

BITRAN BJ SERIES COOLED ASTRONOMICAL CCD CAMERA
MANUAL



by



Switzerland

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Foreword

Thank you very much and congratulation for purchasing recently one of Bitran's Cooled CCD Camera system.

Today's BJ-40 Series is the result of long term developing a modern design of astronomical CCD cameras for the Amateur by BITRAN Corporation, Japan. Since many years, Bitran is the market leader for astronomical CCD cameras in Japan. Since the year 2004, finally BJ-40 Series cameras are also available with an English software version outside Japan.

This Manual gives an introduction how to operate CCD camera, the setup of English control software and explains the fundamentals of astronomical imaging. Please read this manual carefully before starting and: always use camera correctly.

An outline of this product, optional accessories, sample images etc. can also be found in Internet homepage with URL <http://www.the-ccd-astronomer.ch> .Possible upgrades of software etc. are also available on this homepage.

Please make sure to do User Registration soon after receiving a camera system. It is recommended to register when software asks about or later with 'Registration...' in Help Menu of Control software. Support cannot be given unless you have registered and to register is necessary for Security reasons. If you use a PC without Email you can also register manually with support@the-ccd-astronomer.ch. Thank you.

Control software and camera correspond with Windows ME, Windows 2000, Windows XP Home Edition, Windows XP Professional and Windows Vista.

Available accessories: Metal camera tripod attachment, mechanical shutter, Off-axis guider specifically for BJ-40 Series, etc. Since some types of BJ-40 Series offers a C-mount, all kind of commercial accessories with C-mount can be used.

Enjoy!

SAFETY

Security aspects are given by the Manufacturer, BITRAN Corporation. Careful and safe use of BJ-40 Series product are necessary conditions for high quality imaging. Wrong handling or wrong caring are often the cause of failure or incorrect operation. Please remember the following points:

This is an electrical product, so any kind of misuse can lead to electrical shock. This is a danger for the user's health and Life and the camera itself: Both can be damaged or destroyed by electrical shock.

Please make sure that whenever you want to use the camera, power supply is within DC 11V-14V and +(red) and -(black) connection is done right. Do not touch camera, cables and power supply with wet hands and be careful when drinking hot tee etc.

Plug or unplug cables always by the plug and not by the cables.

Turn off power supply when working around telescope because of pulling cables, stumbling etc.

Do not try to decompose camera body, BJ-40 Series has a closed body. Any kind of machining will damage the camera. For example the gas that fills the inside of the camera can escape by machining, then cooling is not possible anymore. Our Guarantee (covering mistakes of production) diminishes with any kind of machining by the user. In case of any problem or questions, contact first your distributor.

When storing the camera, there should be no weight or pressure on the camera body. Use a dry and dust free surrounding for storage.

Avoid the camera to be near of machines with strong magnetic field or strong heat production.

Do cleaning only when really necessary, glass window in front of CCD element can be cleaned like a camera lens with air brush or with damp cloth and weak detergent.

Any source of strong X-ray can damage sensible electronic parts the camera: When being transported by airplane, have camera always with you in hand-luggage!

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SECTION 1

Astronomical Imaging with CCD cameras

In this section, the fundamentals to know about astronomical imaging with digital cameras are explained. Please read before using Bitran BJ CCD camera.

The story of CCD cameras

The CCD (Charge Coupled Device) detector was invented in 1969 as an investigation in techniques for possible use in a 'picture-phone'. CCDs were then first used in astronomy in 1976 by professional Astronomers. At the end of the Eighties, cheaper CCD detectors made the production of customized cameras for the Amateur astronomer possible (OES, Lynxx etc.). And finally in the Nineties, the digital revolution renewed the world of photography.

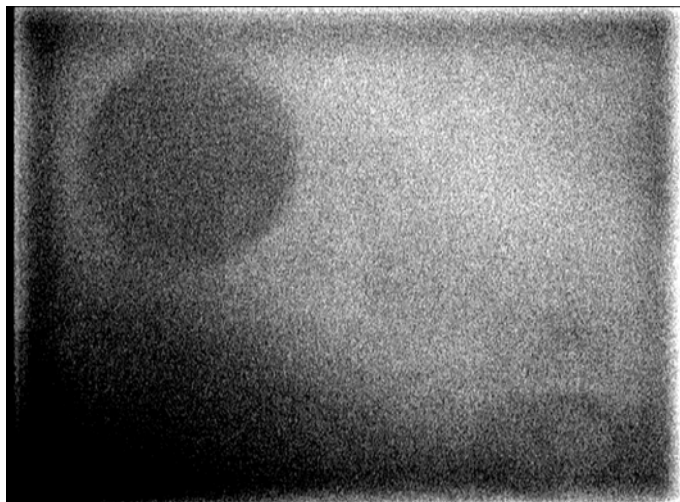
For astronomical imaging, mainly conventional CCD detectors are used. SBIG even launched 2003 a new camera type with large format detectors. But why are CCD detectors for astronomy so much more expensive than detectors used for digital cameras, home video etc.? Best images in astronomical photography can only be obtained with long exposing because of low light levels. This requires detectors and electronics of high quality level. We want to work out finest differences from the available light information where our eyes are already far from being sensitive. It is amazing that even a small lens telescope and a CCD camera show more details in the galaxy M51 than visible with a moderate size amateur telescope. Only superb apertures of 50cm and more, together with best sky conditions, can bring enough light to our limited eyesight!

Properties and quality aspects of detectors used for astronomical imaging

1. Uniform sensitivity of all pixel on a detector

Of course we want to use detectors of uniform sensitivity of all pixel. But what should be the criteria for 'uniform'? For example human eye can detect about 256 gray levels gray between black and white, so maximum sensitivity difference could be $1/256$ or 0.4%. But an image of 256 gray levels (this is called the '8bit mode') is only acceptable for showing processed images. Today standard resolution of a raw image format is 16bit (=65'536 levels), so criteria becomes $1/65'536$ or 0.002%!

No detector can be produced where relative difference in sensitivity between all pixel is not bigger than 0.002%. Sensitivity difference from one pixel to next ones is indeed very small, especially when sensor is cooled. But due to imperfections in the manufacturing process, the sensitivity of pixel varies usually by a few percent across the detector as an aerial effect (see sample image below). Luckily this aerial variation can be corrected with so-called Flatfield process.



This Flatfield image shows the aerial variations in sensitivity (the dark spot is a 'shadow' of a dust particle, description later in this section). The value difference between the brightest area at right edge and darkest area at down left corner is about 4.5%!

In practice, the sensitivity difference of several percent across the detector is not severe because it can be corrected well with Flatfield process. But the image formation is affected by many more severe effects: Thermal or dark current exposition, Bias values and Read-out Noise, bad pixel and bad columns/rows.

Thermal or dark current exposition

Because still today's detectors are based on semiconductor technique, each pixel generates thermal electrons. This effect is called dark current and exposures each pixel although there is no light. Dark current varies somewhat from pixel to pixel and accumulates over the exposed time.

The strength of dark current is directly related to the sensors running temperature. In general dark current is reduced to half when temperature lowers about 7°C. Standard digital camera, webcam etc. have running temperatures between +20°C and +40°C. Then dark current is so high that overexposing happens within seconds. Of course this is not useful for astronomical imaging, cameras must be cooled. Even for high resolution imaging of planets etc. with moderate exposure time (0.1 seconds and more), cooling leads to much better results because of a higher signal to noise ratio. There are also differences between the detectors: Sony for example produces CCD sensors with a lot lower dark current than Kodak.

On every chip there are also pixel that produce a many times higher dark current than in average. Those are called '**Hot pixel**', they show up very well when a long exposure is made without light reaching the detector.

Fortunately, since dark current exposition can be reproduced exactly for each pixel at a specific running temperature, it is possible to do exact correction with so-called Darkframe subtraction process.



This is a Darkframe of a SONY ICX285AL CCD sensor, ten minute exposed at -15°C . It shows 'warmer' areas of the chip as slightly brighter areas and hot pixel like a star field.

Bias values and Read-out Noise

The amplifier which boosts the signal prior to its digitization generates also a false signal, called bias. If an image is made at shortest exposure time (so there is no dark current) and no light is reaching the detector, all pixel show a basic value (false plus Read-out signal). When this image is made again, each pixel shows a different value. So in any kind of image (long or short exposure), this basic value is present as an added value to all light and dark current expositions and cannot be distinguished anymore nor reproduced exactly!

Therefore, basic values of an image cannot be corrected. With subtracting a Master Darkframe (values consists of dark current exposition and basic values), signal to noise ratio can be maximized. But the variation of each pixel stays, all images remain noisy.

As a result, all images we make are affected by noise: The sun's, moon's or a planet's surface looks grainy, details in nebulas and galaxies suffer also from being noisy. Only with calculating several images to one by an add and average process, noise can be eliminated. Today there are also software with filter for noise correction, but please determine well if fine detail gets also 'corrected' ...

The amount or 'strength' of basic noise is also dependent on the type of detector: Among all kind of detectors, still the images of a CCD detector are least affected by noise. For example the structure of a CMOS detector leads to a lot noisier images.

Bad pixel and bad columns/rows

Some pixel of a sensor show nearly no sensitivity at all, together with very hot pixel they are called bad pixel. Of course we want a detector with smallest amount of bad pixel. So this is a selection criterion of sensor quality (called grade) for manufacturers of

astronomical CCD cameras. Although fabrication techniques have improved, bad pixel still exists. Sometimes bad pixel even contaminate all pixel in its row or column, leading to entire rows or columns showing a difference in sensitivity. This can cause slightly brighter or darker lines in images

Unfortunately columns or rows of different sensitivity cannot be corrected by processes like Darkframe subtraction or Flat fielding. Proper image processing is more or less impossible when strong lines of different sensitivity are present. There are two possibilities to help the effect:

1. As described above, it is best to eliminate basic noise by an add and average calculation of several images. The same can be done for eliminating lines of different sensitivity, but for each image the field of view should be moved a little bit (a movement of three lines per image should be sufficient). In practice, with averaging about 6 or 8 well exposed images, noise and lines are well corrected.

2. Lines of different sensitivity in a single image can be replaced by artificial but reasonable values, usually computed from neighboring pixel values. This kind of correction is not recommended to do primarily, although some manufacturers allow correction by writing bad lines into head data of camera. Control software then reads this head data, corrects bad lines automatically while image transfer without user noticing. For Bitran's BJ series, this line correction can be done with a special procedure when wished by user. Please contact us if you wish to have this option.

2. Sensitivity of a detector

When Astronomers talk about sensitivity, they always talk of 'quantum efficiency' (Q.E.). This is simply the fraction of arriving photons on the chip which are detected. When a light source sends 100 photons per second and 60 can be detected, the Q.E. is 60%. This is enormous compared to standard chemical film with Q.E. of only a few percent. Digital sensor also does not suffer from Schwarzschild effect (sensitivity reduction during exposure). So any digital detector's basic sensitivity is many times higher than a conventional film when doing long exposure photography.

Today often Q.E of available detectors are compared very critically. But practical aspects are not considered. For choosing a suitable detector for a certain purpose, practical aspects cannot be ignored:

Pixel size

A pixel is like a pot collecting rain. With increasing diameter more drops can be collected. So when two detectors with the same Q.E. but different pixel surface are compared, the one with bigger pixel surface is more sensitive. Or pixel size is different and the detector with smaller pixel has higher Q.E., in the end both show the same sensitivity. Anyway, pixel size should be adapted to the applied focal length.

Diameter of objective

The objective is another rain collector. The bigger its diameter, more photons are collected and concentrated at the point of focus. Now overall sensitivity of a digital detector is so high, that for small apertures the photographic limits are reached with exposure times of only several minutes! For example with a 75mm lens telescope at f/6.7, exposure times longer than 10 minutes do not really show 'more'. So using higher Q.E. detectors only reduces applicable exposure time! With bigger apertures (15cm and more) there is so much 'light' available, that the use of highest-Q.E. detectors is not really necessary. But it is worth to use low-noise detectors.

3. Overflow of electric charge called, 'Blooming'

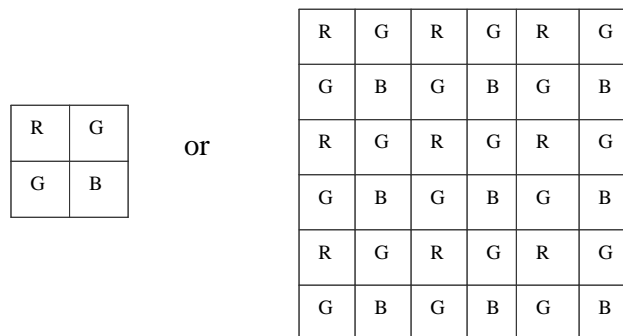
When the rain pot is full but drops are still coming, there will be an overflow. This overflow called Blooming happens easily for brighter stars and shows up mainly as vertical streaks in the image. To prevent from blooming, a barrier has to be made between the pixel. So today's standard digital sensor are delivered with a built in horizontal barrier between the pixel rows, which is called 'Anti Blooming Grid' (ABG).

Now this ABG makes the sensible area of each pixel smaller, resulting in a general loss in sensitivity of the detector. Also the volume of the rain pot (full well capacity) is reduced drastically. Decrease in sensitivity can be up to 50%, so in general the overall sensitivity of a detector with ABG is about half as the same detector without ABG. This loss in sensitivity and full well capacity is sometimes considered as critical, so some company offer to choose the same detector with or without ABG.

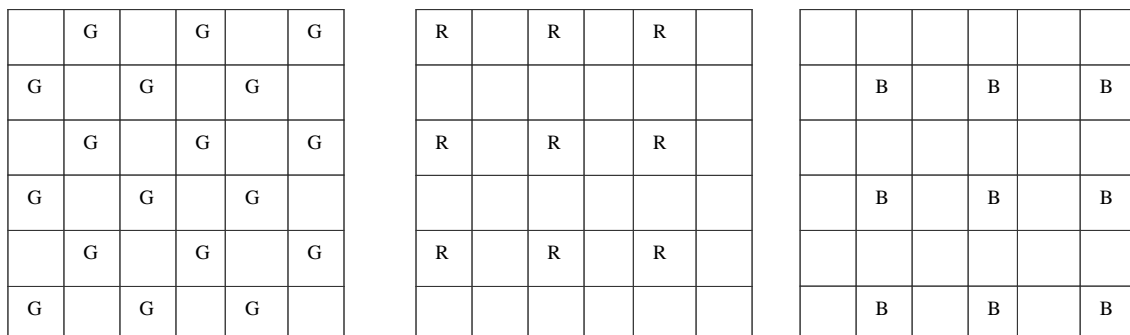
4. Color photography with digital detectors

Today there are several kinds of detectors available to do direct color photography. For common digital camera, mainly CMOS or CCD detectors are used. They all provide basically the same RGB system: On each pixel of the detector there are filters for Red, Green and Blue color, so one pixel is sensitive to exactly one color. The resulting image is indeed a gray level pattern of color information and has to be calculated to a color image.

Now the detectors can differ in the arrangement of the 'RGB'-pixel. The basic arrangement of two green pixel, one for red and one for blue is called the Bayer pattern:



Or analyzed as three color layers:

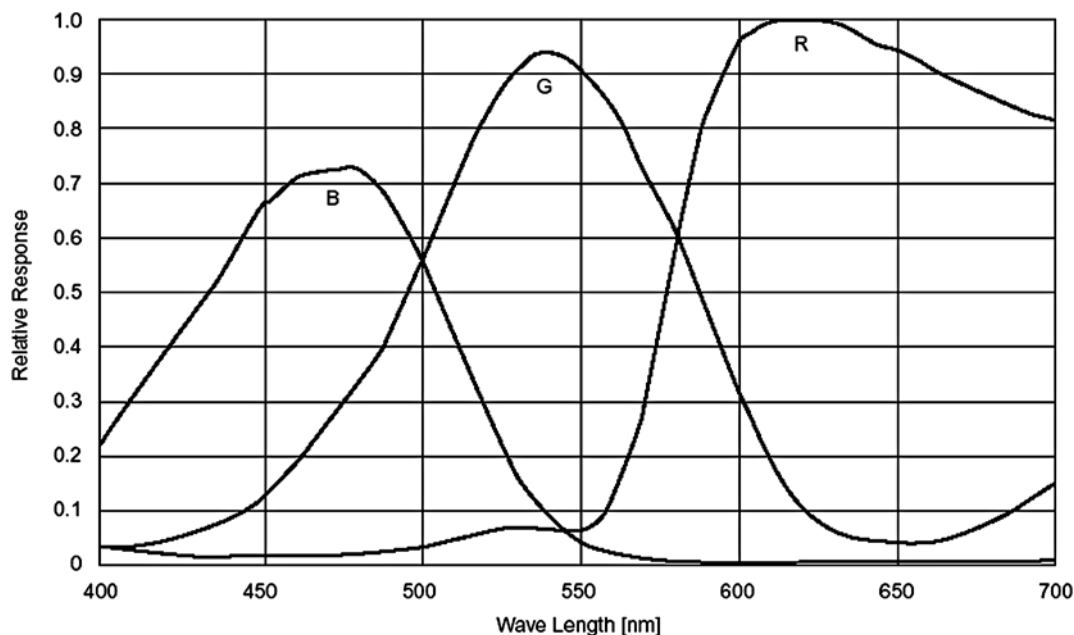


Separating the Bayer pattern into RGB-layers shows the differences in calculating the missing color information very well: While for the Green-layer only 'holes' have to be filled, Red- and Blue pattern are wide open. In general, compared to an image with monochrome

detector, a loss in resolution results and high contrast details suffer from color fringes caused by the calculation of complete color layers.

To help the problems of the basic Bayer pattern, many arrangements of RGB-pixel were made. For one sensor even eight angular shaped pixel and a complex RGB-arrangement was invented for a more versatile calculation of the color layers. But with no arrangement, the resulting color images are really satisfying under critical conditions.

Common RGB detectors are also not really suitable for astronomical photography, because they are made initially for reflective light conditions. Their sensitivity spectra is adjusted to human eye with strongly overlapping color ranges. A typical example is the spectral response of Sony RGB-sensor ICX-285AQ:

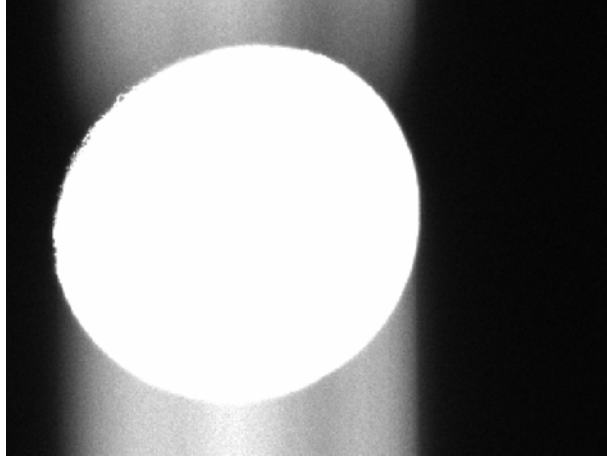


Overlapping color channels create a wide range of color gradation with reflected light, but under emission light conditions this leads often to simplified colors. Dumbell nebula (M27), for example, is displayed in only Red and Blue colors. Strong blue-green, green and yellow colors are 'swallowed' by the overlapping spectra of initial color filters on pixel. On the other hand, RGB-sensors with overlapping spectral response are necessary to show the subtle colors of a planetary surface!

So for more 'true' color photography of objects outside solar system, it is best to use a standard monochrome CCD camera with edge filters for Red, Green and Blue without overlap of the color channels. Overlaying the R,G,B-layers creates then a full resolution color image. Or for suppression of noise and other unwanted effects, a so-called monochrome Luminosity image (calculated from many single exposures) receives color information from R,G,B-images, this technique is called LRGB-composition.

5. Smearing by reading out of sensor

Under strong illumination conditions and short exposure times, smearing effects from reading out can occur when there is no mechanical shutter. See example next page. But even with a mechanical shutter (an external one is available for some BJ-40 types), smearing cannot be avoided completely. It is recommended to use the longest possible exposure time without overexposing the brightest parts.



Until now, we discussed only about the properties of digital detectors in practice. But there are also considerable effects caused by the telescope or other optical components participating the image formation.

Influence of optical components to image formation

There is one major property of astronomical CCD cameras: Since the area around the sensor must be cooled, an optical window is necessary. On this optical window, always dust particles, streaks etc. are present that cannot be wiped away completely and are detectable by the sensor! As a result, all images we make suffer from non uniform illumination. This is a funny example:



Five minute exposure into Virgo galaxy cluster, through a small lens telescope at f/6.7. Although underexposed, galaxies show up well and background illumination can be seen. By accident, a dust particle on the optical window caused the dark shadow around galaxies!

Since dust particles on the front glass are not in the focal plane, they appear with unsharp forms. Their size and strength varies with the applied focal ratio. The longer focal ratio, the smaller but more sharp dust is projected on the detector. A good example is the image on the following page of the sun taken at f/25. Which ones are sunspots?



Luckily, effects of dust can be corrected quite well by the so-called **Flatfield process**: Without removing camera and refocusing, aim the telescope after imaging at an uniformly illuminated background without structure and make a well exposed image. This image called Flatfield shows all irregularities by dust etc., and with applying this image through the Flatfield process on the image we want to correct, all unwanted effects will disappear more or less. Some software offer to create synthetic Flatfield, but they cannot be as good as a real-made Flatfield image.

General aspects of the telescope and camera system

In general there is no difference between astronomical photography with chemical film or digital detector. But the digital detector's higher sensitivity and resolution makes all aspects a lot more critical:

Focusing the telescopes main beam often cannot be done exactly because of turbulence, especially when the telescope's aperture is more than 100mm. Special techniques or / and tools are necessary for exact focusing

Guiding of longer focal length (more than 1000mm) requires highest accuracy of all components of a telescope and camera system

Optical properties of telescope has to be adjusted to criteria's of digital photography. Today, many commercial telescope's optics are made to satisfy photography with chemical film, but the same criteria's are not sufficient for digital photography

Mechanical quality of the whole system should be rock steady, especially when guiding should be done with a guidescope

SECTION 2

Features of BJ-40 Series cooled CCD camera



Detectors used for BJ-40 Series

Higher grade SONY and Kodak CCD still imaging sensors are used for Bitran's BJ-40 Series cameras. They guarantee best possible image quality for astronomical photography. Pixel size is small (8.3, 6.45 and 7.4um) and quadratic, with binning the detectors are also suitable for longer focus photography. All feature standard built-in Anti Blooming Grid (ABG).

BJ-40L is a starter camera, smaller sized sensor Sony ICX-415AL features good sensitivity for long exposures and high-speed imaging possibilities for high resolution photography. With the same features, **BJ-40C** is the best planetary imager available for the planetary specialist.

Bigger sized and more sensitive sensor Sony ICX-285AL makes **BJ-41L** to the maybe most ultimate imager on the market, suitable for all imaging purposes.

Then, **BJ-42L** with big Kodak KAI4021M sensor is the high-end version for long exposure photography of large fields. This imager can only be used with specifically corrected telescope because of its large imaging area!

For BJ-41 and BJ-42, the same CCD detectors are also available as **RGB** versions. Although there is a loss in sensitivity and resolution and compared to monochrome versions, they are still recommendable for purposes like planetary imaging and long exposure photography with bigger apertures.

Controlled cooling

Bitran originally developed CCD cameras for Astronomy that can be used in a hot and humid climate. Sufficient cooling is not possible with only air cooling in a 30C surrounding, so BJ-Series camera offers a cooling option by water cycle. Another problem is high humidity of tropical climate, often dew forms on the optical window in front of the detector while cooling down. But when used in milder climates like Europe, dewing usually does not happen and standard air cooling is sufficient for most nights.

For highest quality imaging in long exposure photography, controlled cooling is necessary, especially when doing RGB-imaging. BJ-40 Series cameras are cooled by one Peltier

element, so detectors show slight thermal variation that can be corrected by Darkframe subtraction.

During cooling, heat produced by Peltier element and fan causes thermal instability of the camera. Therefore a process regulating cooling power to keep cooling temperature stable is implemented in software. In practice, software keeps cooling temperature stable within $\pm 0.1^{\circ}\text{C}$ over the whole using period!

Exposure times

BJ-40 Series has a built-in high-speed electronic shutter. With Sony type detector, exposure time selection is

- 0.001 , 0.002 , 0.004 and 0.008 seconds
- from 0.01 seconds to 0.99 seconds in 0.01 second unit
- and from one second to one hour in 1 minute and 0.1 second unit

With Kodak type detector, shortest exposure time possible is 0.03 seconds.

As an option, an external mechanical shutter is available for BJ-40 and BJ-41 type.

Multiple or Continuous Imaging

For imaging the surface of the sun, the moon and planets, it is necessary to make series of images, because atmospheric turbulence always affects the image quality. Usually in a series of 10 images there is one less affected by turbulence, it can be used for further picture processing. Or for planetary imaging, today the technique of stacking many images is popular. For this purposes, software offers comfortable and easy to use procedures for high-speed full- and subframe imaging with automatic saving options at best 16bit image quality.

Darkframe and Flatfield processing (by command 'Insert Files')

As discussed in Section 1, detector and camera electronics suffer from several effects that should be avoided or corrected:

- Dark current and hot pixel are corrected by so-called Darkframe subtraction process, executed automatically with 'Insert Files...' command.
- Optimum correction of dark current exposing as well as bias and Read-out values can be achieved with making so-called 'Master Darkframes' for long exposed images. With a specific Darkframe wizard, Master Darkframes can be created out of several single ones with ignoring high values caused by X-ray hits during exposing an add and average calculation. Master Darkframes are automatically saved in a special folder and can be used anytime for images made at the same cooling temperature and exposure time.
- Signal/Noise-ratio of long exposed images are maximized with subtraction of Master Darkframes. No extra bias subtraction process is necessary.
- Flatfield process corrects sensitivity variations on the detector and irregular illumination effects caused from the telescope or optical components participating the image formation.

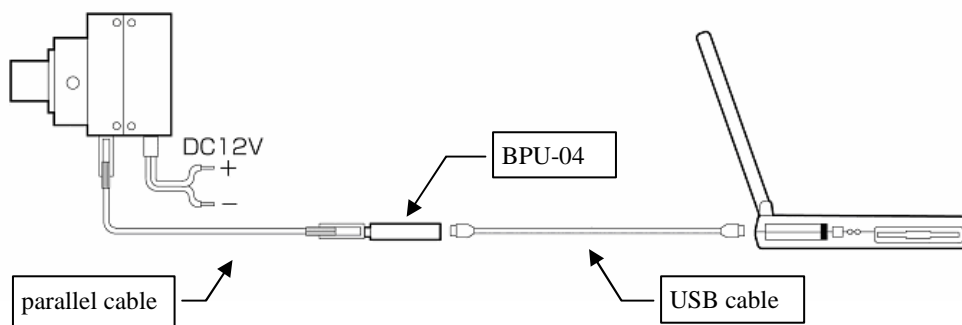
Camera attachment to Telescope and PC

BJ-40 and BJ-41: Standard 31.7mm (1.25") drawtube adapter with 28.5mm filter thread for IR-cut etc. Adapter is connected to camera by C-mount thread, so all kind of commercial C-mount products (objectives, adapters etc.) can be used.

BJ-42: Standard 50.8mm (2") drawtube adapter with 48mm filter thread. Adapter is connected to camera by M42 0.75mm thread.

Cameras can be also attached to tripod; therefore a metal edge is available.

Camera and PC are not connected directly by one USB cable. For maximum data transfer, we use 50cm of USB cable between PC and an interface called BPU-04 connecting to standard parallel cable. With camera set, a standard parallel cable of 4m length is delivered. But even **50m long parallel cable between camera head and interface** can be used!



Control Software

Control software (only English language) corresponds with Windows ME and 2000, Windows XP Home Edition and XP Professional and Vista. Software is easy to use, even the beginner can operate camera easily. A so-called 'Imaging Wizard' guides the first time user through the whole procedure, from cooling down to saving images (see Section 4).

During focusing and imaging, image conversion and zoom factor can be changed for optimized viewing purposes. For comparing a series of images, viewing conversion can be optimized for one image and then applied on all other open windows with command 'Convert all'!

Although software offers some image conversion possibilities, they are not sufficient for picture processing. It is recommended to use specialized software. Therefore, raw and converted images can be saved as various standard file formats like FITS, BMP and TIFF.

Support

With buying BJ-40 Series CCD camera, support by distributor is guaranteed as long as the camera's life. Support covers all questions and problems with using camera and software.

Please do User registration as soon as possible after receiving a camera system. Support cannot be received unless the user has registered. When camera changes its owner, support is not automatically transferred to the new user. Support can be bought new if wished, please contact us.

Guarantee

Bitran Corporation, Japan, gives a standard guarantee on the whole camera covering defects of production for six months. Bitran also guarantees for the gas inside the camera during this six months. Guarantee diminishes immediately in case of any kind of machining on camera body or misusing. Damages caused by accidents from handling, while storing, transports etc. are not covered by guarantee.

Since English BJ-40 Series cannot be sold in USA and Canada, but when still used in USA and Canada, there is no guarantee, support and liability by BITRAN Corporation, Japan, and by The CCD Astronomer, Switzerland.

SECTION 3

Setup of Software

Control software for running BJ Series CCD camera is delivered on a CD together with camera. Installation of software starts automatically with inserting CD into CD-ROM of PC. Setup of software uses standard Windows Installer and can be done with the following Windows system:

- Windows ME and Windows 2000
- Windows XP Home Edition and XP Professional
- Windows Vista

SETUP

For a complete setup of control software it is necessary to run CCD camera. The procedure of installation is:

1. Connect camera with power supply and with PC (but do NOT turn on power of camera yet). Please make always sure that voltage is between 11V and 14V and +(red)/-(black) connection is correct.
2. Insert CD into CD-ROM. Installation will start automatically, select 'BJ Control Soft'.
3. Follow the setup precisely and add all necessary information, especially serial numbers of camera and USB connection.
4. When installation of software is completed, '**Environmental setting**' starts automatically. This procedure checks if communication is correct between camera and PC. Now turn ON power of camera when procedure asks about and set up device driver according to Windows.

Now CCD camera is ready to use!

Software does not operate correctly

If control software cannot be started normally, abnormalities or even errors occurring during execution, software was not installed correctly although installation could be completed. In this case, remove software with CD-ROM or Software Manager of Windows. Do complete installation again and check if 'Mark here if you want to have all setting values as initial settings.' is selected when doing 'Environmental setting'. This sets unusual data to initial ones and now software should operate normally.

Start to work with camera

In principle there are two ways to work with camera. After installation and environmental setting or when control software is started, automatically the procedure '**Imaging Wizard**'

opens. This wizard is a good help when operating with CCD camera and software for the first time. It shows imaging process as a logical sequence.

All operations (cooling, focusing etc.) can be done also **manually** by canceling the Imaging Wizard procedure. With a little bit experience, most users will not work with Imaging Wizard anymore.

For a more detailed explanation about using camera with control software, please go on to Section 4.

Installation of driver for MaxImDL

On installation CD, also driver for using Bitran CCD camera with software MaxIm DL is included when it was bought. Please use specific button on Setup-CD and follow installation steps. Fully installed MaxIm DL is necessary.

SECTION 4

Using CCD camera with Telescope

In this section, imaging with CCD camera is shown with many useful hints about working properly with software and camera. First we follow the imaging procedure as it is supported by Imaging Wizard. When using CCD camera for the first time, it is recommended to follow the descriptions as a tutorial. The second part of Section 4 explains Darkframe Wizard and third part shows more specialized imaging of moon, sun and the planets.

Starfield imaging with Imaging Wizard

We first want to learn how to work precisely with CCD camera and control software. Connect camera with computer and power supply (make sure that plus/minus connection is correct and voltage is between 11 and 14 V DC). Turn ON power of camera head and start control software. Imaging Wizard opens automatically with the introduction window. In the following five windows first settings for imaging can be done and more information is available with HELP. We want to follow the first setting windows and discuss important points. Afterwards wizard will lead us automatically to the execution processes.

First setting window: Cooling

For starfield imaging we need to cool camera. Although exposure time is maybe not longer than 20 or 30 seconds, without cooling many 'fake' stars as hot pixel will appear when camera inside temperature is higher than +20°C. This is the window:



If camera is cooled down already, it is not necessary to do settings for cooling again. Therefore select 'No change of temperature here'.

Mainly two settings can be done here: Selecting type of cooling and setting target temperature. '**Only air**' is cooling with using fan at standard power. '**Fan supported**' means using fan at high power so lower target temperature can be reached. And '**Water cooled**' is cooling with a water cycle, recommended to use in a hot climate.

With selecting cooling types, software calculates for each type suitable target temperature according to current camera inside temperature and applied cooling power of Peltier elements. When you change between 'Only air' and Fan supported', target temperature will

differ about 6°C. With water cooling, target temperature is calculated against water temperature.

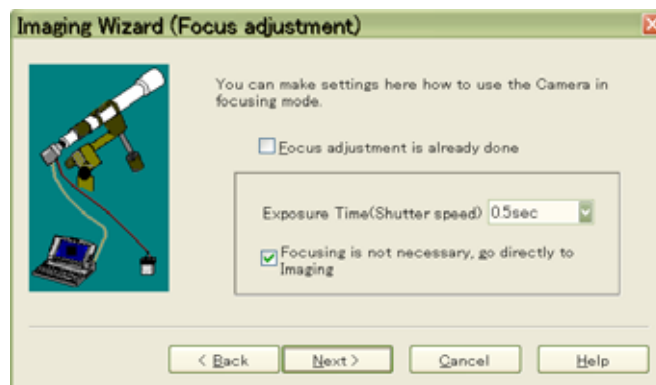
When you change target temperature, software recalculates automatically the necessary cooling power of Peltier elements. Standard power is usually about 50-70% of maximum, with choosing lower target temperature this power ratio gets higher. Of course camera could be always cooled at maximum power, but this is not recommendable because:

- Control of target temperature (after cooling down process) changes cooling power slightly to keep cooling temperature stable
- Running Peltier elements at 100% power heats up camera body constantly, after some time target temperature cannot be kept stable anymore

When using camera for the first time, select only cooling type and do not change calculated target temperature. With more experience, you will anyway make your own preferred settings for cooling process later in the Menu Settings\Options...\Cooling.

Second setting window: Focusing

The focusing process is very delicate, but at the beginning we are usually far away from focus point. It is better to select a longer exposure time (0.1 seconds and more), so that we can see unsharp stars for example.



When using Imaging Wizard for Imaging, maybe focusing was already done. Then select 'Focus adjustment is already done' and with 'Focusing is not necessary, go directly to Imaging' the Focusing window will be jumped over.

Third setting window: Settings for Imaging

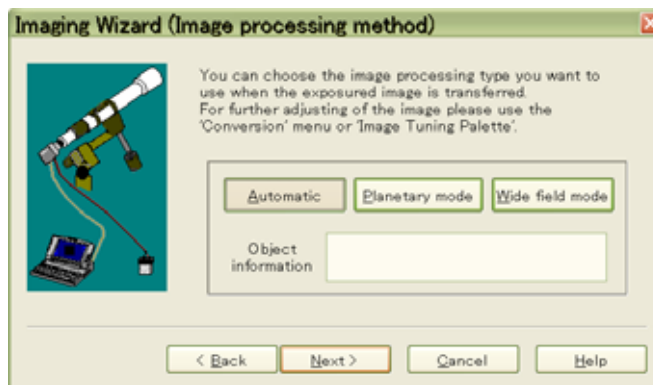
Some settings can be made for Imaging:



Before doing final exposure, usually short exposure are done to see if everything is ok. Select a longer exposure time (0.1 seconds and more) for this purpose.

The other three buttons are settings for making Darkframe. This software offers several ways to make Darkframes. This can be confusing at the beginning. There are several choices in main Imaging window (it is recommended to try out at home), the two lower buttons ('automatically' and 'manually') in the settings window above control settings directly in main Imaging window. The button 'I use Existing darkframe' refers to already made Darkframes with Darkframe Wizard. With selecting 'I use Existing darkframe', software searches if there is already a Darkframe for the selected cooling temperature and exposure time. For more information about Darkframe Wizard please see later and read in HELP. For our purpose select Darkframe 'automatically', or 'manually' if not necessary.

Fourth setting window: Settings for viewing exposed image

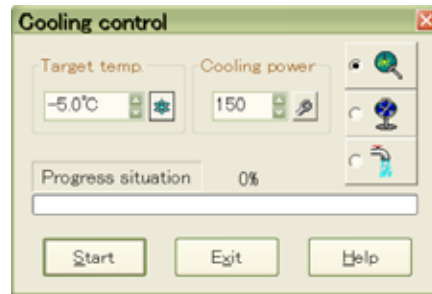


With '**Automatic**', a programmed function calculates the best suitable conversion for pixel value distribution. '**Min-Max mode**' (displayed above as Planetary mode) shows the image from minimum to maximum pixel value (transfer function, linear or logarithmic, is chosen by software). '**Deep Sky mode**' (displayed above as Wide field mode) converts the image for viewing faint details. For our purpose, the automatic image conversion mode should be satisfying. If you would like to add some information (like telescope data, sky conditions etc.) to exposed image, you can write into the field directly. Software adds this information automatically in header of data file when saving the image.

With 'Finish' in the next window, executing processes will start.

First execution window: Cooling

This is the main window for cooling down and control of cooling temperature, showing target temperature and cooling type we set before:



Calculated cooling power of Peltier elements is now also displayed. The ratio is not shown as percentage, but as a value between 0 and 255 (like 8bit-resolution!). Now you can make the following experiment: Change target temperature and then press the ice star button, software immediately calculates and displays necessary cooling power. You can learn about the sensitivity of target temperature and necessary cooling power.

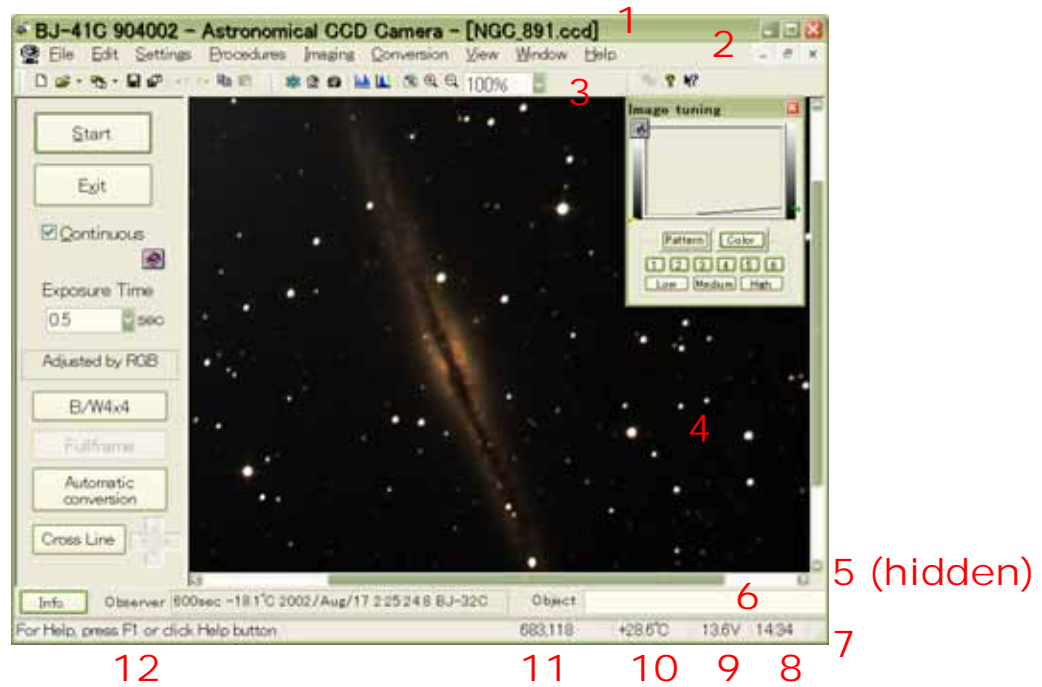
For our purpose, do not change target temperature unless cooling power is higher than 170. Then please select higher target temperature, otherwise camera body heats up constantly. When this happens, cooling temperature cannot be kept stable anymore after a while. So please start cooling down process with a cooling power about 140 or 150. After 'Start', window changes and shows status of cooling down process in percentage. Also focusing window is already displayed; it is even possible to do focusing already while cooling down. When status was 100% for a while, window displays 'Range $\pm 0.5^{\circ}\text{C}$ ' and cooling down process is finished. Now automatically the control cycle of cooling temperature is active, until the camera's power is switched off!

For more information about cooling process and also further settings, please read in HELP of software.

When cooling down is finished, with 'Exit' we go automatically to the next execution window 'Focusing'.

Second execution window: Focusing

Now we want to do precise focusing. Therefore this software offers comfortable functions, displayed on the left side of the window:



Maybe the most important one is 'Continuous'. When selected, software transfers one exposure after another to focusing window. This continuous imaging mode is extremely useful for focusing, searching and centering objects etc.

But before we start with focusing, we want to explain above outnumbered features about the use of software in general:

(1) Title bar

Title bar shows also file name of the active window.

(2) Menu bar

Menu bar displays the main menus of software. Menu selection can be done also by [Alt] key. With down arrow key of keyboard, menu opens and selection can be done by underlined character.

(3) Tool bar

With tool bar, the most used menu commands can be executed easily. When pointing with mouse on a tool, popup information is displayed. Tool bar can be hidden in Menu View.

(4) Picture window

The size of Picture window can be fit to image size (in Menu View – View size -> Fit window to image size) and also defined in general in Menu Settings – Options – Initial – Initial. Background color of a white part (when image is smaller than the window and when not fitted to image size) can be changed also in Menu Settings. And also Night vision mode changes color.

(5) Memory information bar

Shows actual memory status of PC. Can be hidden in Menu View.

(6) Header information bar

Displays image information that is saved in header of each taken photo. The Info-button shows details about type of CCD camera. As described about the fourth setting window, added information is displayed in the field named 'Object' (only when saved in original Bitran file format or FITS). Header information bar can be also hidden in the Menu View.

(7) Changing size

Software window size can be changed with this grip

(8) Voltage (Status bar)

Voltage of power supply is displayed here. When voltage is lower than 10Volt, value is displayed as a blinking red character.

(9) Camera body temperature (Status bar)

It is recommended to display camera body temperature always. It is not displayed by default, so please set it on in Menu Settings – Options – Initial – window Initial.

(10) Camera inside temperature (Status bar)

Shows the actual temperature of the gas-filled space around CCD sensor. When cooling efficiency becomes bad because of running Peltier element at high cooling power, software warns while temperature management with displaying temperature in yellow or red blinking character.

(11) Pixel coordinates (Status bar)

Displays coordinates of actual pointer position of mouse.

(12) Display of a simple help text (Status bar)

Status bar can be also hidden in the Menu View.

And now back to our goal, to do focusing!

At the beginning, the user will spend more time with finding and focusing an object than with making the exposure. So we want to practice this process by the following example:

1. We could aim the telescope directly at an object and center visually. But usually eyepiece and CCD camera differ a lot in their focus point, we will not see anything with the camera. For critical focusing it is anyway better to aim the telescope first at a brighter star near the object. Center the star well in the eyepiece, change to camera and focus 30-50mm nearer to the telescope's optics.
2. Select a longer exposure time (around one second), Binning 2x2 or 4x4, Fullframe and Automatic conversion. Then select 'Continuous' for constant imaging and press 'Start'. Now brighter star should be detectable somewhere in the field as a big round patch.
3. Focus and center the star better. But don't think to have found exact focus point already! We can enlarge the image during continuous mode, but the star will remain a big blob when we try to focus better. Also atmospheric turbulence will affect the star's shape very much. For accurate focusing the star is now overexposed.
4. Select Binning 1x1, change from Fullframe to 'Center512x512' or 'Center256x256' and a shorter exposure (try 0.01 second). We can see the star now as a smaller, but still unsharp patch. Enlarge the image until single pixels can be seen. Now we can do finest focusing. Do not hurry with finding the exact focus and fine-tune exposure time that the slightest changes in the star's appearance can be seen.

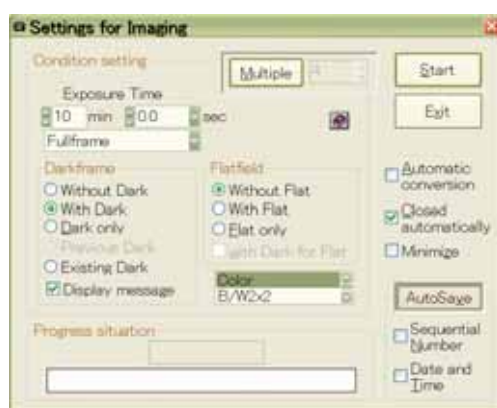
5. Now we want to make an exposure to see the overall image sharpness. Unmark 'Continuous' for a single image, change to Fullframe and select an exposure time between 10 and 60 second. Satisfied?

6. Of course now the telescope has to be aimed at the object. But do not exchange eyepiece and camera again, otherwise the wonderful focus we found will be lost. Best is to use continuous mode with highest binning and longer exposure time to search the object again.

And now we are ready for

Third execution window: Imaging

This is the main window used together with all Imaging devices of this software:



Left side settings in a frame named 'Condition setting' are for the exposure itself, right side are general settings. Choose an exposure time or directly enter numbers with keyboard. If you set minutes, the value in the field for seconds cannot be zero. Please add 0.001 sec to the field. Change Binning and framing mode if wished. Then there are two fields for Darkframe and Flatfield options. If 'Darkframe automatically follows exposure' was selected in the setting window, Darkframe section will show now 'With Dark' selected. Please set on also 'Display message', otherwise after Lightframe is exposed and transferred, exposure for Darkframe follows immediately. You will have no time to close the lid of telescope or CCD camera!

About the general settings: 'Automatic conversion' means software selects automatically the best suitable conversion for the value distribution of the image. It refers to 'Automatic' of the setting window for viewing the exposed image. 'Closed automatically' closes Imaging window after exposure is transferred. 'Minimize' shows the Imaging window as a small bar during exposing.

This software also offers two ways to do automatic save of exposures. For example when doing a sequence of 10 exposures with 'Multiple', it is helpful to use 'AutoSave', otherwise each image has to be saved. With 'Sequential Number', software adds ascending numbers to a chosen name of a file. The 'Date and Time'-format saves exposures automatically with date and time as a file name.

When all settings are done, it is recommended to make a control exposure of several seconds to see if everything is as wished. Then you are ready for the final exposure, congratulation!

Making Darkframes with Darkframe Wizard

Control Software offers a tool specialized for making Master Darkframes. Although Darkframes can be made with Imaging tool, we consider Darkframe Wizard as very important for the user who wants to do best removal of dark current exposition. Why? During Darkframe exposition, hits by X-ray show up as hot pixel or even bright lines. Often values of hits by X-ray exceed the values of the same pixel in the Lightframe, so Darkframe process reduces the values of those pixels to zero! With the result, that many annoying black dots appear in the objects after insertion of Darkframe.

So it is recommended to make three or four dark exposures with Darkframe Wizard and let software calculate a Master Darkframe. This is the tool:



With selecting 'Add and average' **and** 'Ignore excessive values', the process of calculating one Master Darkframe is activated. 'Add and average' averages the values pixel by pixel, but 'Ignore excessive values' does not consider a high value of the same pixel. For example during the third Darkframe exposure out of four, pixel XY was hit by X-ray:

Values: 1070 , 1130 , 8800 , 1100 -> $(1070+1130+1100)/3 = 1100$

The value 8800 for the same pixel is ignored for the calculation. When only 'Add and average' is selected, calculated pixel value of 3025 reduces pixel value in Lightframe by a three times higher value than its surrounding. This leads to an annoying dark spot with Darkframe processing!

The calculated Master Darkframe is saved automatically in a specific folder and can be seen in the second window named 'Existing Darkframe'. So it is also possible to produce Master Darkframes at home and not losing valuable night time. But we don't recommend to use Master Darkframes from long time ago, because slowly sensitivity of CCD detectors changes over the years!

Imaging of the moon, the sun and the planets

When doing Imaging of moon, sun and the planets, turbulence always influences the resulting image. So it is necessary to make a series of exposures and select the sharpest for further image processing. Or feed the whole series into a more specialized software like Registax (as today many Amateur process films made with a webcam).

Turbulence makes also precise focusing very difficult. It is often necessary to use tools for focusing, or reduce the aperture of the Telescope to 100mm or less. Focusing can be done on stars, focus point of all solar objects and stars is exactly the same!

It is also recommended to cool CCD camera for high resolution imaging with longer exposure time. For example when imaging planet Jupiter, exposure time will usually be longer than 0.1 seconds without underexposing. Without cooling, high dark current and Bias values makes the planet's surface a lot more noisy.

The procedure for high resolution is the same: First cool down CCD camera, take time to find the best focus point and then do all preparations to do Imaging. When you are ready, there are two possibilities: Series of images can be made with 'Multiple' in Imaging window, but we recommend to use the more specialized tool 'Sequential Imaging' that is located in Imaging Menu of control software:



This is a very helpful tool in many situations! For example during a Mercury transit in front of the sun, the user wants to make a sequence of single images every ten seconds when Mercury is exiting the sun's disk. So an appropriate number of exposures to be taken and the Interval of 10 seconds has to be set in the field 'Continuous Imaging'. The button 'Set Imaging conditions' leads to main imaging window for choosing exposure time etc. Every exposure is saved automatically after reading out. So please define the saving conditions in the field 'Save under' before starting sequence.

Image conversions

Implemented image conversions are mainly made for examining during imaging and not for image processing. It is recommended to use specialized software. For this purpose, raw and converted images can be saved also as various standard file formats like FITS, TIFF and BMP.

But it is very important to understand and being able to control the image conversions implemented in this software. When doing focusing or imaging, usually automatic conversion is active. This is often helpful, for example for first general focusing of a star. But with automatic conversion there is a danger of producing under or over exposed images. For example Jupiter looks nice on the screen although ten or one hundred times under exposed! Such images cannot be used for further image processing.

Automatic conversion modes

Control software offers next to manual conversion (see later) three main conversion modes: **Automatic**, **Min-Max** and **Deep Sky mode**. For Automatic and Deep Sky mode, software calculates optimized view range (upper/lower limit) and linear or logarithmic stretch for the specific value distribution of an image. Although Deep sky mode calculates for the main frequency of exposure values, often Automatic conversion shows the same result of a deep sky image.

Please open the image **NGC_891.ccd** in the folder [samples] where software was installed (xxx/bitran/bj series/samples). The galaxy looks very nice, doesn't it?!? Please check in Conversion Menu about conversion mode, Deep Sky mode is active. Now we want to know the conversion ranges, therefore open 'Additional parameter setting...' in Conversion Menu

to see the ranges (Red 3669-10356, Green 3530-10228, Blue 3040-9648). After canceling this window, please change conversion mode to 'Automatic'. Was there a change? Please check the ranges again in 'Additional parameter setting...', they will be the same as with Deep Sky mode. Now select conversion mode 'Min-Max mode' and compare ranges once more!

And we want to make the last test with the sample image: Surely you have seen the red and green points in the image; of course these are not stars but hot pixel! So we want to correct them with Darkframe subtraction, please choose 'Insert Files...' in Menu File and open **Darkframe.drk**. Wow! Galaxy shows up nicely like at the beginning, again software selected Deep Sky mode as best suitable conversion mode.

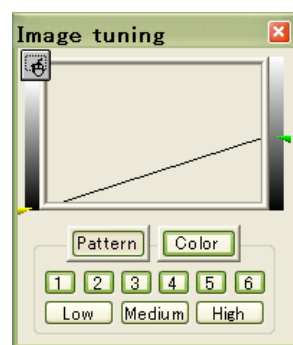
Min-Max mode (showing image from minimum to maximum exposure value) is necessary to determine correct exposure time for high resolution imaging. It happens often that the brightest parts of the moon are over exposed without noticing. While determining the best exposure time, we use Min-Max mode and check the ranges. If upper range shows the value 65535, we know that some parts of the moon are still over exposed. So we reduce exposure time until upper range value drops under 65535.

In general there are two ways for setting the wished conversion mode: It can be changed in Menu 'Conversion' or defined in Menu 'Settings' under Options... -> Initial Settings.

Manual image conversion

For converting an image manually, there is a tool called **Image tuning palette** (if not visible please activate in the Menu View):

The actual conversion of an image is shown in the window of the tool. For the sample image (please open NGC_891.ccd again and insert Darkframe) there is a line from lower left corner to right side with arrows at its ends. The arrows mark upper and lower limit of converted range. Take the right side arrow (green) with left button of mouse and move it carefully up. Image gets slowly darker and galaxy nearly disappears, because right side arrow marks upper limit of range. When moving left side arrow (yellow) up, galaxy disappears soon in the background and only bright stars remains visible!



Now change back to standard conversion by selecting Automatic or Deep Sky mode, point with mouse on the line and click on it with right button of mouse. What a big change! Now line is curved, because with clicking you changed from linear to logarithmic conversion for the converted range.

Upper and lower limit can be changed also by the buttons with numbers of Image tuning palette. From standard linear conversion, start with '1'-button and go on upwards to see the changes. Not only conversion range changes automatically, but also conversion mode (linear or logarithmic). Additionally, each color channel can be changed separately when automatically calculated color balance is not satisfying.

Range conversions can be done manually also with 'Additional parameter setting...'. This is sometimes helpful, for example the user wants to see an image as full CCD range (so from 0 to 65535 in 16bit resolution), especially for B&W images.

A lot more precise information can be found in HELP of software. Please also read there, especially about commands that were not mentioned. Anyway, we hope you enjoy Bitran's CCD camera as much as we do!

Appendix

Manufacturer

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For questions etc., please do not contact Bitran Corporation directly.

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BITRAN BJ SERIES ASTRONOMICAL CCD CAMERA

MANUAL

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