature difference between sensor and ambient air may be reached when the cooling runs at 100% power. However, temperature cannot be regulated in such case, camera has no room for lowering the sensor temperature when the ambient temperature rises. Typical temperature drop can be achieved with cooling running at approx. 90% power, which provides enough room for regulation.

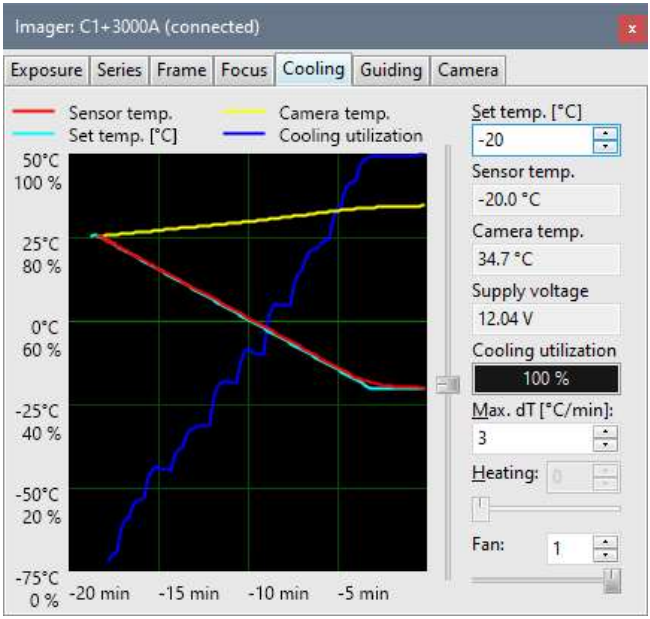


Figure 7: C1+3000A camera reaching maximum -45°C sensor temperature below ambient

Power supply

Certain camera functions need 12 V DC power supply. Power can be sourced from batteries, wall adapters etc. Universal 100-240 V AC/50-60 Hz, 60 W “brick” adapter is supplied with the camera. Although the camera power consumption does not exceed 25 W, the 60 W power supply ensures noise-free operation.

Warning:

The power connector on the camera head uses center-plus pin. Although all modern power supplies use this configuration, always make sure the polarity is correct if you use own power source.

Camera head supply	12 V DC
Camera head power consumption	<1 W without cooling
	22 W maximum cooling
Power connector	5.5/2.5 mm, center +
Adapter input voltage	100-240 V AC/50-60 Hz
Adapter output voltage	12 V DC/5 A
Adapter maximum power	60 W

Power consumption is measured on the 12 V DC side. Power consumption on the AC side of the supplied AC/DC power brick is higher.

The camera can be powered by unregulated 12 V DC power source – the input voltage can be anywhere between 10 and 14 V. However, cooling efficiency can degrade if the supply drops below 12 V.

C1+ camera measures its input voltage and provides it to the control software. Input voltage is displayed in the Cooling tab of the Imaging Camera tool in SIPS. This feature is important especially if the camera is powered from batteries.

Figure 8: 12 V DC/5 A power supply adapter for C1+ camera

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 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. Ability to automatically guide astronomical mounts built into C1+ cameras.

C1+ cameras are 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.

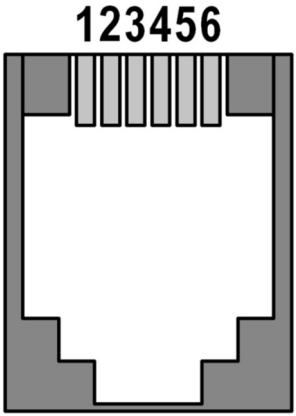
C1+ cameras work in connection with a host computer (PC). Guiding corrections are not calculated in the camera itself, it only sends acquired images to the PC. The software running on the PC calculates the difference from required state and sends appropriate corrections to the telescope mount. The plus 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, but more accurate guiding can be achieved using so called “Autoguider” port. It is enough to connect the 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 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.

Figure 9: Standard 6-pin Autoguider Port is located close to the USB3 port on the back side of C1+ camera

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

Compact and robust camera head measures only 78×78×80 mm (approx. 3.1×3.1×3.2 inches). The head is CNC-machined from high-quality aluminum and black anodized. The head itself contains USB-B (device) connector, Autoguider port connector, connector for External Filter Wheel and 12 V DC power plug.

The front side of the C1+ camera body is not intended for direct attachment of the telescope/lens adapter. It is instead designed to accept tiltable adapter base, on with the telescope and lens adapters are mounted. There are two variants of adapters available:

- **C1 compatible adapter base** with M42×0.75 (T-thread) and back focal distance (BFD) 18.5 mm.

  The 18.5 mm BFD equals to C1 camera with M42×0.75 adapter. Numerous extension adapters are available for C1 cameras, like M48×0.75 thread or M42×0.75 thread (T-adapter) with 55 mm BFD, Canon EOS and Nikon bayonets etc. All these adapters are then compatible with C1+ cameras.

  As opposed to C1 series, these adapters are mounted on the tiltable base and therefore can adjust optical axis if necessary.

- **C2 compatible adapter base** with 16.5mm BFD. This adapter is equipped with four M3 threaded holed 44 mm apart and also M48×0.75 thread.

  Note the 16.5 mm BFD equals to BFD of large cooled C2 cameras without filter wheel. Therefore, it is possible to attach all adapters for C2 cameras as well as external filter wheels to this adapter.

  When used with External filter wheel, this adapter base lacks the tilting spring and pushing screws, which are not necessary as the External filter wheel itself offer tiltable adapters intended for C2 cameras.

Of course, this adapter can be used without External filter wheel and then it provides M48×0.75 with very short 16.5 mm BFD.

Figure 10: C1+ camera with C1 compatible adapter (left) and with C2 compatible adapter (right)

Head dimensions	78×78×80 mm (without adapter base)
Back focal distance	18.5 mm (with C1 compatible adapter)
	16.5 mm (with C2 compatible adapter)
Camera head weight	0.68 kg

Back focal distance is measured from the sensor to the base on which adapters are mounted. Various adapters then provide back focal distance specific for the particular adapter type (e.g. M48 threaded adapter back focal distance is 55 mm).

Stated back focal distance already calculates with glass permanently placed in the optical path (e.g. optical window covering the sensor cold chamber).

C1+ Camera with C1 compatible adapter

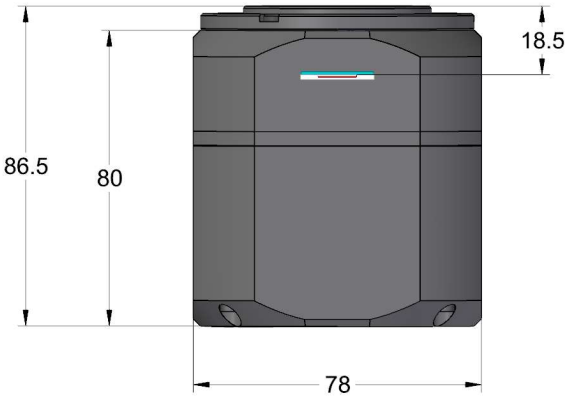


Figure 11: C1+ camera head with C1 compatible adapter side view dimensions

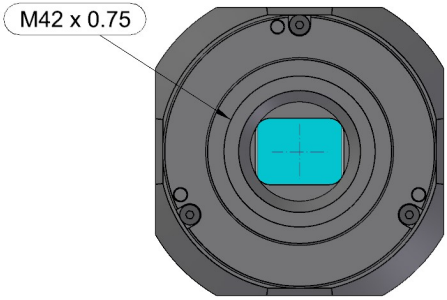


Figure 12: C1+ camera head with C1 compatible adapter front view dimensions

C1+ Camera with C2 compatible adapter

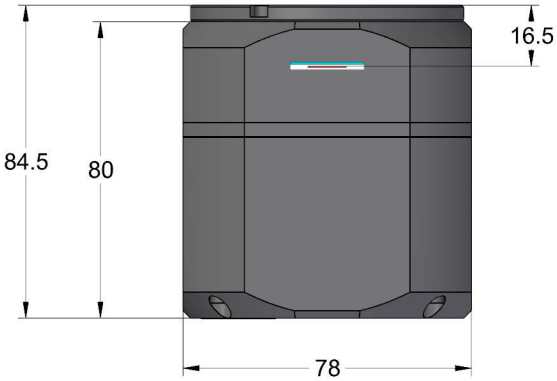


Figure 13: C1+ camera head with C2 compatible adapter side view dimensions

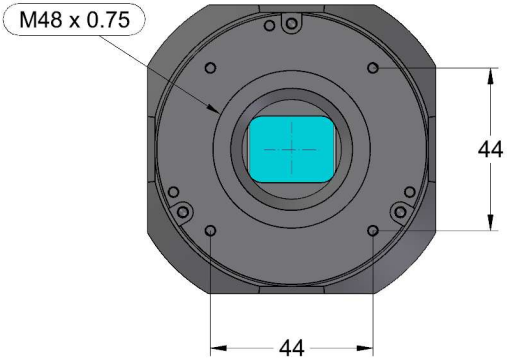


Figure 14: C1+ camera head with C2 compatible adapter front view dimensions

C1+ Camera with "XS" External Filter Wheel

C1+ cameras can be equipped with the same external filter wheels like the C2 cameras. In such case the C2 compatible adapter has to be used as a base for the External filter wheel.

Note the filter wheel can be used only if the C1+ camera is plugged to 12 V DC external power supply.

If the external filter wheel is used, tiltable adapters for C2 or G2 Mark II cameras have to be used with it.

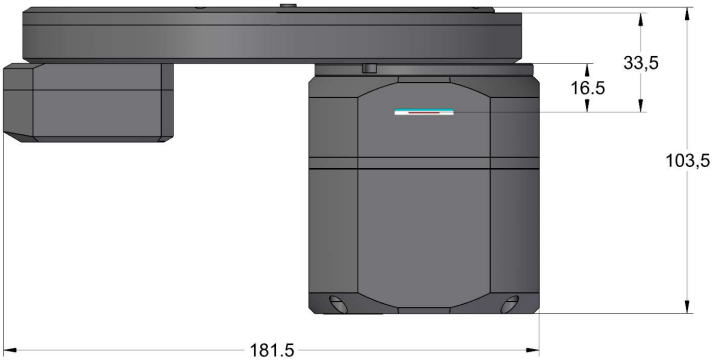


Figure 15: C1+ camera head with External filter wheel side view dimensions

Figure 16: C1+ camera head with External filter wheel bottom view dimensions

The “S” sized External Filter Wheel diameter is greater (see External Filter Wheel User's Guide), but the back focal distance of all external filter wheels is identical.

Optional accessories

Various accessories are offered with C1+ cameras to enhance functionality and help camera integration into imaging setups.

Telescope adapters

Telescope and lens adapters, intended for usage with C1+ cameras, are of two kinds:

- **Adapters for C1 cameras.** These adapters are mounted using M42×0.75 thread with 18.5 mm BFD. C1 compatible adapter base must be mounted on the C1+ camera head.
- **Adapters for C2 cameras.** C2 camera adapters are mounted on a tiltable base, which is manufactured on external filter wheel or on a standalone base if no filter wheel is used. Filter wheel or adapter base is mounted using four M3 threaded holes on a plate 16.5 mm from the sensor.
    - If a C2 adapter has to be used without filter wheel, a stack of two adapter bases must be used on C1+ camera – C2 compatible adapter base for C1+ camera and C2 adapter base on it. However, such combination is superfluous as majority of C2 adapter have an equivalent designed for C1 camera and thus can be used with C1 compatible adapter base.
    - The same tiltable adapter base is manufactured on the front plate of the external filter wheels. External filter wheel needs the C2 compatible adapter base attached to C1+ camera. Then all C2 adapters can be used.

Adapters for C1+ cameras with C1 compatible adapter base

Adapters are mounted to the C1 compatible adapter base, which provide titling mechanism.

- **T-thread with 55 mm BFD** – M42×0.75 inner thread adapter, preserves 55 mm back focal distance.
- **M48×0.75 with 55 mm BFD** – adapter with inner thread M48×0.75, preserves 55 mm back focal distance.

- **Nikon bayonet** – standard Nikon lens adapter, preserves 46.5 mm back focal distance.
- **Canon EOS bayonet** – standard Canon EOS lens adapter, preserves 44 mm back focal distance.

Figure 17: Adapters for C1 cameras, compatible with C1+ models

Adapters for C1+ cameras with C2 compatible adapter base and external filter wheel

C1+ uses the same External filter wheels like the C2 series. These External filter wheels are equipped with tiltable base, intended for adapters.

- **2-inch barrel** – adapter for standard 2" focusers.
- **T-thread short** – M42×0.75 inner thread adapter.
- **T-thread with 55 mm BFD** – M42×0.75 inner thread adapter, preserves 55 mm back focal distance.
- **M48×0.75 short** – adapter with inner thread M48×0.75.
- **M48×0.75 with 55 mm BFD** – adapter with inner thread M48×0.75, preserves 55 mm back focal distance.
- **Canon EOS bayonet** – standard Canon EOS lens adapter, preserves 44 mm back focal distance.
- **Nikon F bayonet** – standard Nikon F lens adapter, preserves 46.5 mm back focal distance.

Attaching camera head to telescope mount

C1+ camera heads are equipped with “tripod” thread (0.25”) as well as four M4 threaded holes on the bottom side of the camera head.

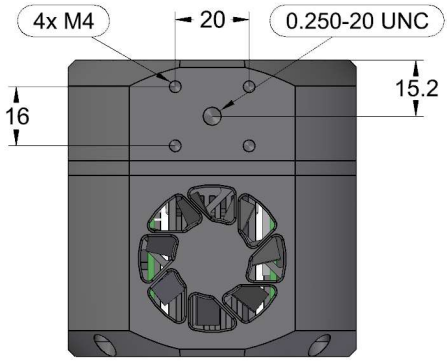


Figure 18: Threaded mounting holes on the camera head bottom side

These threaded holes can be used to attach 1.75 inch “dovetail bar” (Vixen standard). It is then possible to attach the camera head, e.g. equipped with photographic lens, directly to various telescope mounts supporting this standard.

Figure 19: 1.75" bar for standard telescope mounts

Moravian Camera Ethernet Adapter

The Moravian Camera Ethernet Adapter allows connection of up to four Cx and Gx cameras of any type on the one side and 1 Gbps Ethernet on the other side. This adapter allows access to connected cameras using routable TCP/IP protocol over practically unlimited distance.

Figure 20: The Camera Ethernet Adapter with two connected cameras

Adjusting of the telescope adapter

All telescope/lens adapters of the C1+ series of cameras can be slightly tilted. This feature is introduced to compensate for possible misalignments in perpendicularity of the telescope optical axis and sensor plane.

The camera adapter base is attached using three “pulling” screws. As the adapter tilt is adjustable, another three “pushing” screws are intended to fix the adapter after some pulling screw is released to adjust the tilt.

Figure 21: Adjusting of the "pulling" screw

Because the necessity to adjust two screws (one pushing, one pulling) at once is inconvenient, the adapter tilting mechanism is also equipped with ring-shaped spring, which pushes the adapter out of the camera body. This means the pushing screws can be released and still slight releasing of the pulling screw means the distance between the adapter and the camera body increases. The spring is designed to be strong enough to push the camera head from the adapter (fixed on the telescope) regardless of the camera orientation.

When all three pulling screws are fully tightened, releasing of just one or two of these screws does not allow adapter to move, or at last only very slightly thanks to deformation of the adapter body. If the adapter has to be adjusted, it is necessary to slightly release all three pulling screws, which makes room for tilt adjustment.

Only after the proper tilt is reached, the pushing screws should be slightly tightened to fix the adapter in the desired angle relative to camera head. This ensures long-time stability of the adjusted adapter.

Adjustable telescope/lens adapters are attached slightly differently depending if the adapter is attached directly to the camera head (e.g. when camera is equipped with internal filter wheel) or to the External filter wheel case.

- C1+ camera adapters are not mounted directly on the camera head. Instead, a tilting adapter base, holding the circular spring, is always used.
- If the External filter wheel is used, the adapted base is not necessary, as the External filter wheel front plate is already designed to hold the spring and it also contains threads to fix respective adapters.

Figure 22: External filter wheels are already designed to for adjustable telescope adapters

Camera Maintenance

The C1+ camera 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.

Desiccant exchange

The C1+ camera cooling is designed to be resistant to humidity inside the CMOS sensor chamber. When the temperature decreases, the copper cold finger crosses freezing point earlier than the sensor itself, so the water vapor inside the sensor chamber freezes on the cold finger surface first. Although this mechanism works very reliably in majority of cases, it has some limitations, especially when the humidity level inside the sensor chamber is high or the chip is cooled to very low temperatures.

This is why a cylindrical container, filled with silica-gel desiccant, is placed inside the camera head. This cylindrical chamber is connected with the insulated cooled sensor chamber itself.

> **Warning:**
>
> High level of moisture inside the sensor cold chamber can cause camera malfunction or even damage to the CMOS sensor. Even if the frost does not create on the detector when the sensor is cooled below freezing point, the moisture can be still present. It is necessary to keep the sensor chamber interior dry by the regular exchange of the silica-gel desiccant. The frequency of necessary silica-gel exchanges depends on the camera usage. If the camera is used regularly, it is necessary to dry the sensor chamber every few months.

It is possible to dry the wet silica-gel by baking it in the oven (not the microwave one!) to dry it again. Dry the silica-gel for at last one or two hours at temperature between 120 and 140 °C.

The silica-gel used in C1+ cameras changes its color according to amount of absorbed water – it is yellow-orange when it is dry and turns to green or transparent without any color hue when it becomes wet, depending on the

silica-gel type (manufacturer). It is recommended to shorten replacement interval if the silica-gel is completely green or transparent upon replacement. If it is still yellow-orange, it is possible to prolong the replacement interval.

Figure 23: Silica-gel container is accessible from the camera back side

Exchanging the silica-gel

C1+ cameras employ the same desiccant container like the larger C1x, C2, C3 and C4 cameras. The whole container can be unscrewed, so it is possible to exchange silica-gel without the necessity to remove the camera from the telescope.

Silica-gel is held inside the container with a perforated cap. This cap is also screwed into the container body, so it is easy to exchange the silica-gel inside the container after it is worn out or damaged e.g. by too high temperature etc.

The container itself does not contain any sealing (the sealing remains attached to the sensor cold chamber inside the camera head), it consists of aluminum parts only. So, it is possible to heat the whole container to desired temperature without risking of the temperature-induced sealing damage.

Figure 24: Desiccant is held inside container by perforated cap

This design also allows usage of some optional parts:

- Threaded hermetic cap, which allows sealing of the dried container when it is not immediately attached to the camera head.
- Alternate (somewhat longer) desiccant container, modified to be able to be screw in and tightened (as well as released and screwed out) without any tool.

The sealing cap as well as the tool-less container are not supplied with the camera, they are supplied only as optional accessory.

Figure 25: Optional cap, standard container and the tool-less variant of the container

Changing the telescope adapter

Changing of the C1+ camera telescope adapter depends on whether the camera is equipped with C1 compatible adapter of C2 compatible adapter.

Changing the C1 compatible adapter

C1 compatible adapters are simply screwed into the adapter base. Replacing of the adapter needs only to unscrew the original extension adapter and screw in the new one.

Changing the C2 compatible adapter

While in principle the C1+ camera allows usage of C2 adapters through the C2 compatible base, in reality C2 adapters are used only with the External Filter Wheels.

Adapters are attached to External Filter Wheel using three “pulling” screws. As the adapter tilt is adjustable, another three “pushing” screws are intended to fix the adapter in place.

If the adapter has to be replaced for another one, it is necessary to unscrew the three pulling screws. The adapter then can be removed and replaced with another one.

Warning:

Both pulling and pushing screws, used on the External Filter Wheel adapter base, are fine-pitch M4×0.5 thread screws, not standard M4 thread ones. Always use only screws supplied with the adapter, using of normal M4 screws damages the adapter.

Always make sure to carefully locate the ring-shaped spring prior to attaching the adapter.

Figure 26: Replacing the C1 compatible telescope adapter