

SBIG's AO-7 Adaptive Optics Accessory Operating Manual

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Introduction

SBIG's adaptive optics package is designed to enable users of an ST-7 or ST-8 camera to achieve the ultimate in resolution when imaging deep sky objects. The package consists of two components: a high speed tip-tilt mirror capable of correcting the telescope pointing at rates up to 50 times a second, and a software package that implements the Lucy-Richardson deconvolution technique for image sharpening. Both items were developed by SBIG in concert with Benoit Schillings and Brad Wallis, two advanced amateurs well known in the film and CCD imaging field. This package can produce a 2X improvement in resolution over normal self guided images, where corrections are applied only to the telescope drive. This package truly advances the capability of the amateur astronomer, considering that most professional observatories do not have comparable systems.

Theoretical Background

Under good seeing conditions, atmospheric turbulence causes the stellar image to wander about the mean position, in addition to blurring occasionally. Three levels of adaptive optic correction are possible. The simplest technique, which we have implemented, uses a high speed steering device to suppress the wander and hold the star image fixed on the sensing device. A second level of sophistication is to try to correct the lower level aberrations produced by the atmosphere, in addition to stabilizing the image, while viewing a star. The ultimate technique, developed by the military, uses a laser guide star to provide a point-like source high in the atmosphere that provides enough light to enable accurate sensing of the wavefront, and therefore correction. The laser guide star approach, however, can only correct the higher order aberrations; the image must still be stabilized by a tip-tilt mirror viewing the object, not the laser guide star.

The success of any adaptive optic technique is limited by three important considerations: First of all, the atmospheric aberration is not correlated spatially over a large extent. The isoplanatic patch commonly referred to in the literature is the angular extent over which the higher order aberrations are correlated, and is typically only a few arc seconds. The odds of having a suitably bright star so close to an object of interest is small, which is what has motivated the development of laser guide stars, which can be put where they are needed. The tip-tilt component of the aberration is correlated over a larger extent, minutes of arc, improving the odds of finding a suitable guide star.

The second consideration is that the atmosphere is constantly changing. With any system, you have to correct the telescope or adjust the mirror based on the last image acquired, which can be several milliseconds old by the time it is collected. For example, with a 10 millisecond exposure, the average position of the star is sensed as it was 5 milliseconds previously. This consideration forces one to work at very high rates to correct the higher order aberrations. The lower order effects, such as the tilt of the wavefront, change less rapidly and can be corrected with slower systems.

The last major consideration is field of view. Systems which correct the higher order aberrations typically can not improve the image over more than a 1 minute of arc field of view. This corresponds to an ST-7 used with a 934 inch focal length (24 meters).

The importance of these considerations is that a typical amateur CCD camera with a field of view of around 10 minutes of arc, using a guide star about 10 minutes off the center of the field, is not improved by correcting more than the tip-tilt component of the aberration, and does not need to run at excessively high rates to obtain all the possible improvement. The higher order aberrations and fast image variation are simply not correlated between the two CCDs. This is the philosophy behind SBIG's AO-7 tip-tilt mirror design. Our correction rate allows correction of stellar wander up to about 5 hertz (50% wander reduction), assuming a bright enough guide star, and correlation between tracking and imaging CCDs. In general, deep sky objects do not have good guide stars imbedded in them, so our off axis location of the tracking CCD is essential for the user to acquire guide stars over a substantial area by rotating the camera. We do not feel better reduction of atmospheric effects than that provided by our unit is possible for amateur sized telescopes.

In general, adaptive optic techniques used for astronomy are always starved for light. We have optimized our noise performance to where one can typically guide on a 10th magnitude star at 10 frames per second with a 10 inch telescope. We call this rule the "10" rule of thumb! Finding a good bright guide star is aided by a good star atlas program, such as Software Bisque's The SkyTM, and focal reducers or Barlow lenses to put the best star at the right distance off axis. In general, even running at rates as low as 1 frame per second provides some improvement since the AO unit makes an accurate small move, much better than most telescope drives, since it has no backlash and a fast response.

In general, the AO module can not be used to image the moon, since there is no guide star. It cannot improve planet imaging unless a guide star is close by, such as might be provided by a moon of Jupiter.

How the AO-7 Unit Works

In SBIG's AO-7, a tip-tilt mirror is used to make fine corrections to the position of a star to hold the image fixed on the CCD during the exposure. The tip-tilt mirror has magnets on the back, which interact with the current flowing through a set of voice coils on the AO module housing to rapidly move the mirror. The technique is very similar to that employed in loudspeakers, except there the magnet is fixed and the wires are on the moving speaker cone. We put the wires on the fixed housing to better conduct heat away from the moving mirror, where it might distort the optical element.

The mirror and magnets are suspended using a flexible beryllium copper membrane. A needle pushes up against a jewel bearing mounted to the center of the mirror to hold the focus constant. SBIG has developed a proprietary technique to rapidly damp the motion of the mirror, so small moves are precise, with very little overshoot or ringing. The tilt of the mirror during operation is very slight, and does not lead to any measurable defocus at the edges of the frame, even on an ST-8. The correction range of the tip-tilt mirror is about +/- 30 pixels with an ST-7 or ST-8; the software adjusts the telescope position to take care of drive errors greater than this if they exist. The telescope position is adjusted while the AO is running, but this does not cause problems since the

AO corrects much faster than the telescope drive. The telescope drive is adjusted to keep the AO-7 voice coil drive levels between 25 and 75%.

The AO-7 accessory utilizes the tracking CCD integral to the ST-7 and ST-8 cameras. The PC controlling the imaging process uses the tracking CCD to measure the position of the guide star, then sends a position correction to the tip-tilt mirror, waits for the mirror to move, and starts the next tracking CCD exposure. The imaging CCD continuously collects light throughout the cyclical process. In SBIG's tip-tilt mirror the mirror can complete the move in 10 milliseconds. Reading out the CCD and processing the information takes another 9 milliseconds, so with an exposure time of 1 millisecond the unit can achieve update rates of 50 frames per second. With an exposure of 10 milliseconds, the total time to go through the loop once is 29 milliseconds, corresponding to a rate of 34 frames per second. The maximum sinusoidal components of the stellar motion that are well corrected are only about $1/10^{\text{th}}$ of the update rate. For example, a 40 frames per second update rate attenuates a four hertz stellar sinusoidal motion by about 50%.

Compatibility

The AO-7 can be used with SBIG's ST-7 or ST-8 cameras, with or without the CFW-8 filter wheel. The CFW-6 filter wheel is not supported. A new ROM must be installed in the ST-7/8 and the CFW-8 to work with the AO-7. No current functionality is lost with the new ROMs; they merely implement a new communication scheme between the ST-7 and its peripherals.

Installing the CCDOPS Software with AO to your Computer

Installing and running the CCDOPS software: copy the CCDOPS version 3.7 software from the floppy disk to the desired directory. Within Windows 95, double click the CCDOPS.EXE file to start the program. Maximize the program display to use the whole screen.

Mounting the AO unit to the camera and telescope

1) Installing the new ST-7/8 ROM

The AO module requires high speed communication between the ST-7/8 and the AO-7. This high speed communication link requires the installation of a new ROM (Read Only Memory) into the ST-7/8. No capability of the old ROM is lost. Install this ROM by removing the screws that hold the ST-7/8 back plate to the unit, laying the back plate to the side (you don't need to unplug the fan), and removing the large 28 pin integrated circuit labeled ST-7 UP-Vers X.XX (component U3). Note the orientation of the ROM before removing it, so you can orient the new one correctly. When removing the ROM, prying the IC up gently with a small screwdriver on each end between IC and socket works well. We also supply a chip puller tool with the ROM that works nicely. Be careful not to poke the pins into your fingers. Also, make sure you are prying up the integrated circuit, not the socket! Install the new 28 pin ROM labeled ST-7-UP-Ver 1.06.

Make sure that pin 1 of the IC, marked by a 0.1 inch (2.5 mm) diameter circle recessed into the plastic, is at the end marked by the U3 callout, the top edge of the board.

2) Unpacking the AO module

The AO module's tip-tilt mirror is somewhat delicate due to the flex member and the needle bearing support. For shipping a piece of cardboard and a lens cloth is sandwiched between the two halves of the module to prevent the mirror from vibrating or hammering against the jewel bearing. Remove the long screws that hold the halves together, remove the cardboard, and reassemble the unit. Save the cardboard and lens cloth in case you need to return the unit to SBIG for service. If necessary gently clean the mirror with rubbing alcohol and cotton swabs. Never reuse the swabs – wipe the alcohol on with one swab, dry it with another, and repeat the process using new swabs until the mirror is clean. If fingerprints are present, reusing the swabs just moves the grease around, and does not remove it from the surface. This is why the swabs must be thrown away after one use. This is typically a good technique with optical elements.

It is a good idea to check the flexure when it is first unpacked. Gently depress the mirror around the edge with a swab or fingertip about 0.04 inch (1 mm). The mirror should have a firm, smooth spring action, with no gritty feel such as might result if the mirror was rubbing against the support structure. Check it in four places, 90 degrees apart. Contact SBIG if it doesn't feel right, or tends to hang when released.

When reassembling the two halves of the unit, orient the halves so that the cable exits on either the + or – X side of the AO-7. The X axis is the same as the long direction of the CCD.

The CCDOPS software includes an EXERCISE command under the AO menu. This option allows one to drive the mirror to its limits in a rectangular pattern, or each axis individually. You can select the axis or combination, and the update rate between moves. This option is excellent for checking out the AO device after unpacking. Make sure it is connected to the camera, and the combination powered up. (only connect and disconnect the AO module to camera when both are unpowered!). Try an update time of 100 milliseconds initially, and look at a distant light reflected in the AO module mirror. You should see the mirror deflecting. Next increase the update rate to 20 milliseconds. The light should blur into a rectangular pattern of light, with no more than 20% overshoot at each corner. It will probably not be square, and may be slightly parallelogram shaped, with the axes not at exactly 90 degrees. This is satisfactory, since the resultant error of the move is small. Hit ESC to terminate the mirror motion.

3) Connecting the module to the ST-7/8

On a flat table, remove the nosepiece from the ST-7. There are two ways to attach the AO module to the ST-7, depending on your configuration. The first is to use a male-to-male coupler, which is required to connect to the CFW-8 filter wheel; the second is to directly connect the two using machine screws, which is done when there is no filter wheel. The connection techniques are pictured in a drawing at the end of this manual.

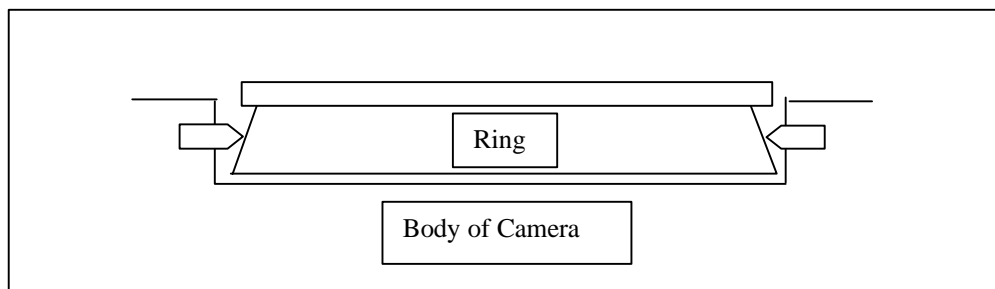
- A) Using a male to male coupler with ST-7 and filter wheel – if you have not already done so, direct connect the ST-7 to the filter wheel. Do this by removing the 2 by 2 inch (5 cm) T-thread “D” block from the front of the ST-

7, removing the carousel from the filter wheel, and attaching the two units with the four short screws included with the filter wheel. Reassemble the filter wheel. Attach the T-thread “D” block removed from the ST-7 to the AO-7 unit using the four flathead screws and nuts provide with the AO-7. Screw the male to male coupler into the T-Thread ring from the “D” block. Next, screw the other side of the male-to-male coupler into the front plate of the filter wheel. The T-Thread ring can be seen to have a conical surface the setscrews bear against. Make sure the top of the “cone” is away from the AO module so the setscrews force the ring into the body of the unit, as shown in Figure One. Also, the small set screws tend to have the heads strip out when tightened with Allen head wrenches. You can use 4-40 socket head screws which have a much larger head and can be better tightened. The only problem with them is they do not have the conical point, so some care must be taken to make sure the rings sit flush. When attaching the camera and the AO module the AO entrance port faces away from the ST-7 connectors. Attach the short cable to the ST-7.

- B) Using the Machine Screws (no CFW-8) – Remove the T-Thread “D” Block from the ST-7 by removing the four screws on 1.6 inch (40.64 mm) centers. Disassemble the AO module into the two major pieces by removing the four long screws. Directly couple the AO module to the front of the ST-7 using the four 4-40 x 3/8 pan head screws. Reassemble the AO module, taking care that the cable exits the unit to the left or right (parallel to the long axis of the ST-7 CCD).

After mechanical connection, plug the short cable from the AO module into the ST-7. The cable has a second socket for SBIG’s filter wheel or telescope control connection. Only make or break this cable connection when the ST-7 is unpowered.

Figure One: Attaching Ring to T-Thread “D” Block



4) Attaching to the telescope

It is important to be able to loosen and rotate the AO/ST-7 assembly without disturbing the telescope or changing the focus. For this reason, we have put four short posts on the telescope attachment so that it can be tightened with a minimum of effort. It is important to put grease on the threads of this coupling to prevent it from seizing. Try to avoid getting grease on the seat, since it is friction between this surface and the mating telescope surface that prevents the assembly from rotating relative to the telescope.

Make sure when attaching the assembly to the telescope that the threads are properly aligned. A good way to ensure this alignment is to rotate the attachment backwards until the threads fall into place, which can be easily felt.

The adapter sold with the AO-7 will attach to most commercial Schmidt-Cassegrain telescopes. It can be removed by loosening the set screw that bears against the threads and unscrewing the adapter. The exposed threads in the AO-7 unit are M42 x 0.75 mm pitch and will mate with commercial T-Thread adapters.

Detailed Instructions: Self Guiding with the AO Unit

It is recommended that when you first use this product, as well as any other product we sell, that you set up your telescope and computer in a location that has a view of the sky, but is also reasonably well lit and convenient. In other words, learn how to use the product under conditions such that an hour lost struggling with unfamiliar software is not an hour lost of good, dark sky. Full moon periods are great for initial experimentation!

Camera Initialization: connect the camera up to the computer as before. Power up the camera. Start up the CCDOPS program. Establish communication with the ST-7 using the ESTABLISH LINK command under the CAMERA menu, set your cooling to about 25 degrees below ambient, and you are ready to begin operation.

Focusing and Initialization: To capture images using the AO module, first point the telescope at a bright star (1st magnitude or so), center the star in the eyepiece, and then attach the AO/ST-7 assembly. Power up the ST-7, establish communication, turn on the cooling, and focus the star carefully. When the focus is close, move to a dimmer star (5th or 6th mag) and complete the focus. Next, move the star up to the tracking CCD with your telescope hand control and switch to viewing the tracking CCD. (When running CCDOPS, the tracking CCD is above the imaging CCD when the imaging CCD output is viewed on the screen.) When the star is centered, pull down the AO menu, and select SETUP. Select YES for USE AO FOR GUIDING. Leave the SLEW RATE setting alone for now.

Calibration: In order to track the star the AO unit must be calibrated, much like the ST-7 calibrated the mount. The nice thing about calibrating the AO unit is that the tip-tilt mirror calibration is not a function of declination, nor does it change when you rotate the camera/AO assembly. You only need to calibrate the AO-7 once a night if you don't interface to the telescope! For calibration, the PC commands the AO unit to make a maximum move in both x and y directions to establish the correction rate. The shortest exposure allowed under the CALIBRATION submenu is 0.11 second. Your 5th or 6th magnitude star should be plenty bright, so select CALIBRATE under the AO menu, pick a 0.11 second exposure, and make the active CCD the tracking CCD, and hit enter. The program will take 5 exposures interspersed with full excursion mirror tilts to establish the correction rate. When it is done, it will show the correction speeds. The values for a +X and -X move should be similar, as well as those for a +Y and -Y move. X and Y values should be within 2X of each other. If this is true, you have achieved a successful calibration!

The AO-7 CCDOPS software does allow the telescope to be controlled at the same time as the tip-tilt mirror. The telescope position is bumped in the appropriate direction to maintain the tip-tilt mirror drive levels between 25 and 75% of full scale. The calibration of the telescope drive controls works identically to an ST-7 used alone. Use the CALIBRATE option under the TRACK menu to calibrate the drive, exactly as described in the ST-7/8 manual (the AO-7 tip-tilt mirror is calibrated using the CALIBRATE option under the AO menu). The only difference between the guiding with the AO-7 software and the guiding with the ST-7 standalone, as far as the telescope is concerned, is that the drive is “bumped” in 0.1 second increments in the proper direction. The standalone software made variable, calculated moves to reduce the error to zero. We use the bump technique here in case the AO-7 is being used at slow rate, such as 1 frame a second. For example, if the AO-7 is running at 40 frames per second, it will operate right through a telescope move without interruption. If it is running at one frame per second, the telescope will only be “bumped” once per AO-7 frame. The AO-7 does make a calculated move, so it should always dominate the tracking performance.

The telescope “bump” correction is always there. If the AO-7:ST-7 combination is connected to the telescope, it should be calibrated, because it will be “bumping” the telescope. If you have not calibrated the mount you should disconnect from the telescope so it won’t be moved in the wrong direction. Your computer speaker will make a short beep every time the telescope position is bumped.

Taking the exposure: Once calibrated, select SELF GUIDE under the AO menu. A dialog box will appear, allowing you to set the exposure time for the imaging CCD, the track time (exposure time for the tracking CCD), the track box size, and whether or not you want to dither the exposure. A dithered exposure is where the AO tracks for five seconds, and then deflects and holds still for five seconds, repeating for the length of the imaging CCD exposure. It produces an image with two sets of star images, close together, where the one on the lower left has been corrected with the AO technique and the one on the upper right has not. This image is very useful for determining if the AO is improving the resolution on that night, since the half widths and peak brightnesses of the two image sets can be easily compared.

To take an exposure, input an imaging exposure and tracking time, select a tracking box size, enter NO for dithering, and hit ENTER. We recommend that for initial experimentation, try a 60 second exposure with a tracking time of 0.1 second, and a medium sized track box. The camera will take a short tracking CCD exposure, and display it on the screen. Select the desired guide star by moving the box onto it (it doesn’t need to be exactly centered) and then hit ENTER twice. The box can be moved using the mouse, the cursor keys, or the I,J,K,M keys. The PC will then capture a series of 8 dark exposures of the track box to create an averaged, low noise dark for the tracking CCD, and then begin tracking at the selected speed. The track box containing the star is shown. The mirror is slightly adjusted to place the star on the corner between four pixels initially, so a very stable stellar image produces a box of four equally bright pixels. Hitting the space bar on the PC will begin the imaging CCD exposure.

Optimizing the high speed guiding: a number of parameters can be adjusted to optimize the guiding. The first is the size of the track box. A small track box uses 4 by 4

tracking CCD pixels, a medium 8 by 8, and a large 16x16. A small track box should be used on a really good night when the stellar wander is small. The small track box, since less pixels are viewed, can be read out slightly faster, resulting in a higher frame rate.

If the night is not that good the star may jump out of the track box, causing loss of the guide star. Under these conditions use the medium track box. The large track box is intended for use by professional observatories with telescopes having focal lengths exceeding 10 meters.

The software displays several parameters when the track box is shown. The parameters displayed are the frame rate in corrections per second, the aggressiveness, the slew rate limit, and the power levels for the tip-tilt mirror drive coils. The aggressiveness is a number from 1 to 30 that is a scaled multiplier to apply to the calculated correction. For example, assume that the calibration of the AO finds that a 50 unit change in the tip-tilt mirror position will move the star 1 pixel. If the star is found 1.5 pixels off from the center of the track box the software would normally send a 75 unit move to the AO module to move the star back. This calculated move is multiplied by the aggressiveness divided by 10. If the aggressiveness is set to 10, the commanded move is therefore multiplied by 1. If you find that the stellar motion is too jumpy, reduce the aggressiveness. If it seems sluggish, increase it. What we recommend is that you observe the rms stellar wander in arcseconds displayed on the screen, and try changing the aggressiveness to minimize the wander. If the aggressiveness is too high, up around 20, you may observe the star starting to oscillate. This is undesirable, and the aggressiveness should be reduced slightly. In practice you will probably use values between 5 and 15. **(The aggressiveness can be adjusted during the guiding by hitting the + and - keys)**

After optimizing the aggressiveness, look at the slew rate. The slew rate is a limit in arcseconds per second that can be applied to the movement of the tip-tilt mirror, and it mainly reduces its response at higher frequencies. If the star is jumpy, lowering the slew rate limit may suppress some of the erratic behavior. Since the unit can theoretically only suppress sinusoidal frequencies corresponding to a tenth of the frame rate, a lot of the high speed motion of the star should be ignored since it doesn't correlate from frame to frame. Once again, vary this parameter to find the optimum value. Increase the slew rate to the point where the rms wander starts to go up, and then back off slightly. **(The slew rate can be adjusted by hitting the > and < keys)**

The wander and the slew rate are both in terms of arcseconds. In order for the value in arcseconds to be correct the telescope focal length must be correctly entered into the program. This parameter is input using the TELESCOPE SETUP option under the MISC menu in CCDOPS.

The total brightness of the star is shown in counts when the track box is shown. The tracking time exposure time should be set to yield several hundred counts in the stellar image for reliable tracking. If the guide star is lost during a long exposure the software will terminate the exposure and read out the imaging CCD. You can then take a comparable length dark frame if you wish to keep the data, or restart the exposure.

The software also allows one to turn the mirror correction on and off during the guiding, and also turn the ST-7/8 fan on and off. This is useful for troubleshooting. We have had an occasional user mention that they believed the fan was shaking the telescope, but no one consistently sees this effect. The only way we believe that this can occur is if

the fan frequency coincides with a resonance in the telescope system. Changing the mass distribution on the telescope should fix this problem, if it occurs. **(The fan can be toggled on and off by striking the F key; the mirror correction can be turned on and off using the A key)**

Tips for Optimizing the Improvement seen with the AO-7

The AO-7 allows the guide star image to be viewed during the imaging camera exposure. On many occasions you may find that the guide star motion is clearly suppressed when the AO-7 is on, but yet the imaging CCD image quality is not improved much. This can occur for a variety of reasons. Typically the rms stellar wander is only about half of the stellar halfwidth, so the potential AO-7 improvement is modest at best. If the star image is further blurred out by optical aberration or defocus the improvement is reduced, since the wander was a smaller portion of the blur to begin with. Make sure your focus is good. To determine the limit of your optical quality, take short images (0.1 second) of a bright star, and measure the half width of the star on the best image you collect. The AO-7 will never improve the quality of what you can get on an above average 0.1 second exposure! If you find that the star image is not too good on the best short exposure, suspect optical aberration. If you are using a commercial Schmidt-Cassegrain, collimation is very important!

If you find that the star is less than 2 pixels halfwidth on the average image, then you may need a longer focal length to see a visible improvement.

If the object you are imaging is small and has a decent guide star near it, add a barlow lens to get to the nearer guide star. In general, a guide star twice as close is better than one twice as bright! The spatial correlation of the wander between two stars falls off quite rapidly with angular separation. Putting the guide star near the bottom of the guiding CCD may help somewhat. Another important point is that the atmospheric path over which the two CCDs view the same turbulence increases with less angular separation. An example is useful. With an 8 inch (20 cm) telescope, F/10, and an ST-7, the two CCD centerlines are separated by 10.3 minutes of arc. The centerlines will be 8 inches apart, and therefore viewing different parts of the atmosphere, a mere 220 feet (67 meters) above the telescope. Large telescope have a real advantage in improving this situation.

The best nights will be those with little wind. If the wind is blowing hard, there will be little temporal correlation between successive guide star frames. The predictive value of each image on correcting the error in the next image diminishes to zero. If one has an 8 inch aperture (20 cm), and the wind is blowing at 10 mph (1.6 kph), the CCD will be looking through a completely new cylinder of air every 50 milliseconds. Once again, large telescopes have an advantage in that the wind takes longer to refresh the air in front of the aperture.

In the final analysis, how much improvement can you expect? Our experience is that on most good nights with a C11 (28 cm), F/10 telescope we found a stellar peak brightness improvement of 50%. Our AO-7 guided images had 2.0 arcsecond halfwidth stars, while the normally guided images yielded 2.5 arcsecond stars. Beta testers of our product found similar improvements. The better the seeing, the greater the improvement. We eagerly await results from other regions of the USA and the world. We suspect that

under arc-second quality seeing the peak brightness would double. In our experience, the image is never degraded by the AO when the seeing is better than 3 arcseconds. While this improvement may seem modest, it is important to remember that there is no other way to achieve this improvement short of moving to a better site, such as a mountaintop. Even on the mountaintop, the AO-7 unit will produce a sharper image!

**CCDSharp
Lucy-Richardson
Deconvolution Software**

Operating Manual

11/14/97

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Image Processing with SBIG's CCDSharp Software Package

SBIG's new CCDSharp processing package will sharpen well exposed CCD images with little noise increase or objectionable artifacts, such as bright rings around stars. The software works with all SBIG images except those captured with an ST-4. The program implements the well known Lucy-Richardson algorithm used on Hubble Space Telescope images. It is designed to run on a PC compatible computer using the Windows NT or Windows 95™ operating system. It will not run under DOS or Windows 3.1. It also is very calculation intensive – a high speed Pentium class machine is strongly recommended. An ST-7 frame will process in about 20 minutes on a 133 Mhz Pentium.

Installing the Software

CCDSharp is installed by inserting the CCDSharp floppy into the A drive, and from the Windows 95 START menu selecting RUN, and then entering A:\SETUP.EXE. The installation wizard will guide you through the process much like other Windows programs.

Using the Software

1) Displaying an image: start the program as you would any other Windows 95 program, and load up an image using the FILE menu item. The file operations are similar to other Windows programs. Once the image is on the screen a CONTRAST dialog box appears that allows you to adjust the brightness and contrast to best show the image, as well as invert the image, smooth it, or pick a contrast automatically. You can modify the image display using the little BACK and RANGE box by positioning the mouse over the center of the box, depressing the left mouse button, moving the mouse to select a contrast setting, and then releasing the button. The computer then redraws the image. BACK stands for the background pixel signal value in the image, and RANGE refers to the range of pixel signal counts that you wish to be mapped from black to white. The magnification of the image on the screen can also be adjusted within this dialog box.

Under the VIEW menu you can turn the toolbars on and off. The TOOLBAR is under the menu bar and contains the image processing tools that you can use. The STATUS BAR is the line at the bottom of the screen that reports deconvolution status during the process.

Under the DISPLAY menu you can select either PARAMETERS, which shows the information recorded with the image during acquisition, MODIFICATIONS, which shows the alterations that were performed on the image, such as dark subtraction, and CROSSHAIRS, which brings up a crosshairs dialog box.

Under the UTILITIES menu, you have a choice of flipping the image either vertically or horizontally to produce a view matching the object's orientation in the sky.

The WINDOWS menu gives you control over the display of multiple images on the screen. When multiple images are shown on the screen, the CONTRAST and CROSSHAIRS dialog boxes give information corresponding to the top, or highlighted image (the bar at the top of the image is colored).

The CROSSHAIR dialog box displays the pixel location in the image in pixels from the upper left corner, the value of the pixel, the average value of the square region centered on that pixel, the rms variation in the signal counts over the selected region, and a coarse measure of the stellar full width at the half maximum points. The last value is useful when evaluating seeing, or deconvolution improvement. One can also select the box size to define the region used in these calculations. One word of warning – do not use too small a box size when measuring halfwidths or the reported value will be erroneous, smaller than they actually are. Use a box size that nicely encompasses a bright, but not saturated star. Too big a box will cause little harm!

Clicking on a star with the left mouse button while the Gaussian profile box is selected (in the toolbar) will bring up a stellar profile graph, which shows the radial energy distribution of the light in a star.

Gaussian Profile Icon



The computer first calculates the centroid of the image, and then displays each pixel in the box (box size selected in the CROSSHAIRS dialog) according to its brightness and distance from the centroid. The horizontal axis is in units of arcseconds, based on the focal length shown under PARAMETERS. The telescope parameters cannot be modified within this program, so take care to set them correctly when running CCDOPS. The stellar profile is useful for viewing the quality of the stellar images, and selecting unsaturated stars for use by the deconvolution algorithm. Saturated stars are obvious since the stellar profile is clearly flat-topped.

2) Deconvolving the image: When a celestial field is imaged the CCD records the field blurred by the telescope optics, atmospheric turbulence, and tracking errors. Usually the blur is constant across the field. Mathematically the final image is described as the scene convolved with the system point spread function. Deconvolution is the process of removing the blur and recovering the original scene. In practice the blur can only be partially removed due to the finite signal to noise of the recorded image, and the fact that the recorded image is sampled. However, even a modest improvement can produce striking results!

To deconvolve an image, first load up the image, and verify that all preprocessing is complete. Preprocessing usually includes dark subtraction, flat fielding, and perhaps warm and cold pixel removal. Select the cross icon from the toolbar, and mark one to eight isolated, not saturated, stars with the crosses by positioning the cursor over them and clicking the left mouse button.

Cross Icon



These stars will be used by the routine to determine the point spread function of the system, which is essential in optimizing the deconvolution. If a star is selected inadvertently, click it again to remove the cross mark.

Next, select the rectangle icon from the toolbar, and select the region to be processed.

Rectangle Icon



If the placement of the box is not as desired, simply do it again. If no box is marked the software will process the whole image. When both isolated stars and the selected region have been chosen, click the GO icon button in the toolbar. Select the number of iterations from the dialog box that pops up, and the deconvolution process will begin. The number of iterations that is optimal can best be determined by processing a small portion of the image initially before doing the whole image. The denser the image, the better the signal to noise, the greater the number of iterations that can be used. Too few iterations doesn't provide much improvement, and too many gives the background and unfeatured portions of the image a "bubbly" look. Five iterations is a good starting point for a well exposed deep sky object. Deconvolution can be overdone, so we recommend selecting this parameter conservatively.

When the software deconvolves the image it applies a background limit to the process to minimize the rings around bright stars that plagued early image processing programs. While this limit produces a much more pleasing visual image, it can alter the total counts associated with the star slightly. In mathematical terms, the total counts in the star are not conserved. This means that precision photometric analysis should not be performed on deconvolved images, but rather be restricted to the original images.

After deconvolution, save your images. The improvement wrought by the deconvolution process is best seen by displaying the original image next to the processed image with an identical contrast setting. Viewing some stellar profiles in each image further illustrates the improvement. The red crosses and selection rectangle can be removed from the final displayed image by using the BROOM button in the toolbar.

Broom Icon



SBIG AO-7 PRODUCT NOTE:

11/21/97

During initial production of the AO-7 device it has become apparent that the adjustment of the needle bearing pivot at the center of the mirror is critical. This adjustment is made here at SBIG and the adjustment screw head staked with a dab of epoxy. We have limited experience with the robustness of this adjustment when subjected to the vibrations and shocks encountered during shipping. When you first assemble the unit to the camera and power it up, hold the AO-7 unit so the mirror faces down. If the bearing has loosened the mirror will go into oscillation, and the vibration will be easily felt. It is also audible. All units we ship pass this test before they leave here.

If your unit exhibits a vibration please contact SBIG. If the unit does not vibrate, then you may use the unit with confidence. We thank you for your patience as we gain experience with the stability of this design.