

# Operating Manual

## ST-402

**Very Important:**

*Before you attach the ST-402 to your computer for the first time you MUST install the software as described Section 2.*

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Note: This equipment has been tested and found to comply with the limits for a Class B digital device pursuant to Part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference in a residential installation. This equipment generates, uses, and can radiate radio frequency energy and if not installed and used in accordance with the instructions, may cause harmful interference to radio communications. However, there is no guarantee that interference will not occur in a particular installation. If this equipment does cause harmful interference to radio or television reception, which can be determined by turning the equipment off and on, the user is encouraged to try to correct the interference by one or more of the following measures:

- Reorient or relocate the receiving antenna.
- Increase the separation between the receiver and the equipment.
- Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.
- Consult the dealer or an experienced radio/TV technician for help.
- Shielded I/O cables must be used when operating this equipment.
- You are also warned, that any changes to this certified device will void your legal right to operate it.

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**1. Introduction**

***Congratulations*** and ***thank you*** for buying one of our ST-402 cooled CCD cameras. The ST-402 has the following features:

- Uses Kodak’s microlensed, blue enhanced **KAF-0402ME** CCD with 765 x 510 9-micron square pixels.
- **16-bit A/D** converter with correlated double sampling running at 1.8 megahertz.
- Temperature regulated Thermo-Electric (TE) cooling with 25C delta for reduction in CCD dark current.
- Single board, small, compact design with internal shutter allowing exposures down to 40 milliseconds that makes taking dark frames a trivial task.
- **USB 2** interface yielding up to 1.2 megapixels per second download rates but full backward compatibility with USB 1.1 computers at 400 kilopixels per second.
- Input power requirements of 10.0 – 14.5 Volts DC at 1 Amp through the ***new*** center-positive locking power jack.
- Telescope interface with four optically isolated normally open signals on the industry standard RJ-11 jack.
- T-Thread based mechanical interface that supports a variety of nosepieces and adapters.
- Optional 4-position filter wheel with parfocal **Red, Green, Blue** and **Clear** filters.
- Powerful yet intuitive **CCDOps** software for image acquisition and processing.

**Getting Started**

In addition to this truly fine **Operating Manual**, the ST-402 package includes the following items:

**ST-402 Camera** – The camera body is 4 x 5 x 2 inches with a T-Thread adapter on the front cover.

**1 ¼ Inch T-Thread Nosepiece** – This screws into the front of the camera for telescope work and includes a soft rubber cap for keeping out the dust when not in use. Optional 2 Inch Nosepiece and Visual Back adapters are available from SBIG. In addition a screw-in T-to-C adapter is available for use with C-Mount camera lenses or C-Mount adapters.

**Power Supply** – US versions of the camera come with a 12V/2 Amp DC power supply. Outside the US the camera is supplied with a Battery Clip adapter.



**Extremely Important!**

In the past SBIG has shipped products like the STV, ST-5C and ST-237/A that used a 12-Volt, Center-Negative power supply. Starting with the ST-402 we are switching to Center-Positive 12-Volt power supplies. How do you know the difference?

*All 12-Volt, Center-Positive power jacks and receptacles are locking with a threaded collar. Don't ever try to mate an unthreaded power supply to a threaded camera or vice-versa.*

**USB Cable** – Included is a 15-foot, USB 2 certified, A-to-B type, USB cable. USB has a limit of 15-foot cables but the range can be extended with active boosters. Relatively low-cost (~\$30) 15-foot boosters that can be strung together are available from such sources such as <www.usbgear.com>. Long haul boosters (more expensive) are available from <www.icron.com>. Also note that putting a hub at 15 feet will allow you to go another 15 feet.

**Tracking Cable** – This cable looks like a simple “RJ-11 telephone cable” but in fact is a “6-pin reversed RJ-11 telephone cable”. Telescopes require 6-pin autoguider cables and reversed means that unlike ordinary phone cables, this one is flips the order of the wires. You can tell a tracking cable from an ordinary cable by noting that with tracking cables the tines that lock the RJ-11 jack into the receptacle are both on the same flat side of the cable or when the ends are put side by side the colored wires inside are in opposite order on the two connectors.

**Software** – We include several CD-ROMs with the ST-402 but the most important one is labeled “**SBIG Software and Catalog**”. This disc contains the *drivers* and *CCDOps* software you’ll need to use the camera.

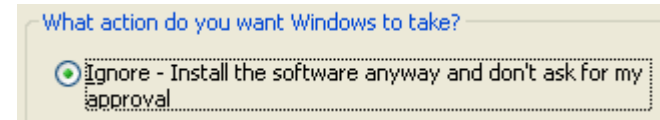
**Very Important:**

*Before you attach the ST-402 to your computer for the first time you MUST install the software as described below.*

**2. Installing the Software**

Installing USB drivers on a *Windows* system can be a difficult task if you don’t follow the instructions to the letter. Please don’t plug the camera into the computer until instructed to do so below and please follow the instructions carefully.

1. **Disable Driver Signing** – *Windows XP* adds an extra level of security to installing drivers that will complicate our installation. To disable it open the *System* Control Panel in the *Start Menu* and then select the *Hardware* tab. Click the *Driver Signing* button and in the dialog that appears select *Ignore* then click *OK*. Click *OK* one more time to close the Control Panel.



2. Insert the **SBIG Catalog and Software** CD-ROM in your computer and on most systems the installer program will automatically start. If it doesn’t, explore the CD-ROM drive and double-click on the *autorun.exe* icon. Then click on the *Setup a New Camera* button.
3. **Install CCDOps** – Click on the *Install CCDOps* button to install it on your computer, and then follow the on-screen instructions. *CCDOps* is our powerful yet simple-to-use image acquisition and image processing software and we’ll use it extensively throughout this manual.
4. **Install the Driver Checker** – Click on the *Install Driver Checker* button to install it on your computer and then follow the on-screen instructions. The *Driver Checker* is a utility program that installs and maintains the drivers that are required for operating the ST-402 under the Windows Operating System.  
At the end of the install when you are given the *option to launch* the *Driver Checker*. Check that option.
5. When the *Driver Checker* starts it will ask you if you have an *Internet Connection* on this machine. If you do then answer *Yes* otherwise answer *No*. The Driver Checker will install the camera drivers and at this point all your drivers should all be current:

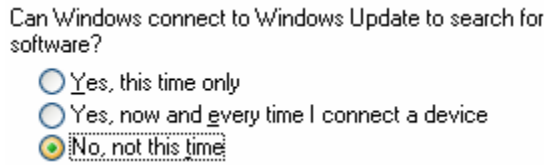
Currently Installed Drivers			
Driver Name	Version	Date	Current
sbigudrv.dll	4.43	01-12-05	Yes
sbigudrv.sys	4.06	08-23-02	Yes
sbiguldr.sys	1.41	11-04-04	Yes
sbiglldr.sys	1.06 Build 2	09-22-04	Yes
sbigfldr.sys	1.07	01-11-05	Yes
sbigusbe.sys	1.1	09-05-03	Yes

- We've finished installing the drivers but now we need to bind them to the ST-402. Quit the **Driver Checker** by clicking the **X** in the upper-right hand corner. If you're running **Windows XP** then continue with **step 7** below. Users of older versions of Windows should now look for instructions particular to their version of Windows in the "**Installing USB Drivers**" Application Note that can be found on the CD-ROM or our web site.

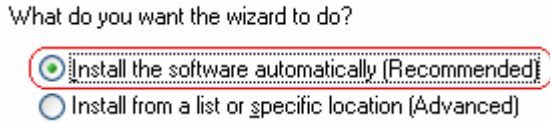
- Now's the moment you've been waiting for. We're going to plug the camera into the computer, but not so fast!  
 First plug the camera into the power source and note that the **Fan** comes on but the **Red LED** does not. The ST-402 actually has its internal firmware downloaded to it by the PC at startup. If the **LED is off** the camera has not been **booted**. Please remember that.  
 Now plug the camera into the USB port on the computer with the supplied USB cable. **Remember** which port you're using because you'll want to use the **same port** again next time or you'll have to go through this process of binding the drivers all over again. Windows will crunch for a while and then present you with the **Found New Hardware Wizard (Wizard)** dialog.



- If you're asked if it should connect to **Windows Update** to search for software click "**No, not this time**", then click **Next**.



- Now the **Wizard** will ask you if you want to install the software automatically. Select to do so then click **Next**.



- Windows will grind for a while copying the **SBIG ST-402 Loader** driver then show you the **Completing the Found New Hardware Wizard** page.

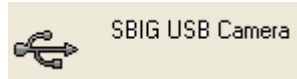
Click **Finish**. At this point the **Red LED** on the back of the camera should be on, and if you had been watching it you would have seen it **blink** several times while the PC was **booting the camera**.



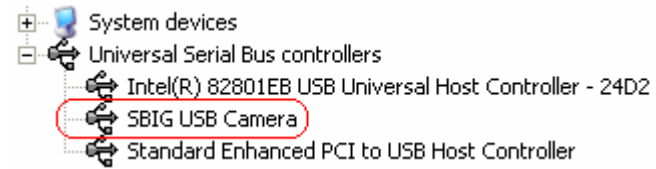
- After booting the camera Windows will bring up another copy of the **Wizard**. The ST-402 actually uses **two drivers**. One to **boot** the camera and one to **talk to it** after it's booted. We now need to walk **Windows** through installing the second driver.
- Repeat steps 8 and 9, again telling the **FNHW** to not check for updates and to install automatically. At this point windows will show you the **Select the best match** page:

Description	Version	Manu...	Location
SBIG USB Camera	2.0.1.0	SBIG	c:\windows\inf\sbigusbe.inf
SBIG USB Camera	2.0.1.0	SBIG	c:\windows\inf\oem22.inf

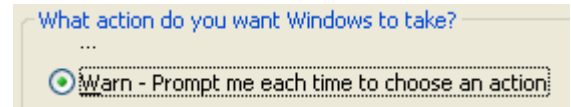
- Select the **oem** file not the **sbig** file (the second item above) by clicking on it then click the **Next** button.
- Windows will grind one last time copying the **SBIG USB Camera** driver then show you the **Completing the Found New Hardware Wizard** page.  
 Click the **Finish** button and **pat your self on the back**. You're done!



If you ever doubt that the camera is actually connected you can open the **Device Manager** from the **Hardware** tab of the **System** control panel and expand the **Universal Serial Bus controllers** section. You should see a **SBIG USB Camera** listed there:



While you've got the **System** Control Panel open, if you want to restore the Windows Driver Signing security check, click the **Hardware** tab, click the **Driver Signing** button and select:



If Windows can not automatically find the drivers , tell it to Install from a Specific Location and then browse to the folder:

**C:\Program Files\SBIG\Driver Checker\SBIG Drivers**

### 3. Using the Camera Inside

When you first receive the ST-402 it's wise to get acquainted with its operation inside the house where it's warm and not to try to fight the telescope operation in the dark. We've included a brief tutorial below to get you acquainted with the ST-402 and the **CCDOps** software.

#### Running CCDOps

Once installed, it's easy to run CCDOps from the Windows **Start** menu. Click the **Start Menu**, then find the **SBIG Folder**, which under Windows XP is under the **All Programs** section. Finally click the **CCDOps Icon** to start the program. You'll be presented with the startup **About Dialog** that shows the SBIG logo and the version of CCDOps. To dispense with it click anywhere in the dialog other than the two blue fields or simply wait and the dialog will close itself.

#### Getting Help

CCDOps includes an extensive help file that can be accessed through the **Help Topics** item in the **Help** menu. In addition many of the dialogs have an embedded **Help button** that will take you to the **Help Topic** for that specific command. Just remember, help is always just a click away.



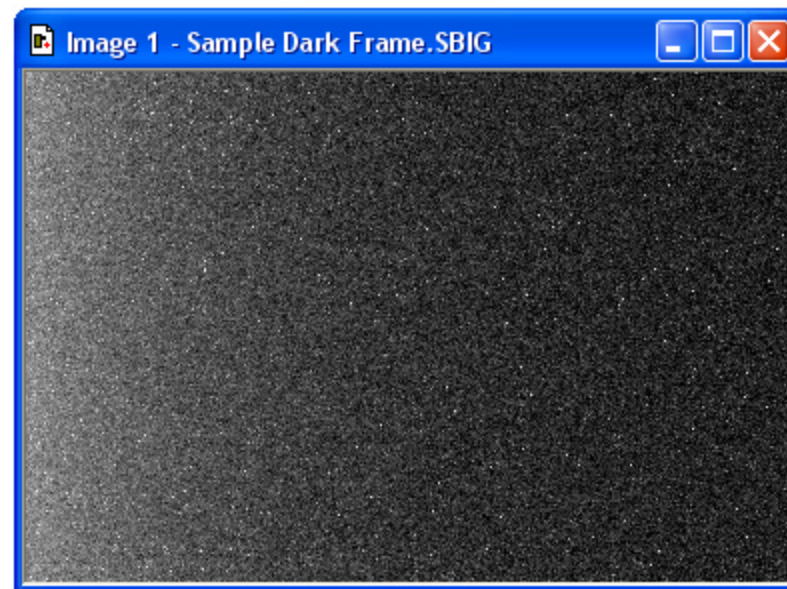
#### Opening and Inspecting Dark Frames

We've included some sample ST-402 images on the **SBIG Software and Catalog** CD-ROM to get you acquainted with what you should expect from your camera.

First, let's look at what is called a **dark frame**. In the **File** menu use the **Open** command and then navigate to the CD-ROM's **Images** directory. Double-click on the **ST-402 Tutorial** folder to show its contents. Finally double-click on the **Image 1 - Sample Dark Frame** icon to open the image.

CCDOps will present you with a dialog listing all the parameters associated with the image such as the **Exposure Time**, the **Date and Time** the image was acquired, etc. Note that the **Exposure Time** was 1.0 second. Spend some time inspecting the data then click in the dialog to close it.

Data like this is always attached to saved images and you can show it using the **Parameters** command in the **Display** menu. After the **Image Parameters** dialog has gone you'll see the image displayed in its own window and the **Contrast** dialog will appear. The image is shown below:



This is what's referred to as a **dark frame** and it's what you get when you take a picture with the nosepiece covered and the shutter closed. It's a picture in the dark. Although there's not much interesting to look at in this image there are some very important features that you need to understand.

The first thing you'll see is that while the image looks mostly like salt and pepper there are hundreds of bright specks. These are called **hot pixels**. They are present in every CCD image to one extent or another, even in images from our most expensive cameras. If your digital snappy camera didn't automatically remove them for you, they would be seen in those images too.

What causes hot pixels? It's an attribute of CCD sensors called **dark current**. A pixel in an ideal CCD, in the absence of light, would maintain a steady value. When exposed to light the pixel's value would increase in response to the light but then as soon as the light went away the pixel would maintain its value again.

In the real world CCD pixels suffer from the affects of dark current whereby the pixel's value slowly increases (brightens) over time. All the pixels in the image shown above have some component of their signal due to the build up of dark current.

Dark current builds up over time in a linear fashion but **cooling** the CCD can reduced the rate at which it accumulates. For example, cooling the CCD by 25°C reduces the dark current 16-fold. That's why Astronomical CCD cameras are cooled – to reduce the dark current when imaging very faint objects.



**Hot pixels** are simply the pixels where the dark current is higher than the average and thus they show up as white specs against the salt and pepper background. Again, this is completely normal for CCD images.

The second effect you'll notice is a brightening on the left of the image, as if something bright was just outside the field of view. This is called the **readout glow** and is caused by the electronics in the CCD, in particular by a very small but ever present glow emanating from in the on-chip amplifier that conditions the weak signals in the CCD so that they may be digitized.

The **readout** (or digitization) of images from CCDs is a sequential process whereby every pixel is digitized one-after-another until the whole image has been digitized. The readout starts at pixel (1,1) in the top-left corner and proceeds to pixel (765, 510) in the lower-right hand corner. As each pixel in a row is readout the pixels to the right of it within the same row are shifted to the left one position in preparation for the next pixel readout. The next pixel is then readout and the process repeated until every pixel in the first row has been digitized.

At this point the whole CCD is shifted up one row and digitization starts with the left-most pixel of the second row. The **readout glow** on the left of the images is a buildup of light from a glow from the preamplifier structures in the upper-left hand corner of the CCD while rows are queuing up for readout.

The final effect you'll notice is the salt-and-pepper look of the background. What you're seeing here is the ultimate noise floor of the CCD whereby adjacent pixels have slightly different values due to noise in the CCD and readout electronics. The noise in dark frames that have a zero exposure time is referred to as the **read noise** of the camera.

Fortunately for us there are very simple image processing techniques we can use to eliminate the effects of **dark current** and **readout glow**.

Let's open another image. Close the first image by clicking the **X** in the upper-right corner then use the **Open** command in the **File** menu again but, this time double-click on **Image 2**. Note in the **Image Parameters** dialog that this image had an **Exposure Time** of 10 seconds. Click in the dialog to close it.

Now this image has a whole lot more hot pixels! That's because this exposure was 10 times as long and the pixels built up 10 times the dark current. It's hard to even see the background through all the hot pixels.

About this time you're probably asking yourself "How can I ever take deep sky images with all these hot pixels?" The answer is simple. Because the build up of dark current at a given CCD temperature is a repeatable effect you can remove the effects of dark current by taking two images, one with the shutter open (**light frame**) and another of equal exposure with the shutter closed (**dark frame**). You then **subtract** the dark frame from the light frame, and because the **hot pixels** and the **readout glow** repeat from one image to another they are removed by the subtraction.

Let's see how this works. Close **Image 2** and Open **Image 3**, which is a 10-second **light frame** where you can get a hint of the object but the hot

pixels are definitely obscuring it. Now use the **Dark Subtract** command in the **Utility** menu. This brings up the **Open File** dialog where CCDops wants you to select which image to subtract. Double-click on **Image 2**, the 10-second **dark frame**. The displayed image turns completely black! What did we do? Did we destroy the image by dark subtracting? No we didn't but it's time to learn something else regarding CCD images.

### Brightness and Contrast

Images from the ST-402 are **16-bit** images meaning any pixel can have values from 0 to 65,535 ADU where ADU is short for A/D Converter Units. Said another way this means there are 65,536 possible brightness or gray scale values that each pixel can have. In CCD lingo this is referred to as the **dynamic range**. But computer monitors and our eyes can typically only distinguish a hundred or so different gray scale values. How do we accommodate the large dynamic range of CCD images with our computer? The answer is through **Brightness** and **Contrast** adjustments of the displayed image.

Getting back to our dark subtracted image and why it's completely black. Find the **Contrast** dialog shown to the right and then click the **Auto** checkbox. Magically our object appears, and as promised, the **hot pixels** and the **readout glow** are gone, replaced by the object and the salt-and-pepper noise. What did we do?

By clicking the **Auto** checkbox we told CCDops to adjust the image display to match the actual image's pixel values. **Auto Contrast** is a very handy tool to have in your bag of tricks.

Just for fun click the **Smooth** checkbox in the Contrast dialog. The noise in the image is greatly reduced. The **Smooth** option is handy when for reducing the noise in underexposed images like **Image 3**.

Let's explore the Contrast dialog further. Close the dark subtracted **Image 3** and when CCDops asks you if you want to save the changes you've made click **No**. Use the **Open** command again to open **Image 4**, which is just like Image 3, but with a proper exposure.

The first thing to notice is that in the Contrast dialog the **Back** is set to 8,000 and the **Range** is set to 20,000. What does that mean? In short it means that pixel values from 8,000 (**Back**) to 8,000+20,000 (**Back + Range**) have been displayed using the monitor's available gray scale. Pixels with values 8,000 ADU or below are completely black. Pixels with values 8,000+20,000=28,000 ADU or above are completely white. Finally, pixels with values between 8,000 and 28,000 are shades of gray.

Click the small up and down buttons adjacent to the **Back** setting several times and you'll see the overall image **brightness** increase



and decrease. Click the ones adjacent to the **Range** setting and you'll see the image **contrast** increase and decrease. Here's a summary of how this works:

*Increasing the **Back** decreases the image **brightness** and vice-versa.  
Increasing the **Range** decreases the image **contrast** and vice-versa.*

Set the **Back** to 8,000 and the **Range** to 20,000 by typing in the fields (without the comma) and then hit the **Apply** button to get us back to where we started. When you manually enter values in the **Back** and **Range** you must hit **Apply** to see the effect.

Let's learn a little more about the controls in the **Contrast** dialog. Click the **Invert** checkbox and notice that the image now looks like a negative. For images of faint objects, viewing the image as a negative by clicking **Invert** can reveal faint structure.

Unclick **Invert** and then click **Sharpen** on and off several times while looking at the fine detail in the image. With the **Sharpen** checked it's almost as if the focus improves. That's the effect of Sharpen. It works great on well-exposed images but tends to increase the noise in faint areas.

The last thing to try in the **Contrast** dialog is the **Mag** popup. It's set to **1:1** but selecting **2:1** or **4:1** zooms in on the image, enlarging the image display. Selecting **1:2** or **1:4** zooms out on the image. Try the **1:2** and **2:1** settings. You may wonder if all these changes to the **Contrast** dialog are destructive to the image data. They are not.

*Changes to the settings in the **Contrast** dialog only affect the way the image is displayed. They **do not modify** the actual pixel values.*

*In Summary*

- Clicking **Auto** is a good place to start with most images.
- **Back** controls image **brightness** and **Range** controls **contrast**.
- Clicking **Invert** can help reveal faint detail in images.
- Clicking **Smooth** can reduce the noise in underexposed images.
- Clicking **Sharpen** reveals additional detail in well-exposed images.

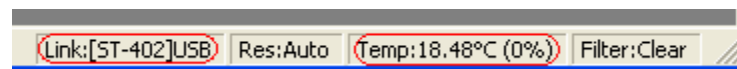
**Establishing a Link**

It's time to actually connect up to your camera and take some images. If you haven't installed the drivers already go back to **Section 2** and do so now.

If you've taken a break from the tutorial and the camera isn't powered up and attached to the computer do so now by plugging in the power source and then connecting the camera to the computer. At this point the **Fan** and **LED** on the back of the camera should be on.

Use the **Graphics/Comm Setup** command in the **Misc** menu to make sure **USB** is selected for the **Interface**. Click **OK** to set/confirm that and then use the **Establish COM Link** command in the **Camera** menu.

CCDOps will try to connect to your camera, which can take several seconds to complete. If successful you'll hear the shutter emit a series of clicking sounds as it finds home and you'll see updated information in the **Link Status** fields show in the lower-right corner of the CCDOps window as shown here:



This shows the link has been established to an ST-402, that the Temperature of the CCD is 18.48°C and that the TE cooling is disabled (0%). The clicking is not a death rattle – it is simply the shutter homing against a stop.

**Camera Info**

After establishing a link to the ST-402 use the **Information** command in the **Camera** menu and you'll see the dialog shown below;

Camera Info

Camera Type: ST-402 without ABG  
 Camera Name: SBIG ST-402 CCD Camera  
 Firmware version: 2.07      Driver info: SBIGUDrv.DLL Ver 4.43  
 Serial number: STFP2      sbigusbe.sys Ver 1.1  
 CCD Temperature: 18.48°C      Ambient Temperature: 25.0°C

Readout mode:	High	Medium	Low	1xN	2xN	3xN
Image width:	765	382	255	765	382	255
Image height:	510	255	170	0	0	0
Pixel width (μ):	9.00	18.00	27.00	9.00	18.00	27.00
Pixel height (μ):	9.00	18.00	27.00	9.00	9.00	9.00
Gain (e-/ADU):	1.47	2.20	2.20	1.47	2.20	2.20

Readout mode:	Hi-DS	Med-DS	Low-DS	ULow
Image width:	765	382	255	85
Image height:	510	255	170	56
Pixel width (μ):	9.00	18.00	27.00	81.00
Pixel height (μ):	9.00	18.00	27.00	81.00
Gain (e-/ADU):	1.47	2.20	2.20	2.20

The **Camera Information** command shows you the capabilities of your camera. There are a few key items here that you should be aware of should you ever need technical support:

**Firmware Version/Driver Info** – Over time we revise the camera firmware and drivers to add new capabilities and fix software bugs. The ST-402 actually has its firmware downloaded to it every time it connects to the PC after a power-up sequence, which makes it very easy for us to update the ST-402 in the field. To make sure you

have the latest firmware periodically run the *Driver Checker*, which checks our servers for later drivers and updates your system accordingly.

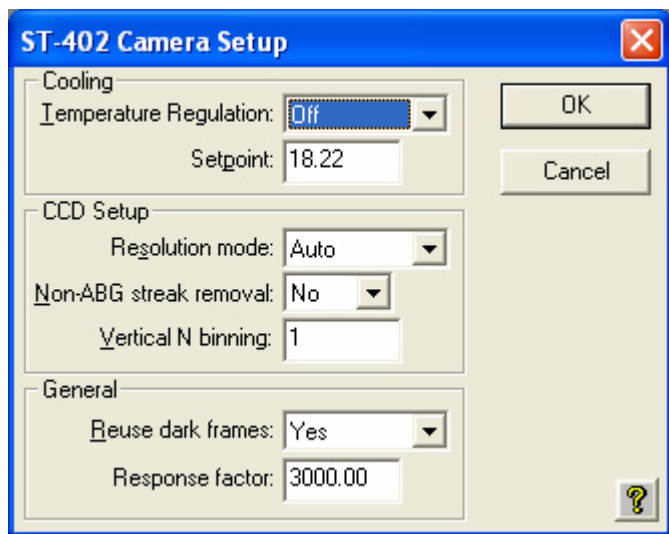
**Serial Number** – If you ever need to know this, here it is. It's on the label on the back of the camera as well.

**Readout Mode Table** – This shows the various readout modes the ST-402 supports. The *High*-resolution mode offers the full 765 x 510 resolution with 9 micron square pixels. The ST-402 also supports *binning* whereby groups of pixels are combined to form a single larger pixel. This reduces the resolution but increases the sensitivity as larger pixels capture more light. The *Medium* and *Low*-resolution modes utilize 2x2 and 3x3 binning as you can see by the *Image Height/Width* and *Pixel Size* entries.

Finally, review the information presented, then close the dialog by clicking in it.

### Camera Setup

Use the *Setup* command in the *Camera* menu to see the *ST-402 Camera Setup* dialog shown below.



The key items in this dialog are described individually below.

**Temperature Regulation** – This allows you to turn the TE cooling on and off. Typically at the start of an imaging session you'll turn the cooling on and then back off at the end of the night. For now let's just leave it off.

**Setpoint** – When the *Temperature Regulation* is on, set this to the *absolute temperature in degrees C* to which the CCD should be cooled. We know that cooling reduces dark current but there is a limit as to how much the CCD can be cooled by the TE cooler.

We recommend choosing a temperature that is 20 to 23 degrees below the ambient temperature. Choosing a lower temperature won't hurt the camera but you'll notice in the *Link Status* field (bottom of screen) that the CCD never attains the temperature and the TE stays at 100%. It can take several minutes for the temperature to settle in, but if you see the TE stuck at 100% simply increase the *Setpoint Temperature* so it can regulate.

**Resolution mode** – This popup controls the readout mode discussed in the *Camera Information* section above. You can select the *High*, *Medium* or *Low* resolutions modes directly but we recommend you start with the *Auto* resolution mode. In *Auto* mode the camera uses the high-resolution mode everywhere except in the *Full Frame Focus* mode (discussed below) where it uses the low-resolution mode to speed up the image throughput.

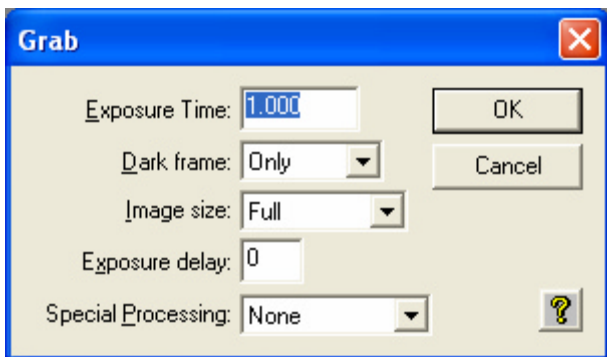
**Reuse dark frames** – This is a handy feature and you should set it to *Yes*. What that means is that when you're taking images where you want to *subtract dark frames* the software will reuse a previously captured *dark frame* if it's the same exposure time and at the same CCD temperature.

You can read about the other items in the *Help* but for now just leave them set the way they are. Click *OK* to register your changes.

### Grab Command

Let's take a *dark frame* with your new camera. If you haven't done so already, screw in the nosepiece and put the rubber cap on it. While the shutter was designed to block light from the telescope for *dark frames*, it can't block flooding room light from leaking around the edges of the shutter blade. That's why you should cover it under bright light illumination. Now, use the *Grab* command in the *Camera* menu and set the dialog as shown below:





Here we're asking for a 1.0-second dark frame of the full CCD. Click the **OK** button and in a few seconds you'll see an image that looks a lot like the *Image 1* from the tutorial. Hot pixels, readout glow and salt-and-pepper noise, they're all there. Congratulations: You've just taken your first dark frame! That wasn't so hard was it?

Let's experiment with the settings in the Grab dialog. Try changing the **Exposure Time** to 10 seconds and grabbing another image but this time watch the LED on the back of the camera. It blinks while the camera is exposing the image. That's a handy thing to remember when you're in the observatory. *Don't bump the telescope when the LED is blinking.*

Anyway, the new image should look just like *Image 2*. Try setting the **Exposure Time** back to 1.0 and the **Dark frame** to **Also**. What happens here is the camera takes a **dark frame** first, and then takes a **light frame**, **subtracting** the **dark frame** from it. The result should be uniform noise without **hot pixels** and without **readout glow**.

Had we had the camera on the telescope we would have seen the object but because we had the nosepiece covered we took a **dark subtracted image** of the dark. If you take enough of these, and stare at them long enough you'll see all kinds of patterns in the random noise, including even pictures of Elvis!

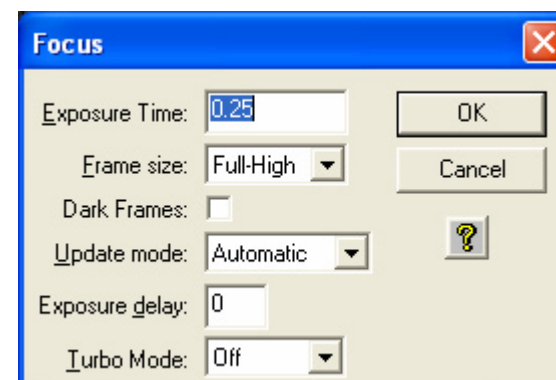
You can read about the other items in the **Grab** dialog by clicking the **Help button**, but in general the **Grab** command is used to **take a single image** and optionally do an **automatic dark subtraction**.

**Note:** Dark subtracted images have an offset of 100 ADU added to them to ensure values near zero are not clipped.

### Focus Command

Using the **Grab** command to focus your telescope would drive you crazy, taking a single image at a time, tweaking the telescope etc. Instead we use the **Focus** command, which is like **Grab** but it takes image after image

automatically. Use the **Focus** command in the **Camera** menu and set it up in the **Focus Setup** dialog as shown below:



Click **OK** and the camera will go into **Focus** mode. You'll see image after image appear in a single window with a new image about every second. The images will vary slightly from image to image, mostly in the random background noise but in general they'll all look a lot like *Image 1*. You'll also notice a new **Focus Mode** dialog appeared.

**Note:** You may notice a slight clicking sound coming from the camera in focus mode. That's the normal sound the shutter makes as it bumps up against the home position.

Here's a brief description of the key items in the **Focus Setup** and **Focus Mode** dialogs.

**Exposure Time** – You'll be able to see most objects in a 1 second exposure. Use shorter exposures (down to 0.040 seconds) for faster rep rates when focusing on bright stars or longer exposures when trying to center dim objects.

**Frame Size** – **Planet** mode allows you to select a portion of the CCD's field of view (**FOV**) for faster rep rates due to smaller downloads. It's great for focusing the telescope on a star. The other three **Full** settings all show the FOV of the CCD but are slower than **Planet** mode because there's more data to download.

**Full-High** uses high-resolution mode to show you all 765 x 510 pixels. **Full-Low** uses low resolution (3x3 binning) which is faster and more sensitive since there are fewer pixels to download and the pixels are larger. Finally **Full** works in conjunction with **Planet** mode and the **Camera Setup** such that when the camera is set to **Auto** resolution mode **Full** uses the low-resolution mode for faster downloads then switches to high-resolution for **Planet** mode.

**Dark Frames** – For most objects you won't need to take dark frames in Focus mode to frame and focus the object because the exposures tend to be short and the build up of dark current minimal. On some dim objects though, checking this item, which uses *dark subtracted* images for *Focus* mode can help to pull the object out of the noise. It's slightly slower when using dark frames so only use this when you need to.

**Update Mode** – Sometimes you want to tweak the focus, look at an image, tweak it again, etc. Setting this to *Manual* causes the Focus mode to pause between images until the **Space Bar** is hit or you click the **Pause/Resume** button.

**Peak** – This shows the position and brightness of the brightest pixel in the Focus mode image. We'll use this later to get the best focus by maximizing the *Peak* on a *star*.

**Pause/Resume** – Click this button at any time to pause or resume the focus mode. This can be handy for going back and forth between the telescope and the computer or for studying the images.

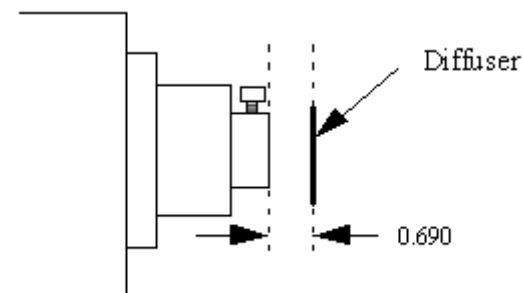
You can read more about the other items in the *Help* but we now know enough for basic operation. Exit *Focus Mode* by closing the *Focus Mode* dialog or closing the image window.

You've come a long way in this brief tutorial. If you want to spend some time reading the *Help* file or the *CCDOPs Manual*, which is included on the CD-ROM that would be useful. Otherwise it's time for trying it out at the telescope.

#### 4. At the Telescope

Connect the camera to the computer and start *CCDOPs*. Establish a link to the camera and run the *Camera Setup* command. Enable the cooling to 20 degrees below ambient and then watch the *Link Status* field to see the temperature come down. Once the temperature reaches the Setpoint it will jump back and forth by about 0.5 degrees. This is normal. The ST-402 regulates the CCD temperature by dithering back and forth across the Setpoint. At this point we're ready to hook up to the telescope.

Focusing a CCD camera at the telescope can be a tedious operation, so a few hints should be followed. Before using the software to focus the camera the first time you should place a diffuser (such as scotch tape or ground glass) at the approximate location of the CCD's sensitive surface behind the eyepiece tube and focus the telescope on the moon, a bright planet or a distant street lamp. This preliminary step will save you much time in initially finding focus. The approximate distance behind the eyepiece tube for the ST-402 is **0.690 inches (backfocus)**.



To achieve fine focus, first center a bright star then insert the CCD head into the eyepiece tube, taking care to seat it, and then enter the CCDOPs *Focus Mode*. Do not initially try to focus on the moon or planet – they are harder. As we learned in the tutorial, the *Focus Mode* automatically displays successive images on the screen as well as the peak brightness value of the brightest object in the field of view. Using the telescope controls, center the star image in the CCD, and adjust the focus until the star image is as small as can be discerned. Next, shift the telescope to fainter stars so the CCD is not saturated. Further adjust the focus to maximize the displayed star brightness in counts and minimize the star diameter. This can be tedious. It helps considerably if a pointer or marker is affixed to the focus knob so you can rapidly return to the best focus once you've gone through it.

An exposure of 1 to 3 seconds is recommended to smooth out some of the atmospheric effects. While you can use the *Full frame* mode to focus, the frame rate or screen update rate can be increased significantly by using *Planet mode*. In Planet mode the Focus command takes a full image and

then lets you position a variable sized rectangle around the star. On subsequent images the Planet mode only digitizes, downloads, and displays the small area you selected. The increase in frame rate is roughly proportional to the decrease in frame size, assuming you are using a short exposure.

The telescope focus is best achieved by maximizing the peak value of the star image. You should be careful to move to a dimmer star if the peak brightness causes saturation. The saturation levels of the various resolution modes are shown in Table 3.2 below. Another point you should also be aware of is that as you approach a good focus, the peak reading can vary by 30% or so. This is due to the fact that as the star image gets small, where an appreciable percentage of the light is confined to a single pixel, shifting the image a half a pixel reduces the peak brightness as the star's image is split between the two pixels. The Kodak CCD pixels are so small that this is not likely to be a problem.

<i>Resolution</i>	<i>Saturation Counts</i>
High Res	~35,000 for ABG Cameras 65,000 for Non-ABG cameras
Med/Low Res	65,000

Once the best focus is found, the focusing operation can be greatly shortened the second time by removing the camera, being careful not to touch the focus knob, and inserting a high power eyepiece. Slide it back and forth to find the best visual focus (don't touch the focus knob), and then scribe the outside of the eyepiece barrel. The next time the camera is used the eyepiece should be first inserted into the tube to the scribe mark, and the telescope visually focused and centered on the object. At f/6 the depth of focus is only 0.005 inch, so focus is critical. An adapter may be necessary to allow the eyepiece to be held at the proper focus position. SBIG sells extenders for this purpose.

### Finding and Centering the Object

Once best focus is achieved, we suggest using *Full-Low* mode to help center objects. This mode gives a full field of view, but reduces resolution in order to increase the sensitivity, and digitization and download rate. If you have difficulty finding an object after obtaining good focus, check to be sure that the head is seated at best focus, then remove the head and insert a medium or low power eyepiece. Being careful not to adjust the focus knob on the telescope, slide the eyepiece in or out until the image appears in good focus. Then visually find and center the object, if it is visible to the eye. If not, use your setting circles carefully. Then, re-insert the camera and use the *Focus Mode* with an exposure time of about ten seconds, if the object is quite dim. Center the object using the telescope hand controls.

**Note:** With a 10 second exposure, objects like M51 or the ring-nebula are easily detected with modest amateur telescopes. The cores of most galactic NGC objects can also be seen.

### Taking an Image

Take an image of the object by selecting the *Grab* command and setting the exposure time. Start out with the *Image size* set to *full*. The camera will expose the CCD for the correct time, and digitize and download the image. One can also take a *dark frame* immediately before the light image using the Grab command by selecting the *Dark Also* option.

Because the ST-402 has regulated temperature control, you may prefer to take and save separate *dark frames*, building up a *library* at different temperatures and exposure times, and reusing them on successive nights. At the start it's probably easiest to just take the dark frames when you are taking the image. Later, as you get a feel for the types of exposures and Setpoint temperatures you use, you may wish to build this library of dark frames. Fresh darks seem to work better, so it is not recommended to build a huge dark library.

### Saving Images

Save the images using the Save command in the File menu. We strongly recommend you save images in the SBIG Compressed format as it is the most compatible. Use the TIFF and JPEG formats only when you are done with the image as you won't be able to reopen it with CCDOps. Those formats are useful for export to photo programs.

### Further Adventures

At this point we refer you to the *CCDOps Manual* that can be found on the *SBIG Software and Catalog* CD-ROM. It has an extensive tutorial section and detailed information about the software and its capabilities.

## 5. Accessories for your CCD Camera

This section describes several of the common Accessories designed to work with the ST-402.

### Color Filter Wheel

The CFW-402 is a 4-position filter wheel that can be installed in the camera. With its *Red*, *Green*, *Blue* and *Clear* filters, the CFW-402 enables collection of color images with the ST-402. Installing the CFW-402 is simple with the following procedure.

1. Remove the camera's front cover by loosening the four socket-head cap screws (SHCS) that hold it in place.
2. Remove the existing shutter by unscrewing the small Philips head screw and washer that holds it in place.
3. Place the CFW-402 onto the motor shaft, aligning the Double-D cutout with the hub of the shaft. Replace the washer and retaining screw.
4. Replace the front cover. You're ready for color imaging!

**Note:** Each color component image is displayed as black & white monochrome when collected. Use the *RGB Merge* command in the *Utility* menu to assemble a color image.

### Battery Adapter

SBIG sells a battery clip adapter that allows you to run the ST-402 in the field off a car battery. Contact us for pricing and availability and make sure you ask for the *Center-Positive* version.

### Camera Lens Adapters

SBIG sells a *T-to-C* adapter that screws into the *T-Thread* on the front of the camera and enables use of the ST-402 with standard *C-Mount* camera lenses. In addition we also sell a line of C-Mount lens adapters for many of the popular 35mm lenses such as *Nikon*, *Canon* and *Olympus*. Contact us for pricing and availability.

### Electromechanical Relay Adapter Box

Older telescopes may not be compatible with our optically isolated telescope driver. We also sell a *Relay Adapter Box* that contains four *electromechanical relays* with *Normally-Open*, *Normally-Closed* and *Common* connections for each of the four directions. Contact us for pricing and availability.

## 6. Glossary

**Antiblooming**- When a CCD pixel has reached its full well capacity, electrons can effectively spill over into an adjoining pixel. This is referred to as blooming. Kodak CCDs like the KAF-0402LE with the antiblooming option can be used to help stop or at least reduce blooming when the brighter parts of the image saturate.

**Astrometry** - Astrometry is the study of stellar positions with respect to a given coordinate system.

**Autoguider** - All SBIG CCD cameras have auto guiding or "Star Tracker" functions. This is accomplished by using the telescope drive motors to force a guide star to stay precisely centered on a single pixel of the CCD array. The camera has four relays to control the drive corrector system of the telescope. The CCD camera head is installed at the guide scope or off axis guider in place of a guiding eyepiece.

**CCD** - The CCD (Charged Coupled Device) is a flat, two dimensional array of very small light detectors referred to as pixels. Each pixel acts like a bucket for electrons. The electrons are created by photons (light) absorbed in the pixel. During an exposure, each pixel fills up with electrons in proportion to the amount of light entering the pixel. After the exposure is complete, the electron charge buildup in each pixel is measured. When a pixel is displayed at the computer screen, its displayed brightness is proportional to the number of electrons that had accumulated in the pixel during the exposure.

**Correlated Double Sampling** - Correlated Double Sampling (CDS) is employed to lower the digitization errors due to residual charge in the readout capacitors. This results in lower readout noise.

**Dark Current** - Dark Noise or Dark Current is the result of thermally generated electrons building up in the CCD pixels during an exposure. The number of electrons due to Dark Noise is related to just two parameters; integration time and temperature of the CCD. The longer the integration time, the greater the dark current buildup. Conversely, the lower the operating temperature, the lower the dark current. This is why the CCD is cooled for long integration times. Dark noise is a mostly repeatable noise source, therefore it can be subtracted from the image by taking a "Dark Frame" exposure and subtracting it from the light image. This can usually be done with very little loss of dynamic range.

**Dark Frame** - The user will need to routinely create image files called Dark Frames. A Dark Frame is an image taken completely in the

dark. The shutter covers the CCD. Dark Frames are subtracted from normal exposures (light frames) to eliminate fixed pattern and dark current noise from the image. Dark Frames must be of the same integration time and temperature as the light frame being processed.

**FITS Image File Format** - The FITS image file format (which stands for Flexible Image Transport System) is a common format supported by professional astronomical image processing programs such as IRAF and PC Vista.

**Flat Field** - A Flat Field is a image with a uniform distribution of light entering the telescope. An image taken this way is called a flat field image and is used with CCDOPS to correct images for vignetting.

**Focal Reducer** - A Focal Reducer reduces the effective focal length of an optical system. It consists of a lens mounted in a cell and is usually placed in front of an eyepiece or camera. With the relatively small size of CCDs compared to film, focal reducers are often used in CCD imaging.

**Full Well Capacity** - Full Well Capacity refers to the maximum number of electrons a CCD pixel can hold. This number is usually directly proportional to the area of the pixel.

**Histogram** - The Histogram is a table of the number of pixels having a given intensity for each of the possible pixel locations of the image file.

**Light Frame** - The Light Frame is the image of an object before a Dark Frame has been subtracted.

**Photometry** - Photometry is the study of stellar magnitudes at a given wavelength or bandpass.

**Pixel Size** - The smallest resolution element of a CCD camera is the CCD pixel.

**Planet Mode** - Planet Mode is the most useful way to achieve focus. When you select Planet mode, a full frame is exposed, downloaded, and displayed on the computer monitor. A small window can be placed anywhere in the image area and the size of the window can be changed. Subsequent downloads will be of the area inside the box resulting in a much faster update rate.

**Quantum Efficiency** - Quantum Efficiency refers to the fractional number of electrons formed in the CCD pixel for a given number of photons. Quantum Efficiency is usually plotted as a function of wavelength.

**Readout Noise** - Readout noise is associated with errors generated by the actual interrogation and readout of each of the CCD pixels at the end of an exposure. This is the result of fixed pattern noise in the CCD, residual charge in the readout capacitors and to a small extent the noise from the A/D converter and preamplifier.

**Resolution Mode** - The resolution of a CCD camera is determined by pixel size. Pixel size can be increased by combining or binning more than one pixel and displaying it as one pixel. Doing so decreases the effective resolution but speeds up the download time of the image. Maximum resolution is determined by the size of the individual CCD pixel. The ST-402 can run in High, Medium, Low and Auto resolution modes.

**Response Factor** - Response Factor is a multiplier used by CCDOps to calibrate CCDOps to a given telescope for photometric calculations.

**Saturation** - Saturation refers to the full well capacity of a CCD pixel as well as the maximum counts available in the A/D converter. The pixel is saturated when the number of electrons accumulated in the pixel reaches its full well capacity. The A/D is saturated when the input voltage exceeds the maximum.

**Sky Background** - The sky background illumination or brightness is the number of counts in the image in areas free of stars or nebulosity and is due to city lights and sky glow. High levels of sky background can increase the noise in images just like dark current. For some objects deep sky filters can be used to reduce the sky background level.

**Seeing** - Seeing refers to the steadiness and the clarity of the atmosphere during an observing session.

**TE Cooler** - The TE Cooler is a Thermal Electric cooling device used to cool the CCD down to operating temperature. The CCD is mounted to the TE Cooler which is mounted to a heat sink, usually the camera head housing.

**TIFF Image File Format** - The TIFF image file format (which stands for Tagged Interchange File Format) was developed jointly by Microsoft and Aldus Corporations to allow easy interchange of graphics images between programs in areas such as presentation and desktop publishing. CCDOps can save image files in this format but unless they're color images it can not read them.

**Track and Accumulate** - The Track and Accumulate function is a SBIG patented feature of CCDOps that allows the user to automatically co-register and co-add (including dark frame subtraction) a series



of images of an object. These exposures can be taken unguided as long as the "Snapshot time" does not exceed the length of time before tracking errors of your clock drive become apparent. This allows you to image and track without guiding or the need to connect the CCD Relay port to your drive motors.

**Track List** - The Track List is an ASCII file generated by CCDOPS during a Track and Accumulate session. The Track List logs all the corrections made by CCDOPS for each of the images. Track lists are required when flat fielding Track and Accumulate images.

**Tri-Color** - Tri-Color refers to color images created using three different colors mixed into a balanced color image using red, green and blue filters. An object is imaged three times, once with each color filter. The three images are then co-added and color balanced with the appropriate software.

**Vignetting** - Vignetting is obstruction of the light paths by parts of the instrument. It results in an uneven illumination of the image plane. The effects of vignetting can be corrected using flat field images.

**Appendix A – Connector and Cables**

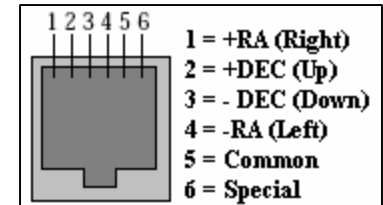
**Power Jack**

The Power Jack is used to supply 10.0 – 14.5 Volts DC at 1 amp to the camera. The jack is locking and *center-positive*. The mating plug is the locking model *Switchcraft S760K* with 0.218 inch outer diameter and 0.080 inch inner diameter (5.5/2.0 mm).

**Telescope Jack**

The Telescope Jack is used to provide tracking signals to the telescope. Viewed from outside the camera, looking in, it has the following pin-out:

The *Left*, *Down*, *Up* and *Right* signals are driven from optically isolated photo transistors that conduct when telescope movement is desired. They can sink up to 25ma and can hold off up to 25V. If what you are plugging into is voltage based you'll need an external pull-up resistor.



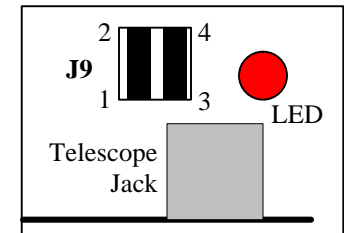
The *Common* signal is connected to the common on the four photo transistors. The *Special* signal is discussed below.

**Jumper Options**

By removing the back of the camera you'll find two jumpers adjacent to the Telescope Jack that have the following affect:

**J9 Pin 1 to 2** – When in place connects the *Common* signal to the minus side of the power source, effectively grounding the *Common*.

**J9 Pin 3 to 4** – When in place makes the raw positive power source (~12V) available on the *Special* signal. You can use this for powering an external relay box. **Do not connect to your telescope with this jumper in place as you will damage the telescope or camera.**



## Appendix B – Maintenance

This Appendix describes the periodic maintenance items you need to perform on your camera to keep it in optimal condition.

### Updating CCDOps and Drivers

We are constantly adding new features and fixing software bugs in our software, which is available for free download from our web site. You should periodically visit our website to check for updated versions of the *CCDOps* software and you should also periodically run the *Driver Checker* to download and update your drivers.

### Cleaning the Window and Filters

- 1) Get a can of compressed air from a photo store, as well as a small camera hair brush
- 2) Thoroughly clean and dry the brush using isopropyl alcohol
- 3) Remove the front cover of the camera. If you want to clean the Window remove the Filter Wheel. While the camera is open be very careful to avoid activities that could spark the inside of the camera with static, just sit in your chair. If you have to get up and get something, discharge your body to a metal surface (not the camera) after sitting back down.
- 4) Tilt the camera up to face horizontally and blow out the entire chamber with the compressed air. Finish with a blast right on the Window from a half inch away. Be VERY careful not to tip the can of compressed air past 45 degrees as often an oily liquid will come out that is hard to clean off.
- 5) If you have a dust particle that will not blow off, poke it loose with the brush. They cling to the surface due to static, so you may end up just pushing them out of the way. The static forces are quite strong!
- 6) The outside of the window is easily cleaned with a cotton swab or Q-tip and a little isopropyl alcohol. Use one end of the Q-tip to swab it with alcohol and the other to dry it. Never re-use a Q-tip and do not scrub – use gentle pressure
- 7) Replace the front lid.
- 8) If you have a few small dust specs, don't worry. it is almost impossible to get them all and a flat field will take care of them well.
- 9) Filters are cleaned the same way.

### Replacing the Desiccant

The ST-402 contains a small packet of *desiccant* that keeps the CCD from frosting when it's cooled. This desiccant should last for several years but it won't last forever. If you start seeing things appear in your images that look like shadowed tendrils you should suspect frost on the CCD and it may

be time to replace the desiccant. You can get the replacement desiccant from us and it's easy to replace with the following procedure:

5. Remove the camera's front cover by loosening the four socket-head cap screws (SHCS) that hold it in place.
6. Remove the shutter or filter wheel by unscrewing the small Philips head screw and washer that holds it in place. Make sure you know which side goes up. With filter wheels it the side with the filters but with shutters you'll have to keep track of it as they won't work right if flipped.
7. Remove the CCD Cover/Window Plate by loosening the four SHCS that hold it in place.
8. Pull out the old desiccant pack and replace it with the fresh one. You may have to wedge it in there or fold the bag slightly to get it to fit.
9. If the CCD cover glass is spotted it is easily cleaned with a cotton swab and isopropyl (rubbing) alcohol. Dust here is very critical, so take care.
10. Replace the CCD Cover/Window plate, shutter and front cover.
11. Let the camera sit for 2 hours before cooling to give the desiccant time to equilibrate the CCD chamber.

**Appendix C – Camera Specifications**

The table below lists the specifications for the ST-402 camera. Specifications are typical and can vary from camera to camera and are subject to change without notice.

<b>CCD Options</b>	
Microlensed CCD	Kodak KAF-0402ME
Non-Microlensed	Kodak KAF-0402E
ABG Protected	Kodak KAF-0401LE
<b>Pixel Array</b>	756 x 510 pixels, 6.9 x 4.6mm
<b>Total Pixels</b>	390,150
<b>Pixel Size</b>	9 x 9 microns
<b>Full Well Capacity</b>	
Non-ABG CCDs	100,000 electrons
ABG CCDs	50,000 electrons
<b>Dark Current</b>	1 e-/pixel/sec at 0°C
<b>Shutter</b>	Electromechanical
<b>Exposure</b>	0.04 to 3600 seconds, 10ms resolution
<b>A/D Converter</b>	16-bit with Correlated Double Sampling
<b>Read Noise</b>	17e- RMS
<b>Binning Modes</b>	1x1, 2x2, 3x3
<b>Full Frame Download</b>	
USB 2	Up to 1,200,000 pixels per second
USB 1.1	Up to 400,000 pixels per second
<b>Cooling</b>	Single Stage TE, Active Fan, ~25C Delta
<b>Temperature Regulation</b>	Closed Loop, ±0.1°C
<b>Power Requirements</b>	10 – 14.5 Volts DC at 1 Amp, Center-Positive
<b>Backfocus</b>	Same as C-Mount, 0.690 inches
<b>Dimensions</b>	4 x 5 x 2 inches