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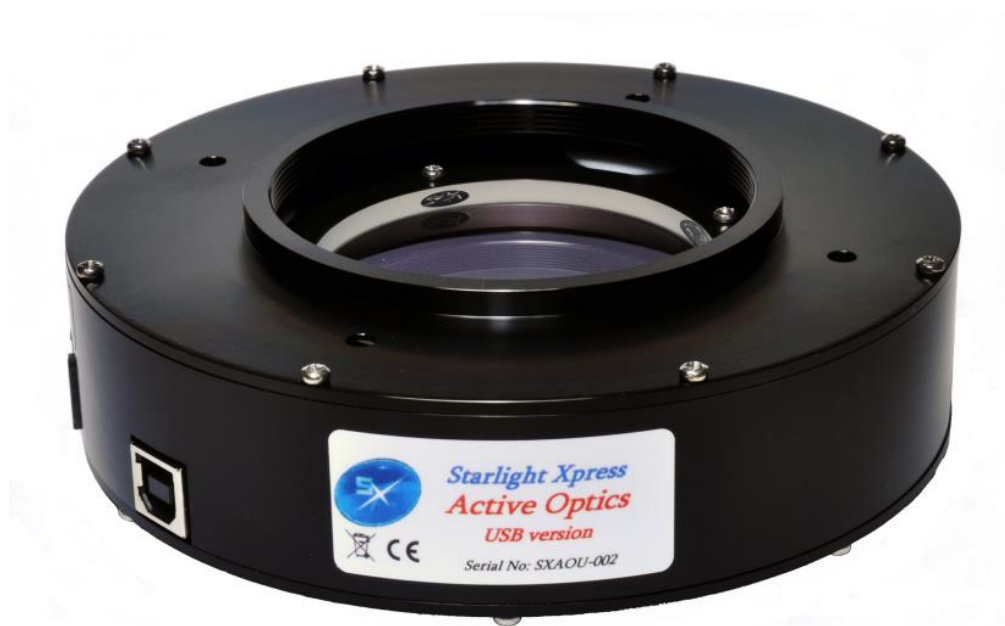
Handbook for the Starlight Xpress SX-AO-USB unit



Thank you for purchasing an SX-AO-USB active optics unit. We hope that you will be very pleased with the performance of this product.

This device should give you much improved guiding accuracy with almost any telescope and mount. Please read the following manual which will explain how the device operates and the best ways in which it can be applied to your optical system.

The SX-AO-USB is an updated and improved version of the AOLP unit that was launched in 2011. It adds an internal USB to serial converter, so that a direct USB connection may be used, and the stepper motor drivers have increased torque capability to reduce the chances of mechanical jamming.



The principle of operation:

The SX-AO-USB device provides an effective method of removing the effects of rapid guiding errors from CCD images. All but the most expensive telescope mounts suffer from rapid gear errors during guiding and such errors are very difficult to correct when the only control method available is to send speed corrections to the drive motors. A device which can adjust the image position by rapidly deviating the optical path, can correct for such errors very quickly and without the associated settling time issues.

The most common method of shifting an image for AO purposes is to use a 'tip-tilt' mirror to reflect the beam through a variable angle. This works well, but deviates the optical path through 90 degrees and takes up a considerable back focal distance. Its motion sensitivity is also affected by the distance between the mirror and the CCD. A 'straight through' device is more convenient and optically shorter, so the SX unit was designed with this in mind. A secondary advantage of the straight through design is that it is possible to construct a system that has a well defined optical deviation for a defined input signal. This means that the 'sensitivity' of the system in pixels shift per input step is essentially constant and is independent of the optical system used and the distance between the CCD and AO.

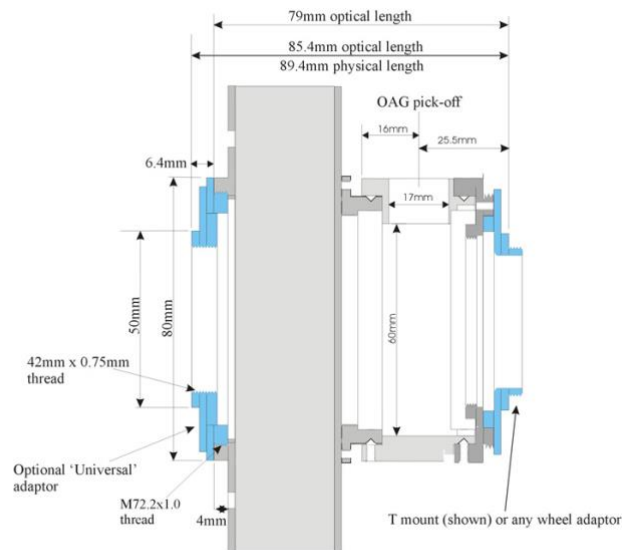
The AO element is a Multi-coated AR bloomed plane-parallel optical window with a thickness of 13mm and a diameter of 60mm. This element can be tilted by up to approximately +/- 3 degrees, by rotating four small stepper motors at the periphery of the aluminium carrier plate. Converging light from the telescope objective lens or mirror, passes through the window on its way to the CCD chip, but is essentially unaffected when the window is perpendicular to the beam. However, when the window is tilted, the converging beam is displaced by an amount which can be defined as approximately 0.075mm per 1 degree of tilt. The maximum image deviation is therefore approximately +/- 0.15mm in both the X and Y planes. This corresponds to about +/- 23 pixels on the CCD of an SXV-H9 camera.

The AO unit is usually controlled by serial data from an RS232 port. This port can be one of those provided on many PCs, or the serial interface of an SXV camera (if supported by the software package in use). A USB to serial adaptor can also be used on a PC without native serial ports. The serial data input of the AO is an RJ11 socket and so a lead with an RJ11 to 9 pin 'D' style socket is provided to enable connection to a standard serial port. The computer port should be set to 9600B, 8 bits data, 1 stop bit, no parity.

A typical application of the AO unit for off-axis guiding:

The following diagram shows how the AO unit may be used with the optional off-axis guider (OAG) and an SX CCD camera. This is likely to be the normal configuration for most imagers, as it offers accurate guiding which is free of flexure and mirror shift problems. The OAG consists of a short aluminium barrel with a pick-off prism which feeds light to a Lodestar, mounted at the end of a short extension tube. The guide camera position is designed to be close to the correct focal distance when a Starlight Xpress camera is mounted on the main optical output of the OAG and brought into focus. Any small errors may be corrected by loosening the set screws in the threaded collar and sliding the camera into the correct position.

The OAG is attached to the AO unit by three set screws which engage with a grooved ring at the output of the AO assembly. Please note that the guider barrel should be oriented so that it projects along the line which joins the North and South motors. When located properly, the two RJ11 sockets on the AO will be at the bottom of the unit, diametrically opposite to the guider barrel. The long axis of the CCD in the guide camera should be oriented so that it is parallel to the AO backplate. This can be seen in the picture at the front of this handbook, as indicated by the orientation of the guide camera socket.



The imaging camera is attached to the rear of the OAG, using a suitable adaptor ring. Two types are supplied – one with a 'T' thread for the PRO 825/674/694/814/16/25C/26C series cameras and one universal adaptor with a M72 thread for the H35 and H36. The orientation of the camera is adjusted by loosening the three set screws and rotating the ring into the required position. As the camera is not involved with collecting guiding information, it may be set at any angle. However, the pick off prism may cause shadowing if the long axis of a large chip is set in the vertical plane.

Both the AO unit and the OAG have recesses which will take a 48mm filter. When using the OAG, it is an advantage to use the recess inside the camera mounting ring, so that the guide camera sensitivity is not compromised by any filters that you may add. This is especially useful if you image with narrow band filters, such as H-alpha. A light pollution rejection filter, such as an IDAS P1 or P2 might be best added at the output of the AO unit (before the OAG), where it will improve the guide star contrast, as well as

improving your camera images. Note that the recesses are not threaded and so you should be careful that a filter does not fall out and get damaged when dismantling the unit.

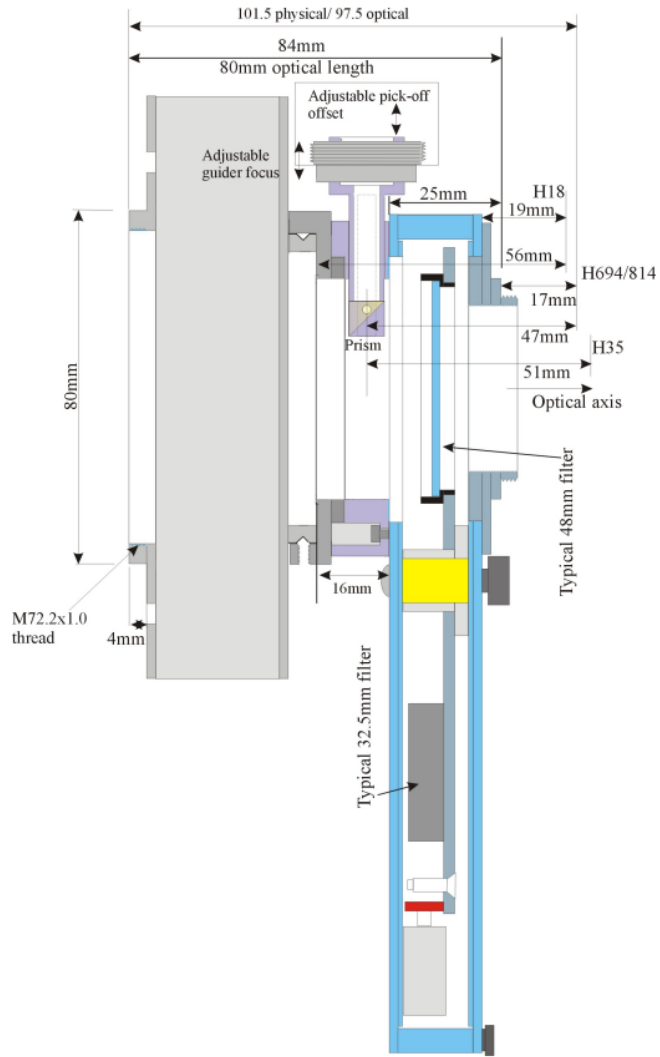
Connecting up the AO electronics for guiding with a Lodestar X2/PRO:

The LAO version 2 has an additional input port in the form of a USB type B socket. This emulates an external USB to serial converter and so you do not need an additional converter with version 2. Just connect a USB cable from your computer and the LAO will be recognised as an FTDI serial device. Most versions of Windows will include FTDI drivers, but they can be downloaded from the FTDI web site, if required.

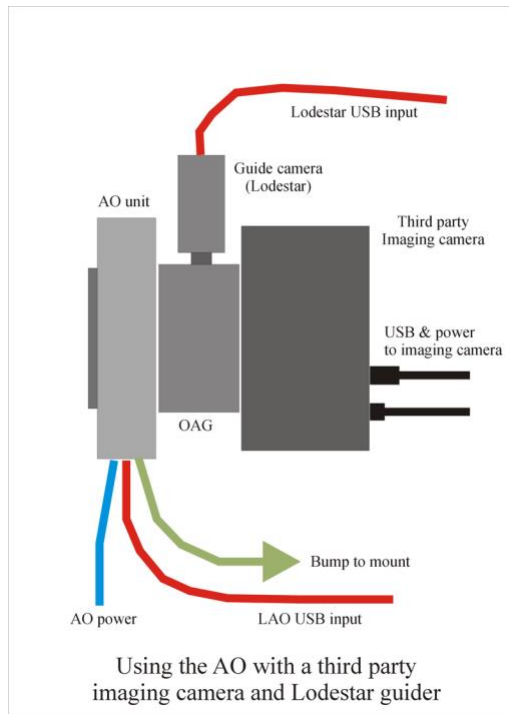
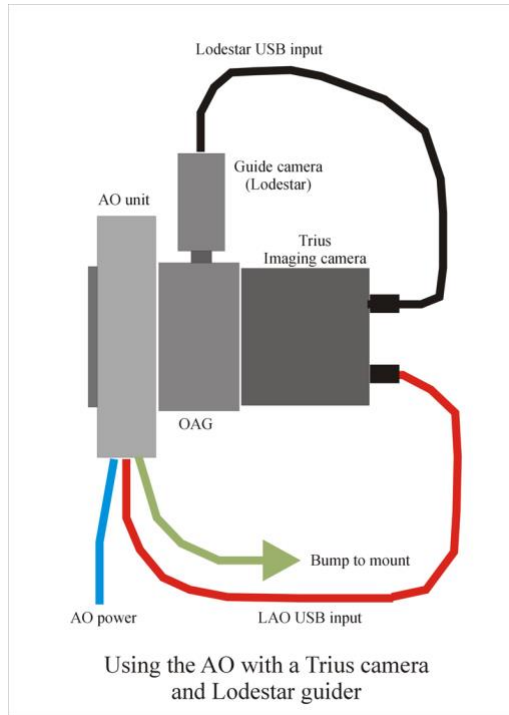
You can still use the serial input of the AO unit, if this is preferred, but this socket is no longer needed for most systems. Both the USB and the serial socket work with the current software, as both will show up as serial COM ports on your computer.

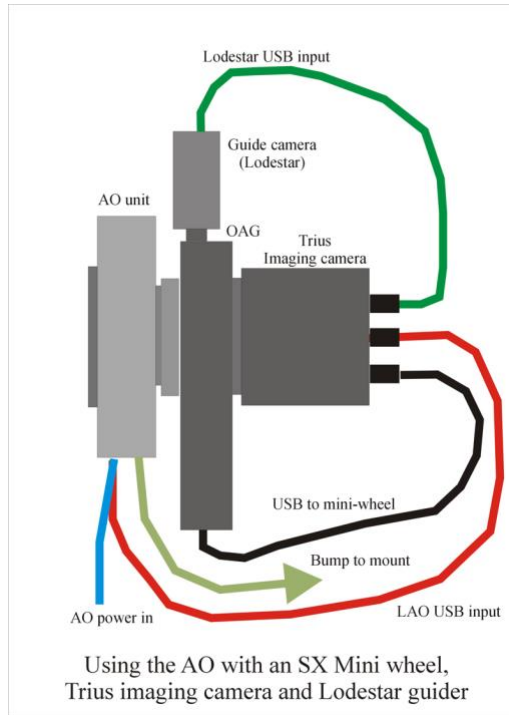
- 1) Connect the USB cable (supplied) into the AO unit USB input socket. If you have a 'Trius' camera, then this can be connected to one of the USB ports on the camera. Alternatively, connect it to a USB socket on your computer.
- 2) Connect the RJ11 to guider port cable (supplied) from the AO output to the guider input on the mount. This cable is not essential, but it allows the software to 'bump' the mount when the errors become too large for the AO unit. Most lower-cost mount users will find it necessary for long exposure times.
- 3) Connect the Lodestar or Superstar guide camera to the USB socket on the PC, or on the back of your Trius camera.
- 4) Connect the AO power lead to the power supply block.

This basic configuration is suitable for use with third party imaging cameras. Most software does require the use of an SX guide camera, but the imaging camera can be almost any type, as it is not involved with control of the AO unit. Some cameras, such as the QSI range, often come with a built-in OAG assembly, and we can supply the SX-AO-USB unit without an OAG, for use with such cameras. This reduces the cost somewhat. You can also use a similar configuration if you have an SX Mini/Midi Filter wheel or a standard wheel with a slim OAG attached. Here is a general diagram of the AO attached to a slim OAG + wheel:

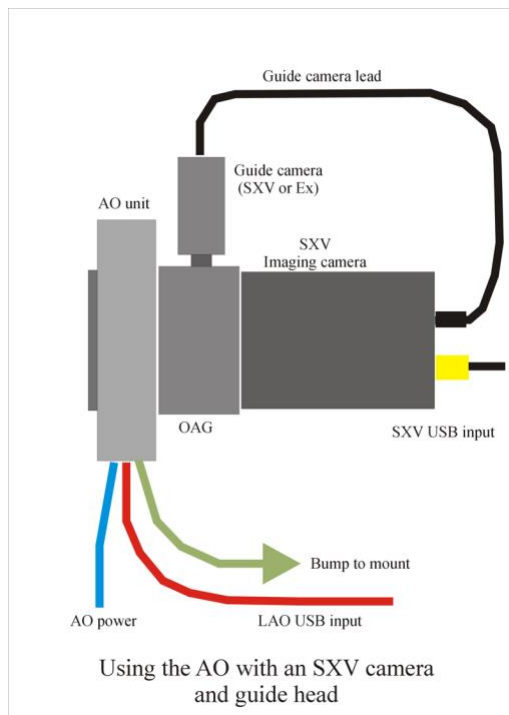


The following drawings indicate some of the options for connecting the SX-AO-USB to the guide camera and computer. The first one will be the most commonly used configuration, if you have a Lodestar X2/PRO and Trius series camera.





Owners of older SXV cameras might use the following option.



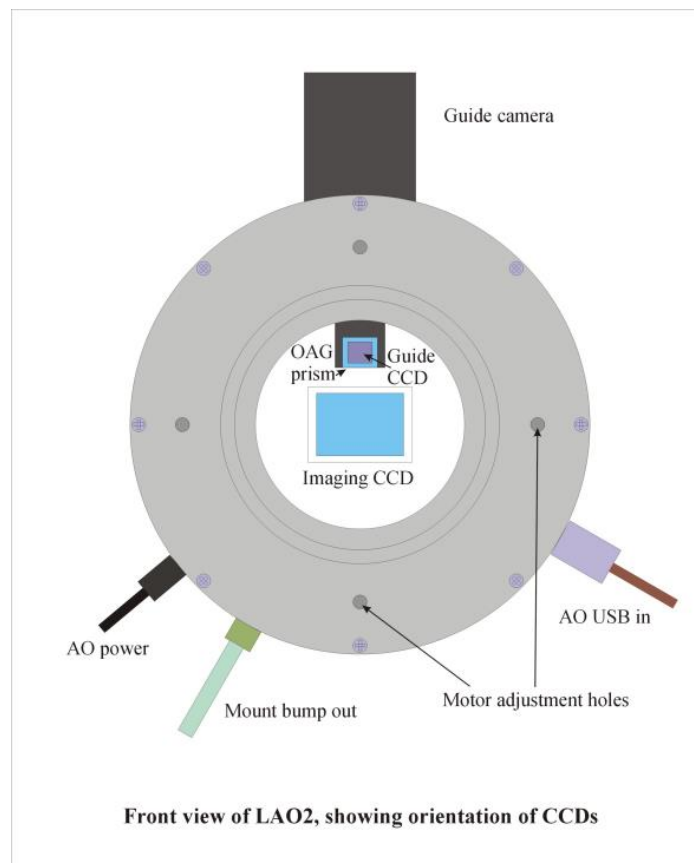
Operating the SX-AO-USB with a Lodestar, Lodestar X2 or Lodestar PRO USB2 guide camera:

The SX 'Lodestar' guide cameras may be used to control the AO unit, especially if you wish to use a third party imaging camera. Many other guiders are too large to fit and some software (e.g. Maxim DL) will not operate the AO unless an SX guide camera is used.

It is best to use USB control of the LAO unit, as shown, and you can use PHD2 software to provide the LAO guiding corrections. Alternatively, AstroArt or MaximDL may be used for both guider and main camera control.

General pointers:

When the AO unit is first attached to the telescope, it is best to arrange the off-axis guide camera, so that the East – West AO axis is parallel to the long axis of the guide image. This is easily done by viewing the guider or camera chip through the front of the AO window. Hold the AO unit so that the two RJ11 sockets are at the bottom and ensure that the guider chip is visible as a horizontal rectangle as seen in the off-axis prism.



The SXV-AO can execute an image position correction in a few milliseconds, but the effective correction rate is limited by the brightness of the guide star and the download speed of the guide camera image. For best results with a poor telescope mount, you need to choose as bright a star as possible and use a small guide window. Binning the guide camera image will also help.

The orientation of the AO assembly is normally arranged so that the East-West RA drift direction is along the long axis of the guider chip. However, there is no reason to conform to this, if the mount corrections can cope with the non-standard orientation. In this case, you can rotate the entire unit about the optical axis for optimising the image orientation or for finding a suitable guide star, but you will need to calibrate the system for each change of angle.

When attaching the AO unit to a T thread adaptor, be careful to ensure that the male thread does not project deeply into the AO body. Any projection can interfere with the movement of the image displacer and may jam the unit. If the thread is too long, add a card or plastic washer between the adaptor and AO front plate.

During extreme movement of the displacer, the motors may encounter excessive friction and fail to start. The 'Calibrate' command will normally overcome this, as it switches to a much lower speed, high-torque stepping rate after 5 seconds of failure to move. However, in the worst case, you can rotate the motors manually by inserting a small screwdriver through the holes in the front plate. Be careful not to rotate them too far, as only 4 turns is required to move the drive through its entire range. Adjust each motor until its shaft rotates as freely as possible before using the 'centre' command again. Our 'AO Utility' has an unjam option called 'Recovery' and this might be useful if the jam will not free when using 'Calibrate'

Using the AO system:

The following instructions are based on the software provided by Starlight Xpress and will be different for other control programs. Please read the relevant help files if you are using AstroArt or Maxim DL. I also assume that you are using the off-axis guider and serial control of the AO.

All SX camera software includes an option to use the AO unit. You do not need extra software to operate the AO, if you already have an SX camera installed.

Open the camera software and check that it recognises the presence of your main camera. Now open the 'Set program defaults' menu (under 'File') and check that the serial control settings are appropriate to your system. For instance, if you are using a serial port on the PC to drive the AO unit, check the 'AO unit available' check box and then set the PC COM port number. The 'Select half rate' box is to slow down the mount corrections that will occur if the AO unit exceeds its useful range. You may find this useful if you have a mount with rather erratic drives, such as an SCT on a fork mount. Now save the program defaults and return to the main program window.

Select the main camera icon (4 from the left) and use a short exposure time to see if there are any stars visible. Adjust the main telescope focus until you have a well focused star field in the main camera image.

Now click on the 'Autoguider' icon (5 from the left) and you will see the guider window and control panel. Select a 1 second exposure time and move the 'Stretch image' slider to 'Maximum'. Press the 'Start' button and you should see a guide camera image appear in the image window. At this point, there may be no stars visible, as the guider focusing might be seriously in error. If no stars are seen, try increasing the guide exposure to 3 or more seconds until you can detect some stars. Now use the Allen key provided to loosen the two set screws in the guider retaining collar and then gently slide the guider backwards and forwards until a sharp star image is seen. Note that the image might be distorted by the telescope optics, as it is well 'off axis'. Once focused, re-lock the collar in place, making sure that the guide camera

orientation is with the input plug parallel to the AO backplate. Briefly blip one of the RA buttons on your telescope handset and ensure that the stars drift parallel to the long axis of the guider window – if not, rotate the entire AO assembly about the telescope axis until they do so. Now check that the AO mode is set for 'serial' and make sure that you have selected the correct AO control port if you are using the splitter box (ser1 or ser2). Press the 'Use default' to temporarily set the guiding speed of the AO. You now have the system ready to test, so proceed as follows:

Find an interesting object or starfield to image and adjust the 'scope until a convenient guide star can be seen in the guider field. Ideally, the star should be easily seen in an exposure of only 0.1 seconds and, if necessary, binning may be used to gain sensitivity. Once the guide star is identified, press the 'Centralise AO' button and watch the star image – it should cycle through a cross shaped figure and then settle after about 2 seconds. Now press 'Select guide star' and click on the star which you think best suited to act as your guide reference (bright and isolated). You can now press the 'Train' button and the AO will cycle automatically while measuring the system sensitivity. If the training cycle is successful, new rate values will be generated, although they will probably be much the same as the default values. If the calibration fails, it will probably be due to one or both of the AO direction settings being wrong. The defaults in the software are for a guide camera mounted as shown in the frontispiece picture of the AO assembly, with its indicator LED towards the camera end of the AO barrel. You can either rotate the guide camera to this position, or try swapping the AO up/down and left/right check box settings. Once you have the directions set and the motion rates determined, calibration of the AO will not be necessary in future sessions as it is a constant factor for all 'scopes. Only one other setting is still necessary. This is the calibration of the mount for 'mount bumps' during your guiding session. Although the AO can take care of the small and rapid guiding errors, there will be steady drifts of the telescope drive which will slowly shift the AO to the limits of its motion range. To combat this effect, we need to send occasional corrections to the mount ('bumps') in order that the AO remains near to the centre of its operating range. A relatively easy way in which to determine the settings required is to set the AO guiding on your selected guide star (press 'Start guiding') and then use the hand controller to move the star slightly East or West until the data boxes on the guider image start to show offset values of more than 50 steps. At this point you will see the text 'Move mount' appear, along with a direction indication. If the result is that the AO error falls rapidly below 50 steps, then the mount direction and rate is about right, but any sign that the error is rapidly increasing will show that the 'Swap e/w' or n/s direction is incorrect. Stop the guiding, reverse the 'Swap' box for that direction and try guiding again. Once you have both directions set correctly, you can experiment with the mount speed (pixels per second) settings to optimise the amount of correction applied – ideally you want the mount correction to move the AO back to the 'zero offset' position, but there is a large tolerance on this.

You are now ready to take an AO guided image.

Re-centralise the AO unit, select your guide star and then press 'Start guiding'. Once the guide star image is stable, press the main camera icon and set your image exposure time in that dialog box. Now press 'Take photo' and wait for the result to appear!

Updating the AO firmware:

From time to time, improved versions of the AO firmware will become available and will be posted on the Starlight Xpress web site. The AO unit is provided with a means of updating its internal firmware via the PC serial port. You will need the serial cable as provided with the AO unit and this should be connected between the AO unit input socket and the serial port of your PC. The updating procedure also requires the power supply to be connected to the AO.

- 1) Download the latest version of the updater software from <http://www.sxccd.com/support/resources>
- 2) Uninstall any previous version of AO Updater using the Add/Remove Programs in the Control Panel.
- 3) Install the AO Updater software by executing the 'Setup.exe' file.
- 4) Connect the AO to a PC USB port.
- 5) Power up the AO unit.
- 6) Start the AOUpdater program by clicking on the screen icon.
- 7) Use the Settings menu to select a valid COM port.
- 8) Press the Handshake button and ensure that a valid version number and TX/RX values appear in the box at the bottom of the window.
- 9) Press the Update button and OPEN the activovxx.sxu file (xxx = version number). The default directory for the hex file is C:\Program Files\Starlight Xpress\AOUpdater\Hex\
- 10) Wait for about 60 seconds to complete the programming. The 'Petrol gauge' bar will show the state of progress. **Do not open or switch to any other applications while programming is taking place!**
- 11) Once successfully updated, exit the AO Updater program and turn the power to the AO OFF. Wait 5 seconds then switch the power back ON. The AO is now ready for use and should show the new version number if you check in the AO utility.

Useful programming info.**The Active optics command set.**

This information is provided for users who wish to write their own control programs.

The serial mode command list

Char 1	Char 2	Char 3	Char 4	Char 5	Char 6	Char 7	Result	Return
K							Find Centre	K
G	N	0	0	0	0	1	AO 1 step North	G or L (hit limit)
G	S	0	0	0	0	1	AO 1 step South	G or L (hit limit)
G	T	0	0	0	0	1	AO 1 step East	G or L (hit limit)
G	W	0	0	0	0	1	AO 1 step West	G or L (hit limit)
M	N	0	0	0	0	1	Mount 1 step N	M
M	S	0	0	0	0	1	Mount 1 step S	M
M	T	0	0	0	0	1	Mount 1 step E	M
M	W	0	0	0	0	1	Mount 1 step W	M
R							Centre at low speed (unjam)	K
L							Get Limit switch status	Character with an ASCII value between 0x30 and 0x3F
V							Code version number	V + 3 digits
X							Handshake	Y
U							Update firmware	U = Success, Z = Fail

Parallel mode - the pulse width input specification

In pulse width mode, the input is a pulse width encoded signal with four direction lines and a common ground, similar to that used for telescope mount control. However, the pulse width per motor step is greatly reduced, so as to minimise the response time. This mode uses the RJ12 'Serial' port of the AO and cannot operate via the USB input. The minimum control pulse width is 10mS, which steps by 1 step in the appropriate direction. Longer pulses follow in a linear progression, increasing by 1 motor step for each 10mS incremental increase in pulse length. Note that only ONE input can be low at any one time, otherwise other control functions may be inadvertently initiated.

Various different functions can be triggered by 'abnormal' input pulse patterns. The most useful of these is the 'centre' mode, which should be used before beginning any guiding sequence. In this, the inputs are all taken low and then simultaneously released. The AO unit will then rapidly cycle between its limit switches and adjust the window to be centred in the dynamic range and normal to the incoming light. Other functions include the transmission of commands through the AO system to the mount (for 'bumping' the mount position) and various setup modes, mostly used for calibration during assembly. Please note that mount commands in serial mode can take place while further AO commands are being received and acted upon. This allows the AO unit to follow the mount correction and 'back off' the AO error without trailing the image. This is not available in parallel mode at the present time, but may be added later. Be careful not to send multiple commands without allowing time for the previous one to complete.

The command list for parallel mode

Please note that negative logic is used for all commands – an ‘active’ input is pulled down to the ground (0v) rail. The directions of movement are based on an inverted image and with the AO unit arranged with its North-South axis at 90 degrees to the Declination axis.

Guiding functions				
East	North	South	West	Function
0	0	0	0	Find Centre / Switch from serial to parallel mode
1	1	1	0	AO West
1	1	0	1	AO South
1	0	1	1	AO North
0	1	1	1	AO East
0	0	0	1	Mount West
0	0	1	0	Mount South
0	1	0	0	Mount North
1	0	0	0	Mount East
0	0	1	1	Force low motor speed
1	1	0	0	Enter set up mode
Set up mode functions				
1	1	1	0	West motor forward
1	1	0	1	South motor forward
1	0	1	1	North motor forward
0	1	1	1	East motor forward
1	0	1	0	West motor back
1	0	0	1	South motor back
0	1	1	0	North motor back
0	1	0	1	East motor back
0	0	1	1	All motors drive back
0	0	0	0	All motors drive forward
0	0	0	1	Enable serial mode and exit set up mode
1	1	0	0	Exit set up mode

Dear Observer,

Thank you for purchasing a Starlight Xpress product. We are confident that you will gain a great deal of satisfaction from this equipment, but please read carefully the instruction manual, supplied with your product, to ensure that you achieve the best performance that it is capable of providing.

As with most sophisticated equipment a certain amount of routine maintenance is necessary to keep the equipment operating at its optimum performance. The maintenance has been kept to a minimum, and is fully described in the manual.

Starlight Xpress Ltd. warrants all Starlight Xpress products to be free from defects in workmanship and materials, under normal operating use and conditions, for a period of two (2) years following the original invoice date. This limited warranty does not cover failures due to abuse, accidental damage, or when repairs have been made or attempted by anyone other than Starlight Xpress. A defective product meeting the warranty conditions set forth herein will be replaced or repaired at no charge.

Replacement or Repair

If a product arrived with the user and is immediately faulty, Starlight Xpress, if contacted within 30 days of purchase, and with evidence proving a defective product, will offer a free replacement, subject to the verification of the defect or malfunction. The customer shall return the complete product package, including all parts, accessories, and manuals, etc. for a replacement.

Exclusions:

1. The equipment shall only be used for normal purposes described in the standard operating instructions, and within the relevant safety standards of the country where the equipment is used.
2. External mechanical force (i.e. dropped, scratched sensor window, damaged metalwork, a broken or damaged USB port, power supply connector etc.)
3. Water or moisture inside the product due to improper storage or use.
4. The guarantee shall not apply to the equipment damaged by flood, fire, earthquake, lighting strike etc. (Force majeure)
5. Disassembling, repairing, or refurbishment made or attempted by anyone other than Starlight Xpress without prior authorisation.
6. This guarantee shall not apply to components that have a naturally limited life.
7. Starlight Xpress' decision in all matters is final, and any faulty component which has been replaced will become the property of Starlight Xpress Ltd.

This Limited Warranty is NOT transferable and applies ONLY to direct customers who purchase product from Starlight Xpress or/and its authorized dealers.

Please don't forget to register your SX Product at <https://www.sxccd.com/support/warranty-policy-and-registration/> to initiate your warranty

For further info. or advice, please contact us:

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