Moravian Cameras

Installing and Using Drivers and Software

Version 3.6

Modified on September 6th, 2019

All information furnished by Moravian Instruments is believed to be accurate. Moravian Instruments reserves the right to change any information contained herein without notice.

Cx and Gx cameras are not authorized for and should not be used within Life Support Systems without the specific written consent of the Moravian Instruments. Product warranty is limited to repair or replacement of defective components and does not cover injury or property or other consequential damages.

Moravian Instruments
Masarykova 1148
763 02 Zlín
Czech Republic

phone: +420 577 107 171
web: http://www.gxccd.com/
e-mail: info@gxccd.com

Table of Contents

Getting Started

Although Gx and Cx cameras are intended for operation at night (or for very low-light conditions at day), it is always better (and highly recommended) to install software and to make sure everything works OK during day, before the first night under the stars.

> The Gx and Cx cameras can be in principle operated under various camera control software packages (refer to our web site for available drivers), this manual demonstrates camera operation under the SIPS (Scientific Image Processing System) – camera control and image processing software suite supplied with the camera.

Camera System Driver Installation

Every USB device requires so-called “system driver”, incorporated directly into the operating system kernel. Some devices (for instance USB Flash Disk dongles) conform to some predefined class (USB mass-storage device class in this case), so they can use the driver already present in the operating system. But this is not the case of the Gx and Cx cameras – they require its own system driver to be installed.

Although 64-bit operating system can run 32-bit application without any problems, it is basically impossible to combine e.g. 64-bit process with 32-bit dynamic link library. The same is valid for operating system kernel – 64-bit kernel cannot use 32-bit system driver. This is why all Gx and Cx camera system drivers are supplied in two versions, one for 32-bit systems (marked x86 according to Intel 386, 486 CPUs) another for 64-bit systems, marked x64 (according to CPUs supporting 64-bit instructions marked x86-64 or only x64).

The simplest way to install the Gx and Cx camera system driver is to run driver pre-installation package (“GxCamDrivers.exe” provided with the camera or downloaded from a web site) on the target computer. This package installs drivers for all cameras on the particular computer. Then it is enough to plug in the camera and the operating system already knows which driver to use.

Pre-installation is the recommended way how to install system drivers. It is not necessary to deal with differences among individual versions of operating systems, described in subsequent chapters. If the user decides not to use pre-installation, it is necessary to consider different implementation of the “Plug-and-play” mechanisms of driver installation in different Windows versions.

> Due to differences in KAF and KAI CCD handling, there are two drivers for cameras utilizing the respective detectors. Driver names are distinguished by the last letter 'F' and 'I'. Cameras based on the E2V back-illuminated detectors use yet another driver with 'BI' suffix.
>
> Also, individual camera revisions may require different drivers depending on the used digital electronics. Older cameras use “g3ccdF.sys” and “g3ccdI.sys” drivers, while newer use “gXccdF.sys”, “gXccdI.sys” and “gXccdBI.sys” drivers.
>
> All Cx CMOS cameras use single system driver “cXcamera.sys”.

Windows 7, Windows 8/8.1 and Windows 10 System Driver Installation

Windows 7 and later versions do not offer users the possibility to install system drivers using Plug-and-Play, like in the case of older Windows 2000, Windows XP and Windows Vista. It is necessary to pre-install all drivers, else the operating system only informs the user that it cannot find appropriate driver for newly connected device.

We can only estimate reasons for this limitation of system functionality, probably it has something common with the inability of many hardware vendors to provide drivers complying to Plug-and-play standards (notification requiring installation of the software first and plugging of the device later was present on many devices).

Although the Plug-and-Play mechanism is hidden in Windows 7 and later, it is still possible to use it. Newly connected device appears in the “Device Manager” as “Unknown Device” (such device is usually marked by a question mark on yellow background icon). It is enough to click on such device by right mouse button to invoke pop-up menu and choose “Update Driver...” menu item. Operating system then opens driver installation wizard, basically identical to the one automatically opened in in Windows XP and Windows Vista.

Let us note that 64-bit versions of Windows 8, Windows 7 and Windows Vista require digitally signed drivers. Drivers without digital signature cannot be installed on these systems.

All Gx/Cx camera drivers supplied by Moravian Instruments are digitally signed.

Windows 10 requires digitally signed drivers regardless of the operating system variant. What's more, drivers for this system must be signed directly by Microsoft corporation, which at the same time tests drivers for compatibility and especially for security, because components of the operating system kernel work at highest priority level and can perform any actions without any access rights restriction. This is why the driver installation package for Windows 7 and 8 is different than installation package for Windows 10 – it contains the same drivers, but with different digital signature.

Windows XP and Windows Vista System Driver Installation

Pre-installation of the system drivers is recommended also on these systems. But it is not necessary, it is enough just to plug the camera to USB port, power it up and follow the instructions provided by the operating system device driver installation wizard.

The operating system notifies the new USB device was plugged in the “Found new hardware bubble”. The system then opens the “Found New Hardware” Wizard.

1. The wizard offers searching for suitable driver on Windows Update site. Reject this offer (choose “No, not this time”) and click “Next” button.
2. Choose the “Install the software automatically” in the next step. Insert the USB Flash Drive into the drive and the wizard will continue by the next step.

   It is not necessary to install files from USB Flash Drive. It is possible to copy the folder containing driver files e.g. to shared network volume etc. Then it is necessary to choose the “Install from a list or specific location” and to define the path to driver files.

3. The wizard starts to copy files. But Windows XP checks for driver file digital signature. If it cannot find the signature, it notifies the user by a message box. Click “Continue Anyway”, the digital signature is only an administrative step and does not influence the proper functionality.
4. The wizard then finishes the installation and the camera is ready to work.

Please note the Windows XP system keeps the information about installed devices separately for each USB port. If you later connect camera to a different USB port (different USB connector on the PC or through the USB hub), Windows reports “found new hardware” again and asks you to install the software. Repeating the installation again brings no problem, just choose “Install automatically” option and Windows will reuse already installed drivers.

Scientific Image Processing System

SIPS is a software package designed to handle hardware devices used for astronomical observations (cameras, filter wheels, telescope mounts, focusers, observatory domes etc.), to perform image acquisition during the observing sessions and also subsequent image processing including calibration, stacking of individual frames etc. SIPS also offers advanced image processing functions (transformations, soft-binning and scaling, filtering, de-bayer processing, …) as well as advanced analysis like astrometry and photometry image reduction.

> Please note this manual is not the SIPS User's Guide – such guide is installed with SIPS as a CHM file (click the Help → Contents... from the SIPS main menu). This manual only briefly describes basic functions directly connected with acquiring images with the CCD camera.

SIPS variants

SIPS is provided in two different variants – 32-bit and 64-bit.

The 32-bit variant can be run on both 32-bit and 64-bit Windows, as the full backward compatibility with 32-bit applications is a key feature of both the 64-bit x64 processors and the 64-bit versions of Windows. However, this variant is limited to 2 GB of accessible memory if it runs under 32-bit Windows or 4 GB when it runs under 64-bit Windows.

64-bit variant requires 64-bit Windows to run. There is practically no limit in accessible memory, but the amount of RAM on the particular computer. Let us also note that 64-bit SIPS handles complex algorithms faster compared to 32-bit variant running on the same computer.

Very important issue is the driver compatibility, because it not possible to mix 32-bit and 64-bit code in one process. Every single process is either completely 32-bit or completely 64-bit, including all DLLs, drivers and other components. If some device driver (e.g. ASCOM focuser or mount controller driver) is 32-bit only, also 32-bit SIPS has to be used as the 64-bit SIPS cannot use 32-bit drivers.

SIPS Software Installation

The Scientific Image Processing System (SIPS) software package is designed to operate without the necessity to be installed in any particular folder. The package can be even run directly from USB Flash Drive.

SIPS package is distributed in the two forms:

1. In the form of the executable installation packages 'SIPS_EN_32-bit.exe' and 'SIPS_EN_64-bit.exe'. Running this package installs SIPS similarly to any other Windows application. The user does not need to care whether other libraries or packages are installed, the setup process installs everything necessary.

   If the SIPS is installed this way, then it can be easily uninstalled from the application management of the Windows operating system.

2. In the form called “portable version” on the USB Flash Drive. The directory called “SIPS (Executable files)” with sub-directories “32bit (x86)” and “64bit (x64)” contain SIPS images (set of EXE and DLL files, as well as auxiliary INI files etc.), which can be directly executed. The image can be copied to computer local drive into the (possibly newly created) directory chosen by the user.

   The portable version can be also downloaded in the form of ZIP archive (files 'sips.en.x86.zip' or 'sips.en.x64.zip') from the web site. Again, it is enough to unzip the archive into chosen directory.

   Uninstalling of the SIPS portable version is also quite easy – just delete the SIPS directory.

The portable version of SIPS needs the Microsoft Visual C++ run-time libraries installed on the particular PC to work. Please note that the 32-bit SIPS requires 32-bit version of these libraries and 64-bit SIPS needs 64-bit libraries. So, the required library version does not depend on the version of Windows operating system, but on the version of SIPS (of course 64-bit SIPS can be used on 64-bit Windows only). If both variants of SIPS are used (for instance 32-bit version is used to control observations and 64-bit SIPS is then used to process acquired data) then it is necessary to install bot version of run-time libraries.

Visual C++ libraries also differ according to the C++ compiler version. Up to version 3.5, SIPS used Visual C++ version 9 (Visual Studio 2008). Beginning with the version 3.5.1, SIPS is built with Visual C++ version 14 (Visual Studio 2015). The portable SIPS versions require corresponding versions of the C++ run-time libraries to be installed.

These run-time libraries are often already installed on Windows PCs, because they are used by many other applications. But if they are not present, it is necessary to install them first. Installation packages can be downloaded from the Microsoft web site and they are also present on the USB Flash Drive, supplied with every Gx camera:

- Redist\VS2008\vcredist_x86.exe (32-bit SIPS v3.5 or lower)
- Redist\VS2008\vcredist_x64.exe (64-bit SIPS v3.5 or lower)
- Redist\VS2015\vc_redist.x86.exe (32-bit SIPS v3.5.1 and higher)
- Redist\VS2015\vc_redist.x64.exe (64-bit SIPS v3.5.1 and higher)

If the SIPS is installed from the installable package, users need not to care about Visual C++ libraries at all. Running of the installation package ensures all required components will be installed on the particular PC.

No matter how is the package installed, the software is run by launching the 'sips.exe' main program file.

SIPS configuration files

The software package distinguishes two types of configuration:

- Global configuration, common for all users.
- User-specific configuration.

Global configuration defines which hardware is used and which drivers controls it. The configuration is stored in the simple text file “sips.ini”, which must be placed in the same folder as the “sips.exe” main executable. The file may look for example like this:

```
[Camera]
Moravian Camera on USB = gxusb.dll
```

```
Moravian Camera on Ethernet = gxeth.dll
Legacy G2 camera = g2ccd2.dll
ASCOM Camera = ascom_camera.dll

[GPS]
GarminUSB = gps18.dll
NMEA = nmea.dll

[Telescope]
NexStar = nexstar.dll
Meade = meade.dll
ASCOM = ascom_tele.dll

[Focuser]
ASCOM = ascom_focuser.dll

[Dome]
ASCOM = ascom_dome.dll
```

Individual sections define which driver would be loaded and asked to enumerate all connected devices of particular type (CCD cameras, GPS receivers, telescope mounts, …).

SIPS package already contains this file containing all included drivers. This file is not modified programmatically, it is necessary to edit it manually if new device driver, not included into basic package, is installed.

User-specific configuration is stored in the file named also “sips.ini”, but this file is placed in the '\Documents and Settings\%user_name%\Application Data\SIPS\' folder (Windows 8 a 10 allows accessing of this folder as '\Users\%user_name%\AppData\Roaming\SIPS'). Number of setting are stored in this text file, beginning from the position and open state of individual tool windows, to the preferred astrometry catalog and parameters for searching stars in images and many others.

User-specific configuration file is always read by SIPS during start-up and overwritten upon SIPS termination with the current configuration. Users never manipulate this file directly, it is always read and written by the program only.

Camera Drivers for SIPS

SIPS is designed to work with any CCD camera, providing the driver for the particular camera is installed. The drivers for Gx CCD cameras are included into the basic SIPS package and is not necessary to install them separately.

All Gx and Cx cameras use common driver 'gxusb.dll' when connected directly to the host computer through USB or 'gxeth.dll' when connected through the Camera Ethernet Adapter.

> Common drivers for all Gx/Cx cameras were introduced in the SIPS version 2.3, previous SIPS versions used different drivers for G0/G1 and for G2/G3/G4 cameras. All G2/G3/G4 cameras used the 'g3ccd.dll' driver (g3 name prefix had historical reasons, all cameras inherited electronics originally developed for G3 series and because they were software compatible, they used the same driver), but it was replaced with the 'gxusb.dll' common driver.
>
> Support for Cx CMOS cameras was added to the gxusb.dll to keep the number of used driver DLLs as low as possible.

Definition of filters in the filter wheel

Every camera driver for SIPS has to provide information about available filters (if the particular camera has the integrated or external filter wheel). But the user can order camera with various filters, it is possible to change individual filters or the whole filter wheel etc. There is no way how to determine the actual filter types (colors) in the filter wheel automatically. So, the user must define such information.

Standalone utility program, contained in the SIPS installation version 3.0 and later, is provided to allow definition of filters installed in the particular camera (or cameras).

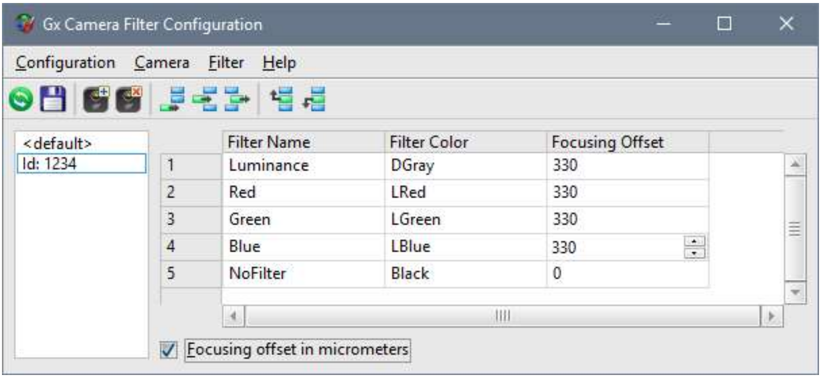


Figure 1: Main window of the filter configuration program

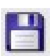
This program is named 'GxFWConfig.exe' and can be run either but clicking of its desktop icon or from the Start menu.

The utility handles filter information, located in the user-specific (HKCU) portion of the Windows Registry (a database containing configuration information for applications and operating system services).

> Please note that because the filter configuration is held individually for every user, definition created by one user is not accessible if another user is logged into the operating system.

The filter description information is read from the Registry upon the program start-up. When the program finishes and modified configuration is not saved back, the user is asked whether to quit the program either way and abandon all performed changes. Read and Write operations can be invoked also manually:

 – refresh (read) the configuration according to current content of the Registry

 – write the current state to the Registry

The configuration tool allows definition of filters used in any particular camera, identified by its Id number:

 – add new camera Id

 – remove currently selected camera Id

Cameras are listed in the left part of the application window. What's more, there is a possibility to define one global <default> configuration, which is used if a camera with Id not listed in the camera list is connected.

Individual filters are described in the sheet on the right side of the application window. Sheet lines, representing individual filters, can be manipulated by the following commands:

 – append new filter description

 – insert new filter description

 – remove currently selected filter description

 – move currently selected filter description one position up

 – move currently selected filter description one position down

If there are more filters in the camera than the configuration describes, other filters will be added with undefined name. And if the configuration describes more filters than the number of filters in the camera, superfluous descriptions will be omitted.

Each filter definition consists of three values:

- **Filter name**: This name is returned to the client application, which can use it to list available filters in the filter wheel.
- **Filter color**: This color can be used by client application to display the filter name with a color, hinting the filter type. The color can

be expressed by a name (White, Red, LRed, etc.) or directly by number representing the particular color (0 represents black).

- **Filter offset**: Distance to move the focuser to refocus upon filter change. Plan-parallel glass shifts the actual focus position back for 1/3 of the glass thickness (exact value depends on the glass refraction index, but for almost all glasses 1/3 is very close to exact value). Refocusing is useful when changing filters of different thickness among exposures or when some exposures are performed through filters and other without filters at all.

  Filter offsets can be defined in the focuser dependent units (steps) or in micrometers (µm). If the micrometers are used, it is necessary to inform driver by checking the "Focusing offset in micrometers" check-box, located below the filter description sheet.

The above-mentioned information will be used e.g. to display the filter-choosing combo-box of the SIPS "Imaging Camera" tool:

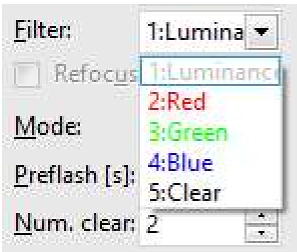


Figure 2: Filters offered by the SIPS Imager tool

Definition of filters using configuration file

If the filter definition is not found in the Registry, the Gx camera driver for SIPS uses alternate way to describe used filters – the 'gxusb.ini' file.

The 'gxusb.ini' file is placed in the same directory where the camera driver and the SIPS itself is installed.

Note that when no portable version of SIPS, which can be located in arbitrary directory, is used, but SIPS is installed into the "Program Files" directory, this particular directory is protected by UAC (User

Access Control) mechanisms in Windows. When the file INI is opened into editor (e.g. notepad) and modified, it cannot be just saved into the same directory. It is necessary to save it elsewhere and then copy it back to its original location in the "Program Files", because it is necessary to confirm UAC dialog box during file copy operation.

Configuration file is ordinary text file following the .INI files conventions. Here is the example of the 'gxusb.ini':

```
[filters]
Luminance, Gray, 330
Red, Lred, 330
Green, Lgreen, 330
Blue, Lblue, 330
Clear, 0, 0
```

Filters are described in the `[filters]` Section. Every line in this section describes one filter position. Filter description is a comma-separated list of three values, identical to items described in the previous chapter.

Filter offsets can be defined in the focuser dependent units (steps) or in micrometers (μm). If the micrometers are used, it is necessary to inform driver by the `MicrometerFilterOffsets` parameter in the `[driver]` section of the ini file.

```
[driver]
MicrometerFilterOffsets = true

[filters]
Luminance, Gray, 660
...
```

Value of the `MicrometerFilterOffsets` parameter can be expressed as keywords `true` or `false` as well as numbers `0` (for false) or `1` (for true).

Using of multiple configuration files for different cameras

It is sometimes necessary to work with multiple cameras, sharing single driver on the computer (whole series of Gx cameras share 'gxusb.dll' or 'gxeth.dll' drivers). If multiple cameras have different filter wheels with different filters, it is rather complicated to adopt the 'gxusb.ini' configuration file to currently connected camera. If there are multiple cameras connected at once, adopting of configuration file is not possible.

This is why SIPS camera drivers (and also Gx/Cx camera drivers for other programs) allows enhanced naming convention of driver configuration file. Every Gx and Cx series camera has unique identification number, stated on the camera shell (this number is also displayed in the list of all connected cameras in the SIPS "Imaging Camera" tool).

Camera driver tries to open configuration file, which name is extended with the camera ID number first. If for instance camera ID is 1234, driver tries to open configuration file named 'gxusb.1234.ini'. Only if such file does not exist, general configuration file 'gxusb.ini' is used. So, it is possible to create separate configuration files describing filters in every connected camera.

Cropping of the sensor area

The camera driver is able to crop the image matrix even before the image is passed to SIPS. Although it is possible to define sub-frames directly in SIPS camera control tool, limiting camera resolution this way is not very convenient when multiple frames of different types (light, dark, flat) are acquired. If for instance the user wants to use only center area of a large CCD because the optics used cannot utilize such large CCD detector, it is possible to read only a sub-frame (sub-frame 256, 0, 1024, 1024 converts 1.5 Mpx G2-1600 camera into 1 MPx camera). But different sub-frame is used e.g. when focusing the camera and it is necessary to properly restore above mentioned subframe before each acquired dark, light or flat field. And 1-pixel difference between light and dark frame harms the possibility to properly calibrate images.

This is why the 'gxusb' and 'gxeth' drivers allow definition of sub frame in the appropriate .ini file in the **[crop]** section:

```
[crop]
x = 256
y = 0
w = 1024
h = 1024
```

Such camera will report resolution 1024×1024 pixels to SIPS and all other sub-frames, defined in the SIPS camera control tools, will be related to the above defined subframe.

> Note that the crop function is not supported by the Driver configuration tool described above. If it is desirable to use driver-level cropping, modification of the INI file is necessary. Individual filters them may be described either in Registry using the configuration tool or in the INI file.

Camera Connection

Camera connection is pretty easy. Plug the power supply into the camera and connect the camera to the computer USB port using the supplied USB cable. Note the computer recognizes the G2 to G4 and C2 to C4 cameras only if it is also powered. Camera without power act the same way as the unplugged one from the computer point of view. G0, G1 and C1 cameras are powered from the USB line, so they work immediately upon the USB cable connection.

When the camera equipped with internal or external filter wheel is powered and connected to the computer (with appropriate drivers installed), it starts with filter wheel initialization. Filter wheel starts to rotate and the camera control unit searches for the filter wheel home position. This operation takes a few seconds, during which the camera does not respond to computer commands. Camera indicates this state by flashing the orange LED. See the “Camera LED state indicator” chapter for details.

Figure 3: Camera without internal wheel (left) and with internal filter wheel (right). USB and power connectors are on the bottom side of the camera head.

The G2, G3 and G4 cameras are fully powered by the external power supply, they do not use USB cable power lines. This means it does not draw laptop batteries and long USB cables with thin power lines (which can cause voltage drops and power-related problems for USB-powered devices) does not affect operation of these cameras.

Camera LED state indicator

There is a two-color LED on the camera body, close to the USB connector. The LED is functional only upon camera start-up not to influence observations.

The LED starts blinking orange when the camera starts to initialize filter wheel. Orange blinks are not always the same – they depend on the filter position when the camera is powered up.

If the case the camera control unit cannot find the filter wheel origin, the camera notifies the user by 2 s long red flash immediately after filter initialization failed (orange blinking terminates).

> The whole filter wheel initialization procedure is skipped in the case of G0, G1 and C1 cameras, as well as if the Gx or Cx camera does not include internal neither external filter wheel.

So, if you notice orange blinks followed by 2 s red blink, the filter wheel failed to initialize. Although the camera continues operation like the model without filter wheel, it is not recommended to start work with such camera – it is not clear which filter is in front of the sensor or the wheel can be in the inter-filter position. Return the camera to manufacturer for maintenance in such case.

Camera firmware finishes initialization by signaling the USB speed, on which it is currently operating. The indication differs depending on the USB version supported by particular camera series.

Gx cameras with USB 2.0 interface:

- USB 2 High Speed (480 Mbps) is signalized by 4 short green blinks.
- USB 1 Full Speed (12 Mbps) is signalized by 4 short red blinks.

Cx cameras with USB 3.0 interface:

- USB 3 Super Speed (5 Gbps) is signalized by 4 short green blinks.
- USB 2 High Speed (480 Mbps) is signalized by 4 short orange blinks.
- USB 1 Full Speed (12 Mbps) is signalized by 4 short red blinks.

Working with Multiple Cameras

It is possible to connect multiple cameras to single computer, be it directly to USB ports available on the computer I/O panel or through the USB hub. The operating system assigns unique name to every connected USB device, but this name is rather complex string derived from the device driver GUID, USB hub identifiers, USB port number on the particular hub etc. Simply put, these identifiers are intended for distinguishing USB devices within operating system, not to be used by computer users. And when multiple cameras are connected through the "Camera Ethernet Adapter", distinguishing individual cameras through the USB path is completely unavailable.

But the user always needs to distinguish individual cameras – for instance one camera should be used for pointing, another for imaging. This is why every camera has assigned unique identifier (ID number). This number is engraved into camera body and it is also displayed in the list of all available cameras in the "Imaging Camera" tool in SIPS. This enables the user to select the particular camera he or she needs.

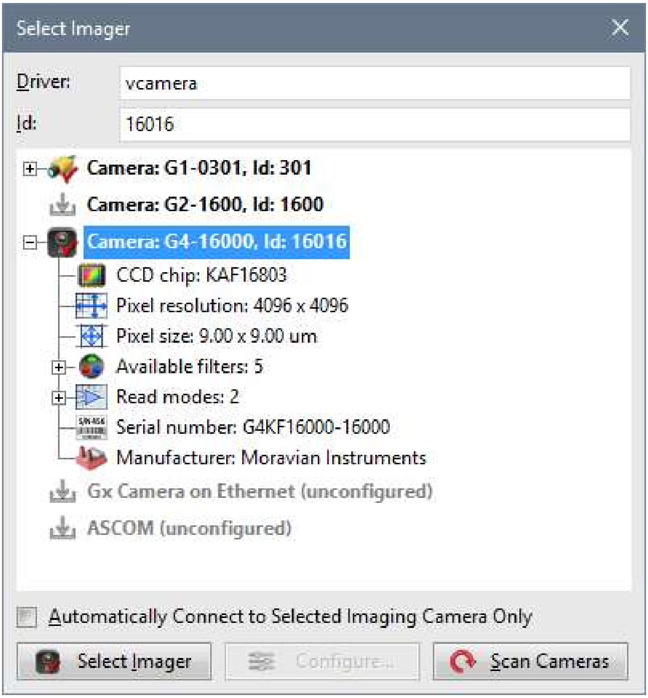


Figure 4: Camera Id number is displayed after camera name in SIPS

Camera Operation

Camera operation depends on the software used. Scientific cameras usually cannot be operated independently on the host computer and Gx cameras also need a host PC (with properly installed software) to work. Camera itself has no displays, buttons or other controls. On the other side, every function can be controlled programmatically, so the camera is fully controllable from the (possibly remote) computer, no operation requires personal presence of the user.

Plug the camera into computer and power supply and run the SIPS program. Open the “Imaging Camera” tool (choose the “Tools” menu and click the “Imaging camera...” item or click the  tool button). The camera name (e.g. “G2-1600”) should be displayed in the title bar of the tool window.

However, algorithms used by SIPS to select camera is more complex:

- SIPS remembers, which camera was selected last time and tries to select it as imaging camera when it is launched again.
- If the remembered camera is not connected to the computer (or powered up) upon SIPS startup (or there is no remembered camera at all – either SIPS is run for the first time or no imaging camera was selected during last run), SIPS selects the first enumerated camera.
- If no camera is connected when SIPS is run or different camera has to be used as imaging one, then it is necessary to select camera manually after it is connected to the computer.

  Select the “Camera” tab and open the camera selection dialog box by clicking of the “Select Imager” button. Then click the “Scan Cameras” button. The Gx camera should appear in the displayed tree. Select it (click its name by mouse – its name should be highlighted) and click the “Select Imager” button.

- If it is desired to connect SIPS to a fixed set of cameras regardless if they are connected upon SIPS start or not, it is possible to check the “Automatically Connect to Selected Imaging Camera Only” check box in the “Select Imager” dialog box. SIPS then always connects only to this particular camera until another camera is manually selected or this option is unchecked.

If the chosen camera is not connected to the host PC when SIPS is run, camera driver name is displayed instead of proper camera name, because SIPS has no means how to determine unplugged camera name. When the camera arrives to the system, SIPS connects to it without any user’s intervention.

Note this feature was introduced into SIPS v3.7 and later.

If the Gx camera does not appear in the tree of available cameras after clicking of the “Scan Cameras” button, check the following items:

1. Check the USB cable – make sure both connectors are properly inserted to PC (or USB hub) and to camera head.
2. Check the camera power – the power adapter should be plugged to AC source (the green LED on the adapter should shine) and the power output cable connector must be properly inserted to camera head connector.
3. Check if the camera system driver is properly installed. Refer to the “Camera System Driver Installation” chapter for information about system driver installation.

Camera and the Telescope

The camera needs some optical system to capture real images. It depends on the telescope adapter to which telescopes (or lenses) the camera can be connected. It is recommended to use some threaded adapter (M42×0.75 T-thread, M48×0.75 or M68×1 threaded adapter, depending on the camera model and sensor size), as the threaded adapter provide much more reliable connection and better optical axis alignment compared to simple barrel adapter used for eyepieces.

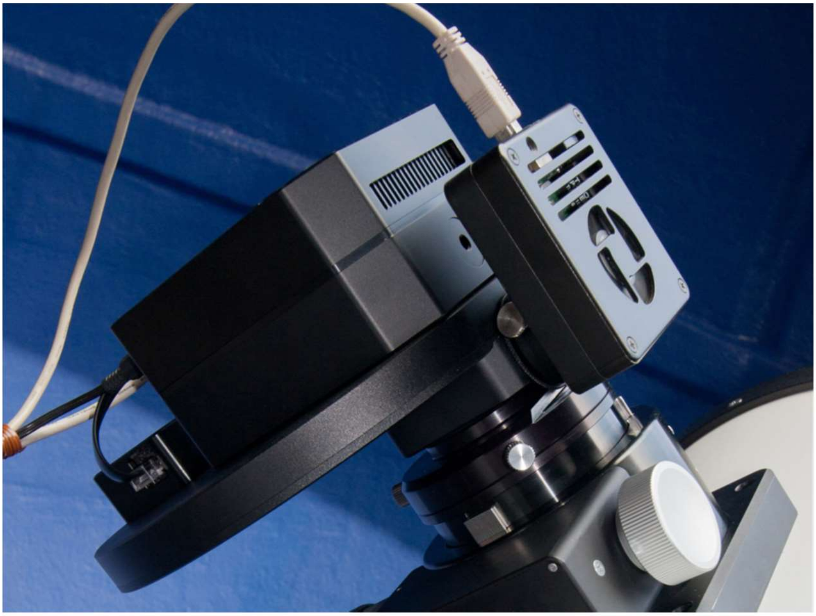


Figure 5: Complete system consisting of G2 camera, External Filter Wheel, Off-Axis Guider adapter and G1 guider on the Newtonian reflector telescope

Photographic lens or some small refractor are the best optical systems to start experimenting with the camera. If you are using some bigger telescope at home for the first experiments, make sure the telescope can be focused to relatively nearby objects in the room.

It is better to start experimenting with slow-scan CCD cameras (G2, G3 and G4) at night, because it is very easy to saturate the camera at daylight. The shortest exposure of the G2 cameras is 0.1 s and G3 and G4 cameras offer shortest exposure 0.2 s, which can be too long at daylight conditions. G0, G1 and all Cx cameras allow exposures as short as 125 µs, so they can be used ad daylight without problems.

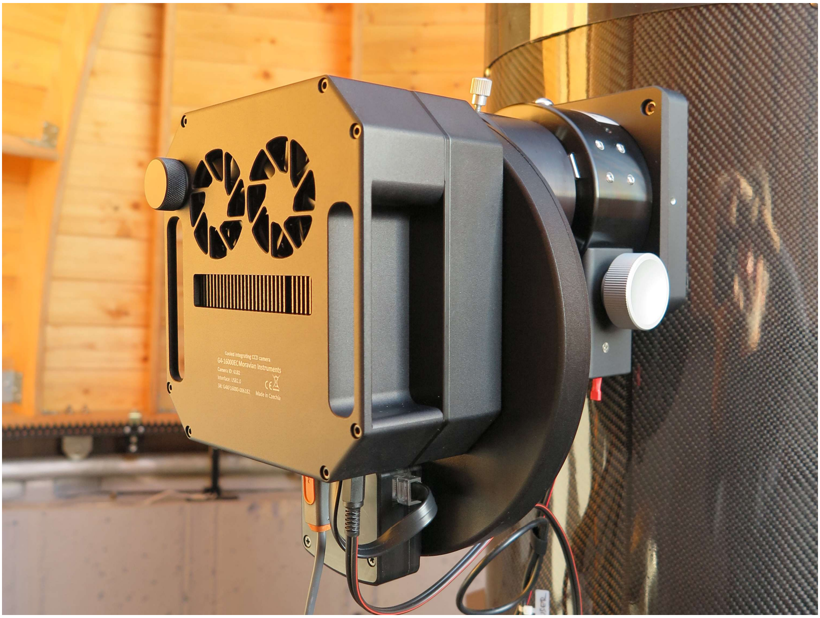


Figure 6: G4 camera and External Filter Wheel on the Newtonian reflector telescope

Temperature Control

Active chip cooling is one of the basic features of scientific cameras (SIPS User's Guide explains why cooling is important to reduce thermal noise). If you plug the Gx/Cx camera to power supply, you may notice the fan on the back side of the camera head starts operation. This fan takes away the heat from the hot side of the Peltier modules, which cool the CCD chip. Fan is running continuously when the camera is plugged to power supply, independently on the Peltier cooler (it is also used to cool down the camera power supplies etc.).

Peltier cooler can be controlled from the “Cooling” tab of the SIPS “Imaging Camera” tool.

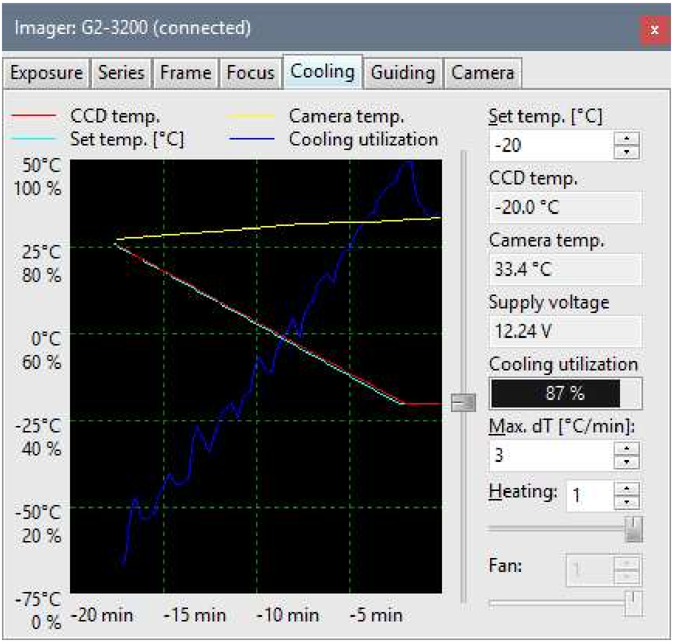


Figure 7: Cooling tab of the CCD Camera Control tool

The required sensor temperature can be set either by entering a number (the “Set Temp.” count-box) or by moving of the slider. The “Max. dT” count-box defines the maximum speed, with which the temperature can change. If the required temperature is greater or equal to the current sensor temperature, the Peltier cooler is off. The “Cooling utilization” indicator displays 0% and the camera consumes minimum energy.

To cool down the sensor, set the required temperature to target value. Camera does not switch the Peltier cooler to 100% immediately but starts changing of the target temperature according to defined maximal speed. The target temperature is displayed in cyan color on the graph. The current chip temperature is displayed in red. Also notice the blue line, which displays the cooling utilization – it starts to grow from 0% to higher values.

Also notice the yellow line in the graph – it displays camera internal temperature. This temperature also somewhat grows as the cooling utilization grows. The hot air from the Peltier hot side warms up the camera interior slightly.

> How fast can be the chip cooled? Can be the chip damaged, if it is cooled too fast? Unfortunately, the maximum speed of temperature change is not defined for OnSemi CCD chips (at last the author does not know about it). But in general, slow temperature changes cause less stress to electronic components than rapid changes. The SIPS temperature change speed default value is 3 °C per minute. It is usually no problem to switch the camera earlier and to provide time for slow cooling. However, if it is necessary to cool the camera rapidly, alter the “Max. dT” value.
>
> It is also easier to achieve higher temperature differences if the temperature is changed only slowly. Switching the Peltier cooler from zero to 100% immediately provides a lot of heat and, especially in the case of air-cooled Peltier, the overall camera temperature can raise more than necessary. The result is the chip temperature is higher in absolute numbers, because the hot-side temperature is also higher. It takes long time before the hot side slowly settles.

What is the best temperature for the sensor? The answer is simple – the lower the better. But the minimum temperature is limited by the camera construction. The Gx and Cx cameras are equipped with multiple-stage coolers, which can cool the sensor up to 50 °C below ambient temperature with air cooling (this value varies according to camera model). But it is not recommended to use maximum possible cooling. If the environment conditions change, the camera may be unable to regulate the temperature if the environment air temperature rises. Set the target temperature, which requires approx. 90% of the cooling utilization. The remaining 10% provide enough room to compensate environment temperature changes.

The power supply voltage is also displayed in the “Cooling” tab. Especially when the camera is powered from 12 V battery, this information can be used to estimate when the battery should be replaced and recharged. Note that working with less intensive cooling can significantly prolong the battery life.

The last two controls “Heating” and “Fan” allow controlling of the sensor cold chamber front window heating and the camera cooling fan. It depends on the connected camera model whether these values can be even set and if yes, in what range. Currently only C1 and G1 cameras allow switching of the camera fan on and off and this control is disabled if another camera is connected.

The purpose of the sensor cold chamber front window heating is to prevent fogging of this optical element, as its temperature can often drop below dew point. It depends on the Gx/Cx camera revision as well as on the currently installed camera system driver version what is the maximum heating value.

Typically, just switching on and off is supported by G2 cameras, while larger G3 and G4 support also one more step of heating due to their much larger front window, which is more sensitive to fogging.

Cooled Cx cameras offer precise front window heating regulation with 1 percent resolution.

First Images

Actual exposure is performed from the “Exposure” tab of the “Imager” tool.

It is necessary to define few parameters before the first shot. First, it is necessary to define the image type – choose “Light” from “Exposure” combo box. Then choose the exposure time. If you experiment with exposures in the dark room with a camera connected to some f/6 refractor, start with 1 second. Do not forget to review the image handling options on the right side of the “Exposure” tab. Let the “Open new Light image window” and “Overwrite image in selected window” check-boxes checked, uncheck other options for now (we do no plan to save our first images).

Then click the “Start Exp” button. Camera will open the shutter, perform 1 s exposure, close the shutter and download the image. Image is then opened in new image window. If this is the first shot, it will probably be far from sharp focused image. Alter the focuser and try again.

Notice that options determining the new image handling on the right side of this tab changes with every change of the exposure type. SIPS remembers these options for every exposure type separately. So, it is possible e.g. to define separate folders for dark frames and for flat fields.

Always check whether new image processing options are defined properly before you start any exposure.

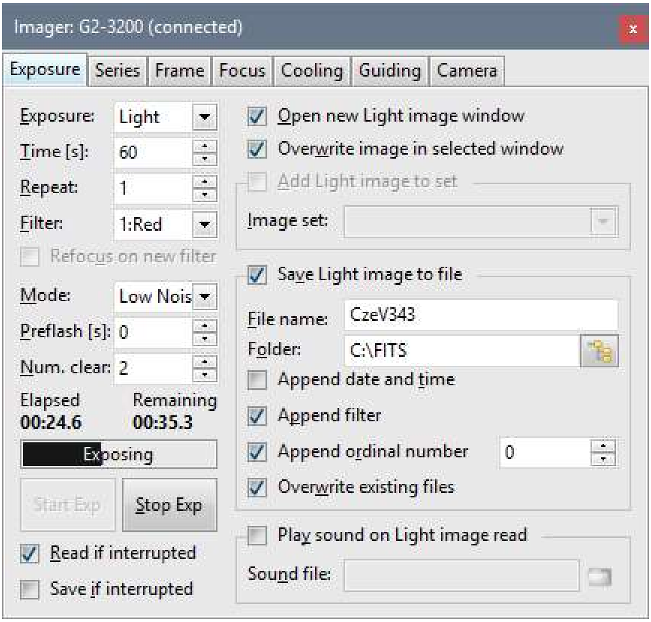


Figure 8: "Exposure" tab of the "Imager" too

If you choose "Dark" from "Exposure" combo box (remember the image handling options on the right-side changes – make sure they are properly defined), image will be captured without opening the shutter. The captured image will represent the thermal noise, generated by the CCD chip itself, combined with the CCD chip and camera electronics read noise. Such images are subtracted from normal images during image calibration to reduce the dark current effects.

Brightness and Contrast – Image Stretching

The Gx CCD camera dynamic range spans 65 536 levels. But only imaging of perfectly illuminated and perfectly exposed scenes can result in images with pixels spanning this range. Usually only a fraction of this range is used, e.g. the black background can have values around 500 counts and the brightest part of the image can have around 10 000 counts. If we assign the black to white range to the full possible range (0 to 65 535), the image with 500 to 10 000 counts will be displayed only in dark gray tones. Therefore, image brightness scale should be "stretched" before they are displayed.

CMOS based Cx cameras must rely on the A/D converter included in the sensor itself. Typically, the CMOS sensors offer multiple dynamic range resolutions spanning from 8-bit to 12-bit. Sometimes also 14-bit variant is available, depending on the sensor model.

Open the "Histogram and Stretch" tool .

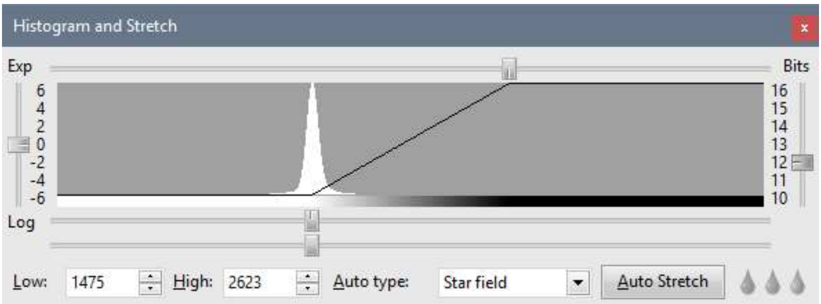


Figure 9: SIPS "Histogram and Stretch" tool

The exact meaning of the histogram chart is explained in the SIPS software documentation. Now only try to play with "Low" and "High" count-boxes or better with the related horizontal sliders. Observe how the image view is changed when you alter these values.

The best positions of Low and High control are as follows: The "Low" count should be on the count value representing black on the image. Any pixel with value lower than this count will be displayed black. The "High" count should be on the count value representing white on the image. Any pixel with value higher than this count will be displayed white.

Similar adjustments are usually called brightness and contrast adjustments.

- Brightness is changed by moving both Low and High values together up and down. Try to move both values using the second slider below the histogram chart.
- Contrast is changed if the relative distance between Low and High values changes. Try to narrow or widen the distance between Low and High values.

But astronomers often need precise control of Low and High values, so the terms brightness and contract are not used within SIPS.

Calibration

If you preform short exposure of bright object, the signal to noise ratio of the image is very high. Image artefacts related to CCD chip (like hot/cold pixels or thermal noise) almost do not affect the image. But all unwanted effects of unevenly illuminated field, CCD dark current etc. significantly degrade image quality when imaging dim deep-sky objects for many minutes.

This is why every CCD image should be calibrated. Image calibration basically consists of two steps:

1. **Dark frame** subtraction
2. Applying **flat field**

Image calibration is supported by the "Calibration" tool in SIPS .

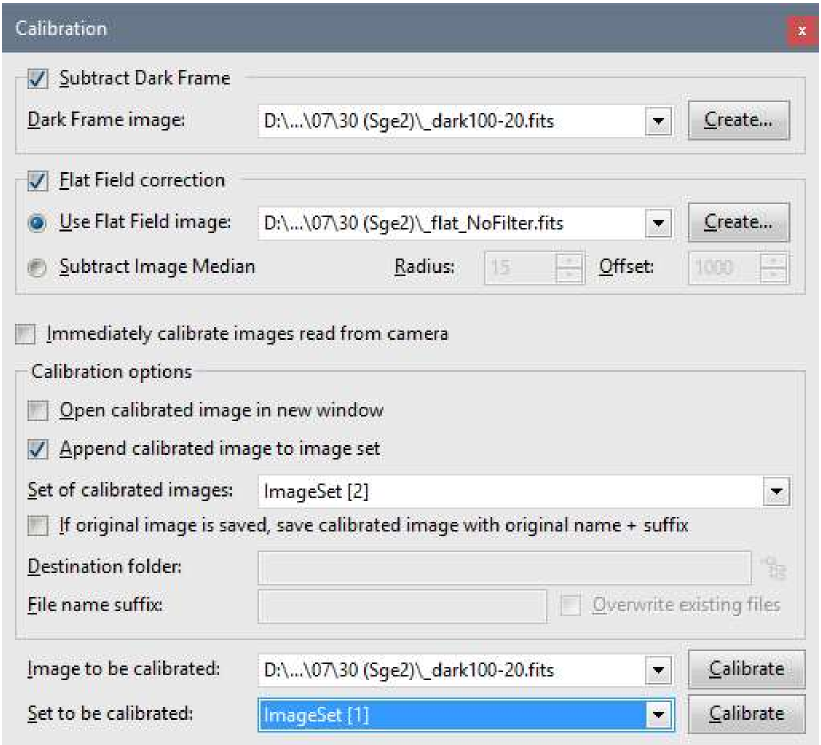


Figure 10: SIPS "Calibration" tool window

The raw image downloaded from the camera contains not only the information desired (the image of the target field), but also the accumulated CCD thermal current and artefacts caused by unevenly illuminated field (vignetting), shadows of dust particles on camera cover glass and filters etc.

Figure 11: The raw image downloaded from the camera

The Dark frame is taken with the same exposition time at the same sensor temperature. Because hot pixels are less stable than normal pixels, it is always better to take more dark frames (at last 5) and to create resulting dark frame as their average or better median.

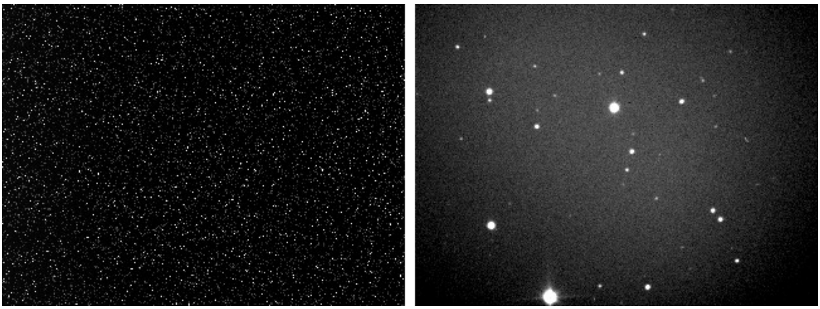


Figure 12: The dark frame corresponding to the above raw image (left) and the raw image with subtracted dark frame (right)

Subtraction of the dark frame eliminated majority of thermal noise, but unevenly illuminated field is still obvious. Image center background is much brighter than the border parts.

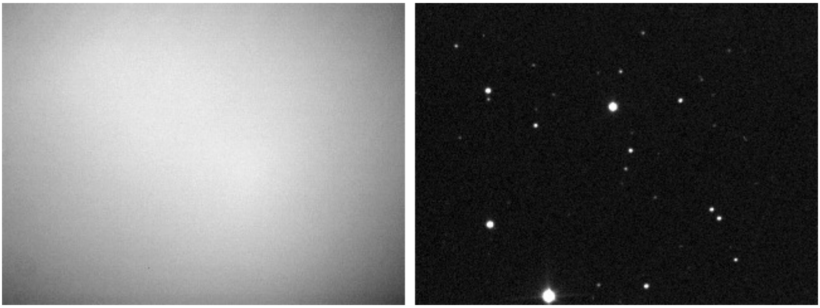


Figure 13: Flat field represents the telescope/camera response to uniformly illuminated field (left) and fully calibrated image with dark frame subtracted and applied flat field (right)

Image calibration is described in detail in the SIPS User's Guide. Refer to the “Introduction to CCD Imaging” and “Calibrate Tool” chapters for calibration description in theory and in practice.

Color images

Color images are more appealing than black and white ones. It is also easier to gather more information from color images – for instance it is possible to distinguish which part of the nebula is emission (red) and which is reflection (blue). But astronomical cameras are only rarely equipped with color sensors from number of reasons. The color and monochrome chips are discussed in the SIPS User's Guide – refer to the “Introduction to CCD Imaging” chapter.

Color Images with monochrome camera and filters

Even if the Gx or Cx camera is equipped with monochrome sensor, it is capable to capture color images, at last when the attached filter wheel contains RGB filters. Instead of shooting single color image, three images – each for Red, Green and Blue colors, must be obtained and combined. This process is not suitable for fast moving/changing objects, but astronomical objects usually do not change so fast.

Taking three images and combining them is undoubtedly more complex procedure than shooting simple color image. But using of monochrome chip brings so important advantages for astronomical usage, that bothering with multiple images is worth the effort:

- Color sensors have one fixed set of filters without the possibility to exchange them or to completely remove them. Monochrome chip is capable to take images with narrow-band filters like Hα, OIII, etc.
- Color chips have less Quantum Efficiency (QE) then monochrome ones. Limiting QE from around 80% to around 30% by color filters only wastes light in number of applications.
- Interpolation of pixel luminance from surrounding pixels, necessarily performed when processing images from color chips, introduces significant error and prohibits precise measurement of position (astrometry) and brightness (photometry).
- Color sensors do not allow reading of binned images.

Another huge advantage of monochrome chip is the possibility to combine color images from three color images and one luminance image. Luminance image is captured without filter, using maximum chip sensitivity. This technique is often called LRGB imaging.

> Inserting the color filter into the light path significantly reduces the amount of light captured by the chip. On the other side the human eye is much less sensitive to changes of color than to changes of brightness. Therefore, the sensor can be binned when capturing color images to 2×2 or 3×3 to significantly increase its sensitivity. Luminance image is taken without binning, so the image resolution is not degraded.

Let us note that imaging through separate color filters is close to impossible in some cases. For instance, taking images of some fast-evolving scenes, like planet occultation by Moon, imaging of fast moving comet etc. There is no time to take separate exposures through filters, because the scene changes between individual exposures. Then it is not possible to combine red, green and blue images into one image. In such cases using a single-shot color camera is necessary.

The color images can be combined in the (L)RGB Add Tool  in SIPS. This tool is thoroughly described in the SIPS User's Guide.

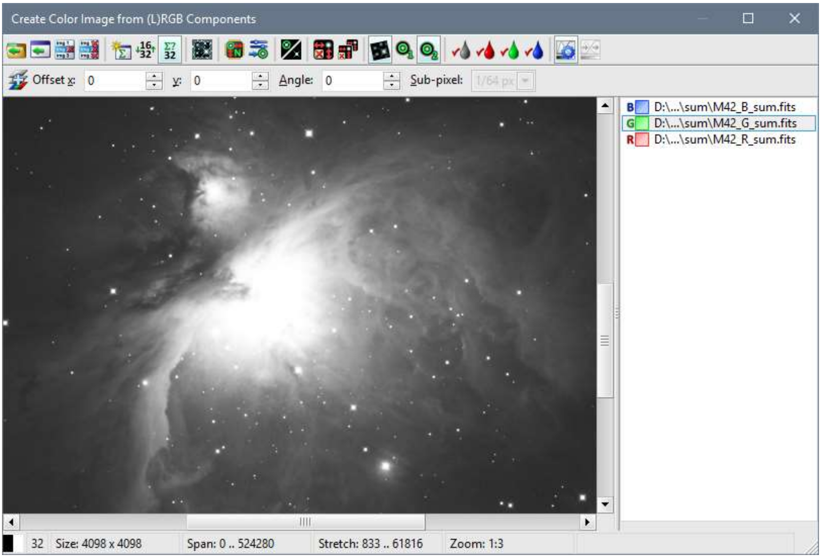


Figure 14: "Create Color Image from (L)RGB Components" tool in SIPS

If we take images for individual colors and luminance image, possibly with different binning and exposure times, the calibration starts to be relatively complex. We need dark frame for every exposure time and binning. We need flat field for every filter and binning. We need dark frames for every flat field. This is the price for beautiful images of deep-sky wonders.

Let us note the primary purpose of SIPS is to control camera and other observing hardware during observing session and to perform research-related image processing (mainly plate solving and photometry – the first "S" in SIPS means Scientific). For any serious astrophotography image processing, other software packages, purposely developed to perform "aesthetical" image processing, must be used.

Color images with color camera

Single-shot color cameras use special detectors with red, green and blue color filters applied directly on individual pixels. Gx cameras can be equipped with such detectors (the name of the camera is then followed by the letter “C” to indicate color sensor).

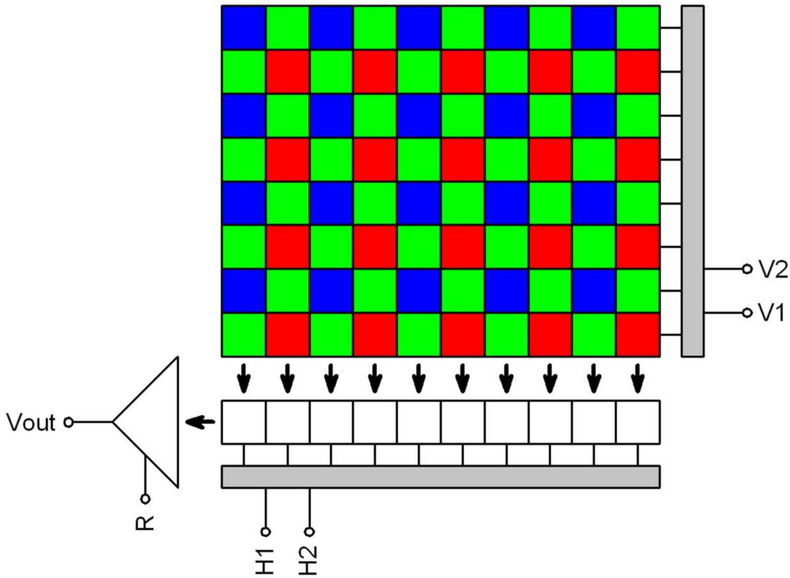


Figure 15: Schematic diagram of color CCD detector

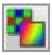
Every pixel receives light of particular color only (red, green or blue). But color image consists of pixels with all three colors specified. So, it is necessary to calculate other color from the values of neighboring pixels.

> Covering pixels with such color mask and subsequent calculations of remaining colors was invented by Mr. Bayer, engineer working at Kodak company. This is why this color mask is called Bayer mask and the process of calculation of missing color is called “debayer processing”.

There are several algorithms for calculating missing color components of individual pixels – from simply using of color from neighboring pixels (this method provides quite coarse images) to more accurate methods like bilinear or bicubic interpolation. There are even more sophisticated algorithms like pixel grouping etc.

No Gx camera performs the Debayer processing itself. The raw image is always passed to the host PC and processed by control software. It is also possible not to perform Debayer filtering and save images in the raw form for processing by some other software packages.

SIPS software implements simple and fact bilinear Debayer interpolation as well as sophisticated multi-pass Debayer filter. It is possible to perform Debayer processing immediately when the image is downloaded from the camera (color image is then immediately displayed and/or saved and no raw monochrome image is shown) or to perform this processing anytime later.

Debayer processing can be performed from "Image Transform" tool (to open this tool click  button in the tool-bar or choose "Image Transform" from the "Tools" menu). Check box "Debayer new images" allows immediate Debayer processing of images downloaded from the camera. The  button performs Debayer processing of currently selected image.

The Bayer mask displayed on the schematic image above begins with blue pixel. But there are no rules specifying the color of the first pixel – in principle there can be also green pixel from the blue-green line on the upper-left corner as well as green pixel from the green-red line or red pixel.

There is no way how to determine the Bayer mask organization from the image. Therefore the "Image Transform" tool provides two check-boxes called "Bayer X odd" and "Bayer Y odd". Combination of these check-boxes allows specification of Bayer mask organization on the particular sensor.

State of "Bayer X odd" and "Bayer Y odd" check-boxes are always updated when you connect camera with color CCD according to the information provided by the driver. It is necessary to update them manually only if the raw color image is loaded from the disk file and needs to be processed without connected camera.

Wrong definition of these two flags results in wrong color calculation. Proper settings can be easily determined by the try-and-error method. But

Debayer processing discards the original raw image so it is always necessary to backup the original raw image.

Also, please note the settings of the “Bayer X odd” and “Bayer Y odd” check boxes must be altered when any geometric transformations are applied to the raw image (e.g. mirroring, rotation, etc.). Some transformations (e.g. soft binning or resampling) cannot be performed on raw image at all. It is always better to Debayer images first and process them later.

Also note that stacking of raw color images results in loss of color information. Stacking algorithms align images regardless if the particular pixel is red, green or blue. SIPS allows also sub-pixel stacking, which can mix pixels of different colors. Images must be Debayer processed first and then stacked.

Balancing colors

Sensor sensitivity to red, green and blue light is different. This means the exposure of uniformly illuminated white surface does not produce the same signal in pixels covered with different color filters. Usually blue pixels gather less light (they have less quantum efficiency) then green and red pixels. This results into more or less yellowish images (yellow is a combination of red and green colors).

The effect described above is compensated by so-called “white balancing”. White balancing is performed by brightening of less intensive colors (or darkening of more intensive colors) to achieve color-neutral appearance of white and/or gray colors. Usually is one color considered reference (e.g. green) and other colors (red and blue) is lightened or darkened to level with the green.

Automatic white balancing can be relatively easy on normal images, where all colors are represented approximately uniformly. But this is almost impossible on images of deep-space objects. For instance, consider the image of emission nebula, dominated by deep-red hydrogen alpha lines – any attempts to lighten green and blue color to create color-neutral image result to totally wrong color representation. Astronomical images are usually color balanced manually.

As already described in the “Brightness and Contrast – Image Stretching” chapter, image can be visually brightened by altering its stretch limits. SIPS “Histogram and Stretch” tool displays and enables altering of stretching curve limits and shape for red, green and blue color individually.

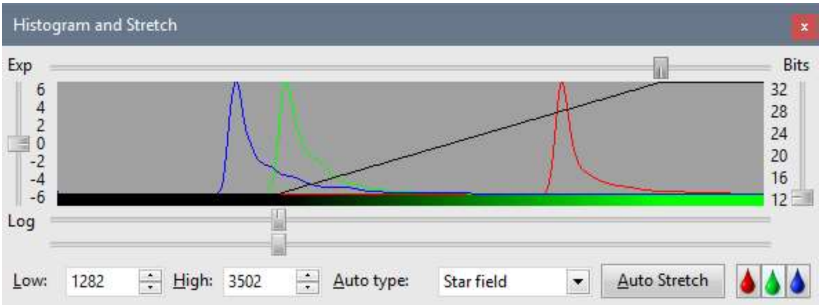


Figure 16: "Histogram and Stretch" tool shows histograms of individual colors

Camera Configuration Tools

There are tools intended for performing some special camera configuration tasks. Because such configuration is required only rarely and majority of users never need to use these tools, they are not included in the SIPS distribution. If needed, both tools have to be downloaded from the web site or located on the Flash Drive accompanying every Gx or Cx camera.

> Please note while these utilities need not to be installed, they need the Microsoft Visual C++ 2015 run-time libraries installed on the particular PC to work. VS runtime libraries are often already installed on all modern PC, as many software packages need them.
>
> However, if they are missing, it is possible to download the installation package from the Microsoft web site and the installation package is also present on the accompanying Flash Drive at 'Redist\VS2015\vc_redist.x86.exe' folder.

Number of filters definition tool

If the camera is equipped with internal or external filter wheel then the number of filters in the wheel is stored in the camera permanent memory. Similarly, in the case the camera is not equipped with filter wheel at all, number of filters 0 indicates to the firmware that the filter wheel initialization routine should be skipped and camera start-up time is reduced significantly.

If the number of filers in the attached filter wheel changes (e.g. 5-positions filter wheel is replaced with 7-positions one), it is necessary to change the camera permanent memory.

Similarly, if the filter wheel is added to the camera, which was not configured to control filter wheel (number of filters was 0) or filter wheel is completely removed from the camera (number of filters should be 0), camera permanent memory must be changed, too.

If a filter wheel is attached to camera configured not to use filters, the newly added wheel simply does not work. On the other side, if the filter wheel is removed from the camera, configured to use filters, camera firmware tries to initialize the filter wheel upon startup. Initialization sequence fails and camera then continues to operate, the time needed to start the camera is unnecessarily long.

This is also the reason to store number of filters in camera permanent memory. In principle camera firmware would be able to check the filter wheel presence and to count the number of filters if the filter wheel is connected, but the start-up sequence would be much longer.

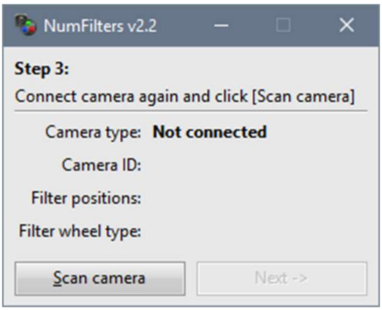
Number of filters configuration tool is located in the folder '\Tools\GxNumFilters\ GxNumFilters.exe' on the accompanying Flash Drive.

Please note the GxNumFilters utility needs administrative permissions to run. Windows indicates it by displaying of the small shield on the bottom-right corner of the program icon and users are prompted to allow it to run with administrative rights upon launch.

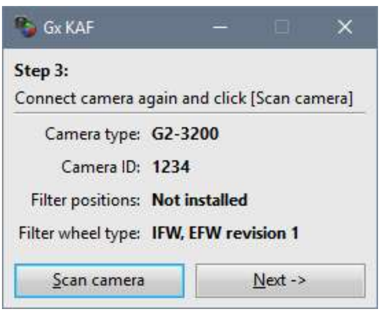
When the tool is run, it checks whether some camera is connected. If yes, it connects to it and shows its ID. If not, user have to connect camera and click “Scan camera” button.

> Always run this utility with one camera connected only. If multiple cameras are connected, the utility may fail.

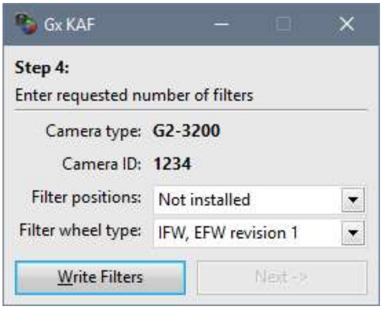
Then it is necessary to un-plug and plug again the camera.



When camera is again plugged, click the “Scan camera” button.

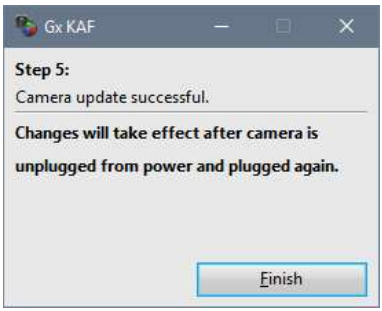


Note the tool shows the information about number of filter positions as well as about type of filter wheel.



Information texts are replaced with edit controls, allowing to change current status.

Choose the desired values and click the “Write Filters” button.



Please note changes in the camera permanent memory will be applied only after the camera is powered off and on again.

The “Filter wheel type” allows selection of two types:

- IFW, EFW revision 1
- EFW revision 2

If internal filter wheel is used, always choose the first option.

To distinguishing external filter wheel revision 1 and 2, check the size of the motor box on the bottom of the external filter wheel housing. Revision 2 motor boxes are bigger and slightly extends the filter wheel shell outline.

Figure 17: External filter wheel revision 2 (left) and revision 1 (right)

All new Mark I external filter wheels as well as all Mark II external filter wheels are manufactured as revision 2 only.

Over-scan region configuration tool

CCD sensors, used in G2, G3 and G4 cameras, are manufactured with total number of pixels somewhat greater than useful number of pixels comprising image. By default, camera returns only image pixels. But some users may appreciate full image, including shielded pixels outside of the image area (called over-scan regions).

> Including over-scan regions may be useful for some specialized image processing etc. despite they are always cropped from final image.

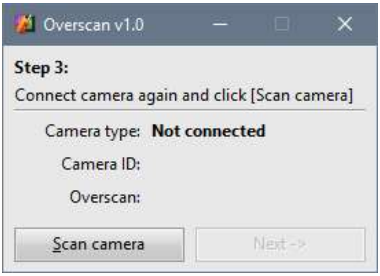
The GxOverScan tool allows switching of the camera from default state (returns image pixels only) to state, in which the camera returns also over-scan regions. The tool is located in the folder ‘\Tools\GxOverScan\GxOverScan.exe’ on the accompanying Flash Drive.

Please note the GxOverScan utility needs administrative permissions to run. Windows indicates it by displaying of the small shield on the bottom-right corner of the program icon and users are prompted to allow it to run with administrative rights upon launch.

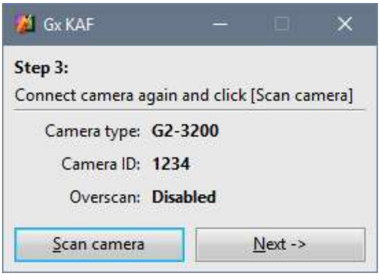
When the tool is run, it checks whether some camera is connected. If yes, it connects to it and shows its ID. If not, user have to connect camera and click “Scan camera” button.

Always run this utility with one Gx camera connected only. If multiple cameras are connected, the utility may fail.

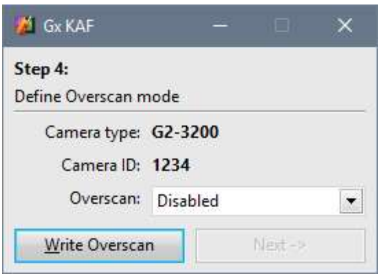
Then it is necessary to un-plug and plug again the camera.



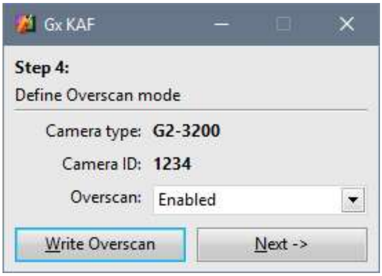
When camera is again plugged, click the “Scan camera” button.



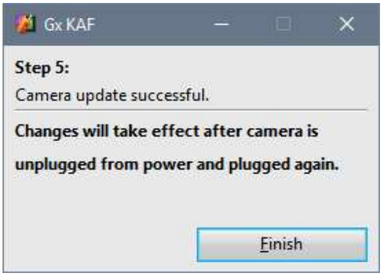
Note the tool shows the information whether the over-scan region read is enabled or disabled.



Information text is replaced with combo-box, allowing to change current status.



Choose the desired value and click the “Write Overscan” button.



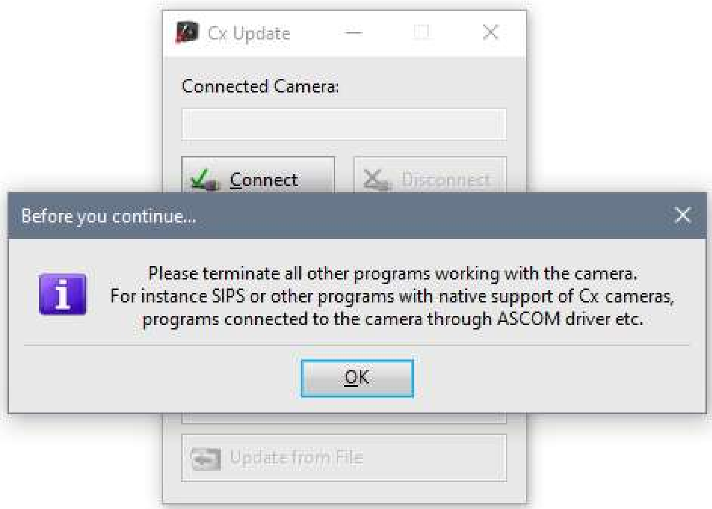
Please note changes in the camera permanent memory will be applied only after the camera is powered off and on again.

Cx camera firmware update tool

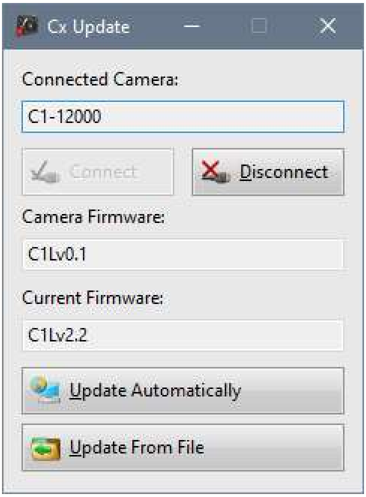
Firmware in all Cx series CMOS based cameras can be updated to latest version using a tool located in the folder ‘\Tools\CxFirmware\CxFirmware.exe’ on the accompanying Flash Drive.

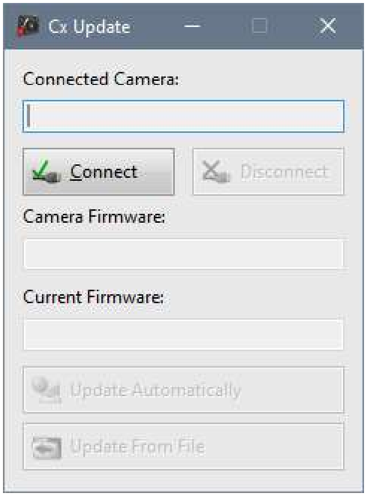
Warning:

It is important to close all other software packages working with the respective camera prior to running the CxFirmware update utility. Accessing the camera from some other software during the firmware update process may result into camera malfunction and a necessity to send it to manufacturer for fix.



The CxFirmware tool checks whether some Cx camera is connected to the host PC and if yes, it connects to it. The “Connected Camera” box shows the camera name and the “Connect” button remains disabled (camera is already connected). If the camera is attached to the PC only after the CxFirmware tool is launched, it is necessary to explicitly connect to it using the “Connect” button.





Please note the CxFirmware tool can work with one camera at a time only. If there are multiple Cx cameras connected upon the tool starts, only the first enumerated camera is connected.

If we want to update other connected camera than is the first enumerated and connected one, click the “Disconnect” button, which unplugs the first enumerated camera. Then unplug the unwanted camera from the PC and click the “Connect” button again. The remaining camera will be connected to the tool.

The “Camera Firmware” box shows the firmware version in the currently connected camera. The second box labelled “Current Firmware” shows the latest released firmware version for the particular camera.

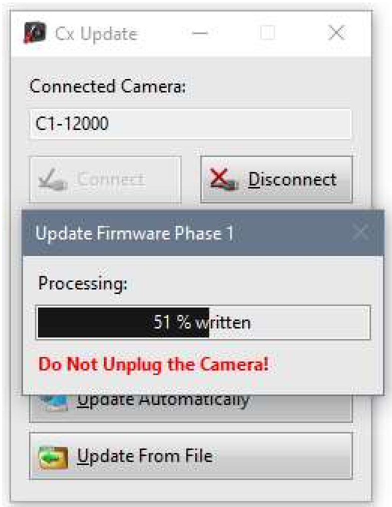
There are two ways how to update camera firmware:

1. **Fully automatic update**. The tool downloads the latest firmware and writes the camera Flash memory. No other action than clicking the “Update Automatically” button is required from the user.
   If the camera firmware and the current firmware versions are the same, the “Update Automatically” button remains disabled as no update is necessary.

This method requires active Internet connection.

2. **Manual update**. This method requires the desired '*.cfx' file with respective camera firmware is already downloaded. Clicking the "Update from File" button opens a file-choosing dialog box. The selected file is then written to the camera Flash memory.
   The CxFirmware tool performs extensive check to ensure only a file compatible with connected camera is written. Also, any file corruption is detected.

The update process is performed in two phases. **Do not unplug the camera while the firmware update is in progress!**



Some General Rules for Successful Imaging

Advanced CCD and CMOS cameras caused a revolution in amateur astronomy. Amateurs started to capture images of deep-sky objects similar or surpassing the ones captured on film by multi-meter telescopes on professional observatories. While the CCD technology allows capturing of beautiful images, doing so is not easy and straightforward as it may seems. It is necessary to gain experience, to learn imaging and image processing techniques, to spend many nights mastering the technology.

Although camera can convert majority of incoming light into information, it is not a miracle device. Keep on mind that laws of physics are still valid.

- Camera does nothing more than converting image created on the chip by telescope (or objective lens) into information. A quality telescope and quality “photographic-class” mount is absolute must for successful imaging. If the mount cannot keep the telescope on track or the telescope cannot create perfectly focused image, result is always distorted and blurred.
- Ideally the exposures should be automatically guided using guiding CCD camera or at last webcam or similar device. Tracking errors caused by drive periodic error, mount polar misalignment or other mechanical issues (often unnoticeable by eyes) cause streaking of star images. Note the exposure time for each color often reaches tens of minutes or even hours if the really high-quality images are taken.

> The C1 series of CMOS cameras and G1 series of CCD cameras are especially designed with guiding on mind. These cameras are equipped with “autoguider” connector, which allows direct connection between the G1 camera head and telescope mount. The SIPS software package supports both imaging and guiding cameras and implements sophisticated guiding algorithms.

- Focus image properly. Almost unnoticeable focuser shift affects star diameter. Focusing, especially on fast telescopes, is critical for sharp images. Electrical focuser is a huge advantage, because it allows focusing without shaking the telescope by hand and with precision surpassing the manual focusing.
  Keep on mind that the star images are affected not only by focusing, but also by seeing. Star images will be considerably bigger in the night of poor seeing, no matter how carefully you focus.
- Master image calibration (dark frame subtraction and flat fielding) and carefully calibrate all images. Various artifacts (thermal noise, hot pixels, gradients, telescope/lens vignettation, dust particles on filters etc.) degrade the image and properly calibrated image always looks better. Take care to obtain dark frames and flat fields for all filters used, for all resolutions/binnings etc.
- If the image is processed to be as aesthetic as possible, other processing than basic calibration can significantly improve its appearance. Nonlinear stretching (called “curves” in some image-editing packages), special filters (hot/cold pixels removal, noise reduction etc.) and other processing (e.g. deconvolution) enhances the image.

  Never perform these enhancing filters on images intended for data reduction processing. It is always good idea to store original image and to enhance only its copy. Scientific information can be significantly degraded by various noise filters, deconvolution etc. If for instance the image of some galaxy contains newly discovered supernova, photometric reduction of the original image can be scientifically very important.

- A common saying “there is a science in every astronomical picture” is especially true for CCD images. Examine your images carefully, blink them with older images of the same object or field. There is always a chance some new variable star, new asteroid, new nova or supernova appear in the image.
- Be patient. Although many advertisements proclaim “capture images like these your first night out”, they probably mean your

first successful night out. Nights can become cloudy or foggy, the full Moon can shine too much, the seeing can be extremely bad… Number of things can come wrong, but the bad luck never lasts forever. Start with bright objects (globular clusters, planetary nebulae) and learn the technique. Then proceed to more difficult dimmer objects.

If you are new to astronomical imaging and terms like “dark frame”, “read noise” and “image binning” sound strange to you, refer to the “Introduction to CCD Imaging” chapter of the SIPS software documentation. This chapter explains basic principles of camera operation and their usage in astronomy, discusses color imaging, sensor dark current and camera read noise, chip resolution and pixel scales in relation to telescope focal length, explains basic image calibration etc.