

## INSTRUCTION MANUAL

# Orion® SteadyStar™ Adaptive Optics Guider

#53076



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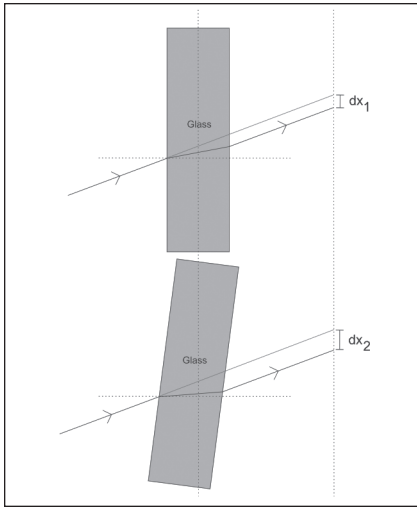
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# Table of Contents

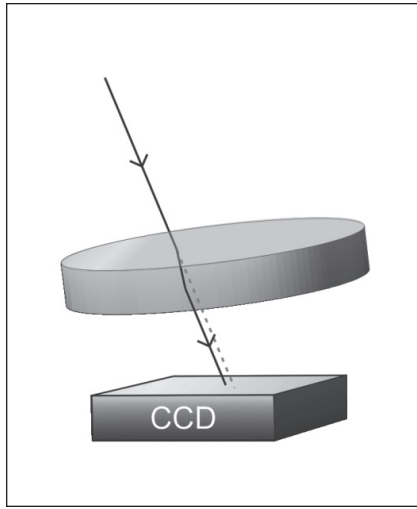
<b>1. Introduction</b> .....	<b>4</b>
1.1. What is the SteadyStar? .....	4
1.2. How Does it Work? .....	4
1.3. The SteadyStar Highlights .....	5
<i>Optical Highlights</i> .....	5
<i>Mechanical Highlights</i> .....	6
<i>Electronics Highlights</i> .....	6
<i>Software Highlights</i> .....	6
<b>2. Getting Started</b> .....	<b>7</b>
2.1. Parts List .....	7
2.2. System Requirements .....	8
<i>Telescope and Backfocus Requirements</i> .....	8
<i>Mount</i> .....	8
<i>Autoguider</i> .....	8
<i>Main Camera</i> .....	9
<i>Computer</i> .....	9
<i>Power</i> .....	9
2.3. Software and Driver Installation .....	10
<i>Prerequisites</i> .....	10
<i>Software Installation</i> .....	10
<i>A Note About StarShoot AutoGuider 32bit and 64bit Operation</i> .....	10
<i>The SteadyStar Driver</i> .....	12
2.4. Hardware Setup .....	13
<i>Inputs / Outputs</i> .....	13
<i>Off-Axis Guider (OAG)</i> .....	13
<i>Adapters and Backfocus</i> .....	14
2.5. Attaching Your Imager and Autoguider to the SteadyStar .....	18
2.6. Attaching the SteadyStar to Your Telescope .....	20
<b>3. Software Walk-Through</b> .....	<b>21</b>
3.1. How the Software is Structured .....	21
3.2. The Setup Tab .....	21
<i>Mount Setup</i> .....	23
3.3. The AO Control Pad .....	23
3.4. The Locate Tab .....	24
<i>Setting the Exposure Parameters</i> .....	24
<i>Search for the Guide Star on the Covered Sky Area</i> .....	25
<i>Select a Proper Star Envelope Size</i> .....	25
<i>Calibrate the AO Unit</i> .....	26
<i>How to Calibrate the Mount</i> .....	27
<i>Create a Dark Frame</i> .....	28
<i>Create a Hot Pixel Map</i> .....	28

3.5. The Guide Tab .....	28
<i>Dither</i> .....	30
<i>The Tracking Error Graph</i> .....	30
<i>Saving and Loading Calibration Sets</i> .....	31
<b>4. Quick Start Guide</b> .....	<b>32</b>
<b>5. Advanced Topics</b> .....	<b>33</b>
5.1. Why Fast Guiding? .....	33
5.2. How to Achieve High Number of Corrections Per Second .....	33
<i>Camera Characteristics and Exposure Time</i> .....	34
<i>Exposure Time vs. Guide Star Brightness</i> .....	34
<i>Computer</i> .....	35
<i>Summary</i> .....	35
5.3. Finding a Suitable Guide Star .....	35
<i>Determining the Focal Length</i> .....	35
<i>Rotating</i> .....	38
5.4. What to Expect from AO Guiding .....	38
<i>Mount</i> .....	38
<i>Focal Length</i> .....	39
<i>Aperture</i> .....	39
<i>Guide Rate</i> .....	39
<i>Seeing</i> .....	39
5.5. Dithering .....	40
5.6. Integration with MaxIm DL for Automatic Dithering .....	40
5.7. Mount Guiding .....	41
5.8. Using a Different Optical Window .....	43
<b>6. Troubleshooting</b> .....	<b>43</b>
6.1. I Can't Find a Suitable Guide Star .....	43
<i>Having a FOV Indicator With a Correctly Calculated Focal Length</i> .....	43
<i>Having Set the Correct Angle Between the Two CCDs</i> .....	43
<i>Having a Good Measure of the Angle Between the SteadyStar and the Telescope</i> .....	43
6.2. Guiding is Very Unstable .....	44
6.3. The Star Rapidly Drifts When It Is Near the SteadyStar's Limits .....	45
6.4. AO Calibration Fails .....	45
6.5. Mount Calibration Fails .....	45
6.6. The SteadyStar Seems to Be Jammed .....	46
<b>7. Care and Maintenance</b> .....	<b>48</b>
<b>8. Messier Catalog Guide Star Suggestions</b> .....	<b>48</b>

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**Figure 1.** Light refraction through a flat optical window.



**Figure 2.** Placing the optical surface in the light path.

*Congratulations on your purchase of the Orion SteadyStar Adaptive Optics Guider.* The SteadyStar takes your astro-imaging to the next level! The most accurate guiding at high resolution is more achievable by autoguiding with adaptive optics (sometimes called active optics) which is significantly faster and more responsive than traditional autoguiding. This method of guiding, while different than the adaptive optics used in professional observatories, delivers sharper astro-images with smaller and rounder stars.

## 1. Introduction

### 1.1. What is the SteadyStar?

The SteadyStar is an innovative active optics unit that allows an exceptionally high guiding accuracy for high resolution imaging.

The SteadyStar works with virtually any telescope and mount combination.

### 1.2. How Does it Work?

The SteadyStar works similar to a traditional auto guiding system. A guide camera follows a guide star, calculates the telescope's pointing error and issues a command to correct that error.

The main difference is that instead of moving the mount to correct the error, the SteadyStar moves a small optical window, deflecting light and as a result correcting the guide error.

***It is easier and faster to move a 2 ounce lens than to move a 30 pound telescope.***

The SteadyStar makes use of a well known optical phenomenon, *refraction*. When light changes from a medium to another, its velocity and angle change, depending on incident angle and composition of the two mediums.

Figure 1 shows how light is refracted through a flat optical window. The red beam shows the light path if there was no optical window.

By tilting the optical window, a small vertical deviation of the light is obtained ( $dx_2$  is bigger than  $dx_1$ ).

A small flat optical element is placed in the light path between the telescope and the CCD (see Figure 2).

Tilting the optical window in x and y axis makes it possible to shift the light on both axis.

Because the optical window is flat, there is virtually no image distortion, only image shift. The optical window maintains a diffraction limited system.

Four high speed stepper motors are used to precisely adjust the tilt of the optical window. And because no gears are used, there is virtually no backlash. This allows much faster and more precise corrections than any mount is capable of.

Each step increment deviates the light beam by approximately 2.14 $\mu$ m.

The maximum correction is +/- 214  $\mu$ m. As an example, this is equivalent to a correction of +/- 27 pixels on a SS Pro camera (7.8  $\mu$ m pixel size) and +/-33 pixels for the SSDSMI III (6.45  $\mu$ m pixel size).

If, for example, a sampling of 1 pixel /arc- second is used, it means that it will compensate a maximum of +/-27 arc-seconds, which means it will probably correct for all of the mount's periodic error without issuing a mount correction.

## 1.3. The SteadyStar Highlights

### Optical Highlights

- 1.9" (48mm) clear optical path (a 40mm optical window is supplied)
- Allows different optical windows, up to 2" (50mm) in diameter (contact Orion customer service for details)
- Adds just 1.68" (42.5mm) of mechanical back focus, which is equivalent to 1.57" (40mm) optical back focus
- Integrated Off Axis Guider (OAG) placed as close as possible to the optical window
- Integrated OAG allows adjustment of prism "Z" axis position and tilt

## Mechanical Highlights

- CNC machined aluminium body with anodized finish
- Lightweight (less than 18.7oz, 530g)
- High speed tilt (**1.25ms per step**, 60 degrees/second)
- Maximum tilt corrections of +/- 4.4°. Enough for most PE compensation
- Extremely small backlash (< 1 motor step)
- Operation temperature: between -35°C and approx.+55°C (-31°F – 131°F)

## Electronics Highlights

- Intelligent power management. The unit only draws the needed power when it is moving
- Idle consumption of around 20mA
- Integrated temperature sensor
- Controllable Internal temperature (dew prevention and operation in extreme conditions)
- Works with field batteries (10V – 18V power supply)
- External expansion port
- USB connection
- Firmware upgrades

## Software Highlights

- No driver is required, the SteadyStar connects as a Human Interface Device (HID)
- Standalone SteadyStar guiding software provided
- Works with several different guide cameras (see section 2.2, “System Requirements – Autoguider”)
- Special optimization used to work with Orion SSAG guide camera, improved SNR
- Less than 1ms processing speed per frame
- Guide rates up to **40Hz** (faster guide rates are possible with a very fast computer)
- AO and mount calibration do *not* require special axis alignments between guide camera, optical window axis and telescope
- Windows XP, Vista, and 7 supported in both 32-bit and 64-bit
- MaxIm DL integration for dithering

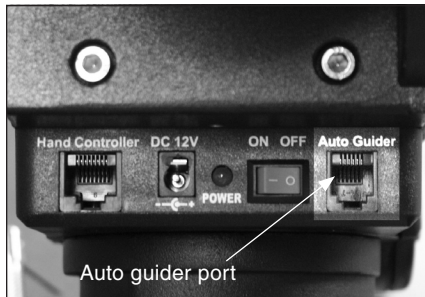


**Figure 3.** Parts list

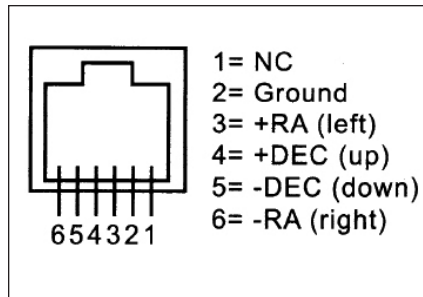
## 2. Getting Started

### 2.1. Parts List (Figure 3)

- The SteadyStar Adaptive Optics Guider with built-in Off Axis Guider
- 2" nosepiece
- Fine focus guiding adapter
- 48mm thread to male T-thread adapter and rotation lock ring (for back side)
- 48mm thread to female T-thread adapter (for front side)
- T-adaptor Extensions
  - 30mm
  - 17mm
  - 7mm
- 10' USB Cable
- 12' 12VDC Socket Cable
- 10' Autoguider Cable
- Hex key
- Carrying case
- Software CD



**Figure 4.1.** The SteadyStar requires motorized equatorial mount with an autoguider port.



**Figure 4.2.** This is the autoguider pin diagram for the SteadyStar and “ST-4” compatible mounts.

## 2.2. System Requirements

### Telescope and Backfocus Requirements

The SteadyStar can be used with most telescopes compatible with 2" format eyepieces. The unit is simply inserted into a focuser in the same way as a standard eyepiece. The unit is also compatible with 1.25" focusers that include camera T-threads, although the OAG prism might not fall on the light cone.

*Caution: Be sure to always firmly tighten the thumbscrew(s) that secure the SteadyStar in the telescope focuser, or it could fall out and onto the ground!*

The SteadyStar's advantage is best seen with long focal length telescopes, as the guiding improvements will be more evident. However, any telescope, regardless of the focal length, will benefit from the SteadyStar's improved guiding, especially when used on mounts with significant periodic error.

**Newtonian telescopes and other types with a short backfocus might not be suitable as the SteadyStar requires a minimum of 3.6in – 4.2in (92 – 105 mm) of backfocus, depending on the image train (see Figure 10).**

### Mount

Deep sky imaging with the SteadyStar requires an equatorial mount with a right ascension (R.A.) motor drive. The goal for your mount is to seamlessly track the apparent movement of the sky as the Earth rotates. The SteadyStar will correct all of the mechanical errors of the mount's tracking. It is recommended that the mount has a ST-4 compatible autoguider input port, as featured in the Atlas and Sirius EQ-G mounts (Figure 4.1). Refer to the pinout diagram in Figure 4.2 to determine if your mount is compatible.

### Autoguider

The SteadyStar requires an autoguider capable of fast framerates to take full advantage of fast guiding. A monochrome autoguider is also recommended for maximum sensitivity.

As of December 2009, the following autoguider cameras are supported:

- Orion StarShoot AutoGuider
- Starlight Xpress Lodestar
- Any ASCOM capable camera with fast readout
- Any video-capable camera what supports DirectShow, including:
  - Imaging Source DMK cameras
  - Philips TOUCAM and SPC900, or similar web cameras
  - Luminera cameras

Please check <http://www.OrionTelescopes.com> to check for the most up-to-date camera compatibility and drivers.

*Note: Exposure and gain control for video or web cameras that support DirectShow must be done independently from the SteadyStar software, using whatever proprietary software that is included or offered for that camera.*

### Main Camera

The SteadyStar's main goal is to stabilize image before it is captured by a camera. This camera can be any CCD or DSLR. The SteadyStar's 40mm optical window supports APS-C sized formats and slightly larger. The prism spacing in the “Z” axis has already been set for cameras like the Orion StarShoot Pro or Parsec series cameras.

### Computer

The SteadyStar requires a PC to operate the camera. For astro-imaging in the field at night, a laptop computer is highly recommended.

The included software is a standalone guiding software which requires Windows XP, Windows Vista or Windows 7 operating systems, either 32bit or 64bit versions.

- ASCOM 5.0b (included in the software CD)
- Processor: 700 MHz speed or higher, Pentium™ III equivalent or higher. For very fast guide rates, a dual core processor is recommended
- Recommended minimum memory size is 512 MB
- Disk Space: 10 MB for program installation
- Video Display: 1024 X 768 or higher, 16-bit color or higher
- Mouse
- USB 2.0 port

### Power

The SteadyStar requires 12 volts DC (12VDC) with approximately 1 ampere of max current. Power to the entire unit is supplied by the included power cable when plugged into a 12VDC power source.

Imaging in the field usually requires the use of a portable field battery to supply power, or you can use an 110VAC to 12VDC power converter if you have access to an AC outlet. Make sure the power supply provides at least 1 ampere of current. For safest operation, we recommend using a power supply that provides

up to 1.5 amps or more of current. A 12VDC 2.1A power supply is available from Orion.

### 2.3. Software and Driver Installation

#### Prerequisites

The software requires some basic prerequisites. You may already have some or all of the following software programs installed on your computer, but please confirm these programs and install them with the provided software CD:

- DirectX 9.0c must be installed. It is included with Windows XP SP2 and later. If you are using a previous version of Windows XP, an installer is provided in the installation CD.
- ASCOM platform 5 must also be installed.

Any other components will be automatically installed during the SteadyStar installation. For example, .Net framework 2.0 is required but the installer takes care of the installation procedure.

#### Software Installation

Before operating the SteadyStar, you must install the software.

1. Insert the software CD into your computer's CD-ROM drive.
2. Select Install in the Orion SteadyStar Setup screen (Figure 5)
3. Follow the prompts to complete the Orion SteadyStar installation (Figures 6.1-6.6).

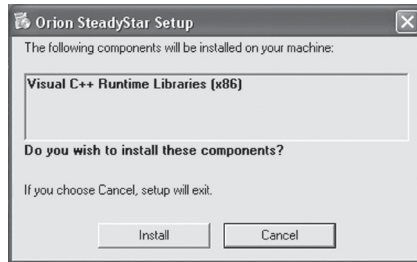
*Note: Please install ASCOM platform 5.0b from the software disk if you don't already have this version installed on your computer.*

#### A Note About StarShoot AutoGuider 32bit and 64bit Operation.

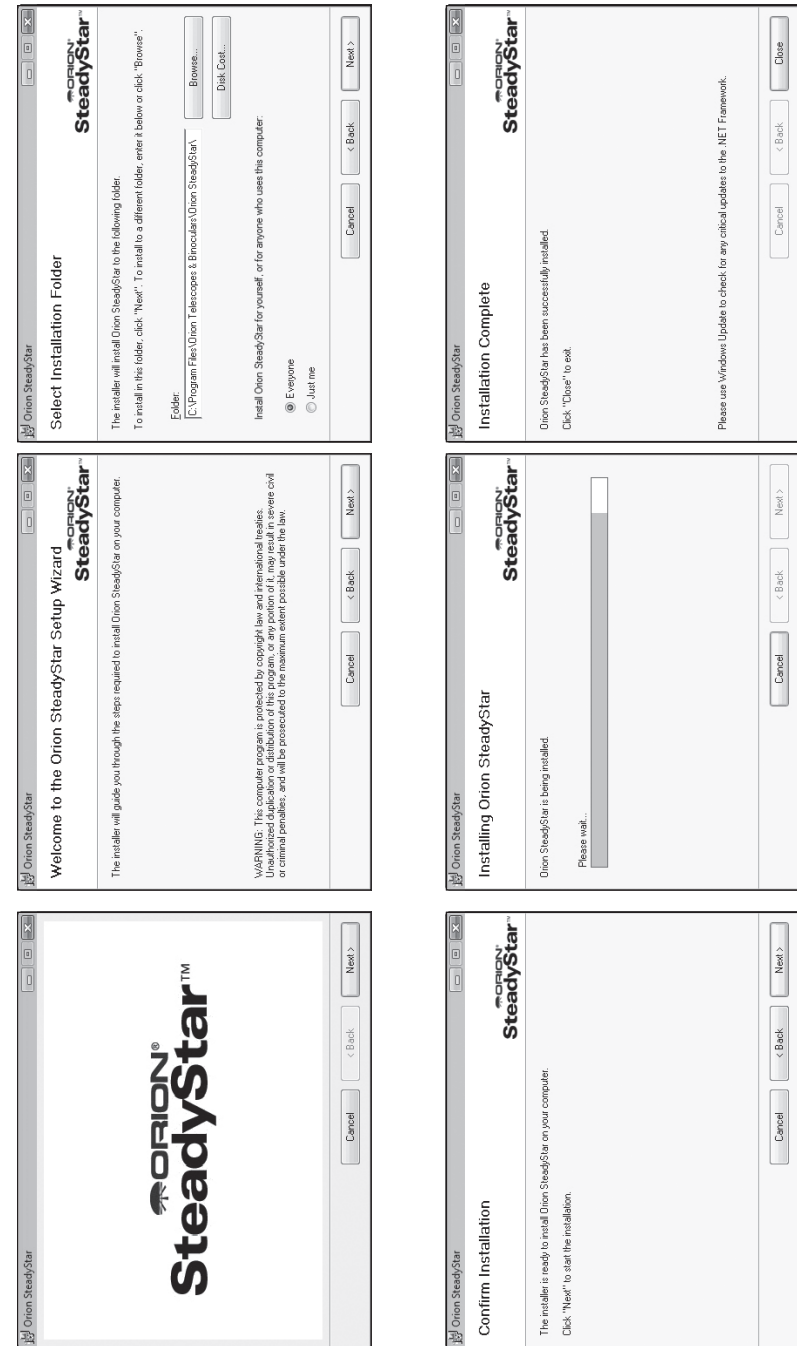
If you are using the Orion StarShoot AutoGuider with the SteadyStar, please read this section.

The SteadyStar software includes a 32bit camera plugin for the Orion StarShoot AutoGuider. If you are using Windows Vista or Windows 7 in 64bit, please follow this procedure:

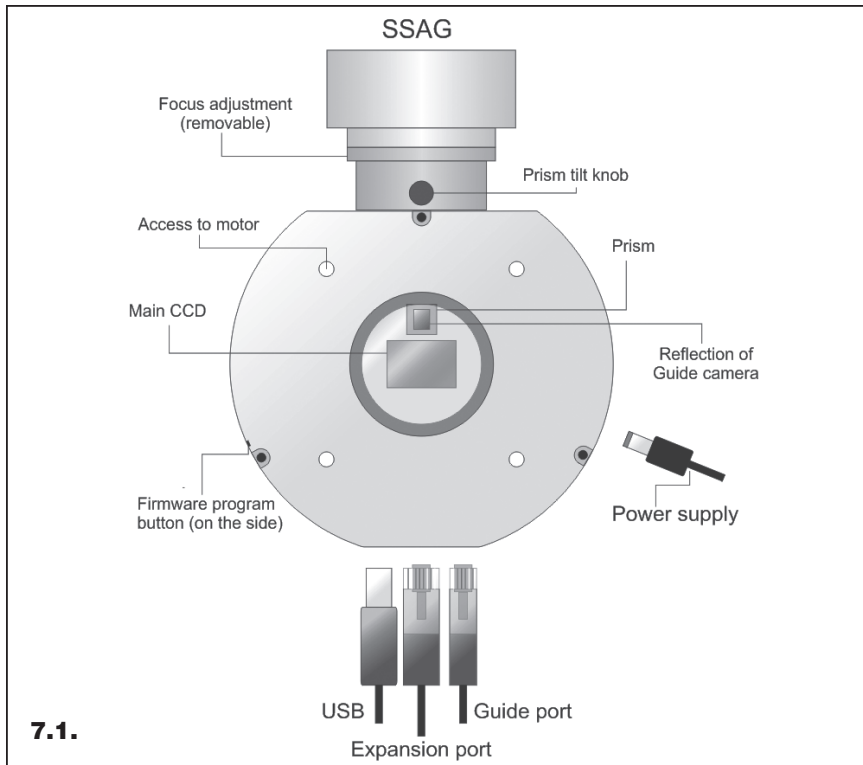
1. Install the 64bit drivers for the StarShoot AutoGuider with the included software CD. Refer to the "StarShoot AutoGuider 64bit Drivers" folder in your software CD, and load "SSAGSetup.exe".
2. Locate "SSAGIF.dll" file in the "Plugin DLL for SteadyStar" subfolder.
3. Copy "SSAGIF.dll" (press **Ctrl** and **C** simultaneously).
4. Locate your "SteadyStar" program folder on you computer.



**Figure 5.** The Orion SteadyStar Setup begins.



**Figure 6.1-6.6.** Click **Next** to continue through and complete the software installation.



**7.1.** Front view of the SteadyStar with the SSAG (not included).

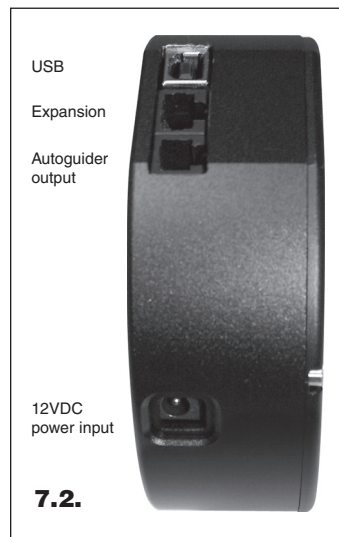
**Figure 7.2.** Side photo of the SteadyStar showing the USB port, autoguider port, expansion port, and power port.

5. Paste "SSAGIF.dll" into your folder (press **Ctrl** and **V** simultaneously).
6. Windows will warn you that this file already exists. Select "Copy and Replace".

### The SteadyStar Driver

The SteadyStar does not require driver installation.

Plug the SteadyStar into your computer's USB port. You do not need to plug power into the SteadyStar for this process.



**7.2.**



**Figure 8.** The prism can be lowered or raised in the "Z" axis by loosening the small hex screw in the back of the unit.

Windows will automatically install the SteadyStar, recognized as a Human Interface Device (HID).

## 2.4. Hardware Setup

### Inputs / Outputs

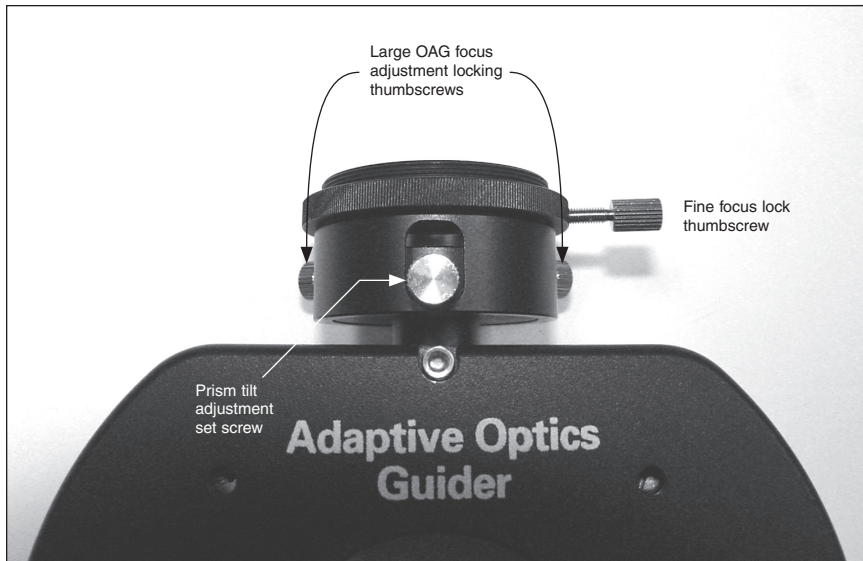
The AO unit has the following inputs and outputs (Figures 7.1-7.2):

- 12V "M" type plug with positive inner hole (tip positive polarity)
- Small pinhole to allow firmware upgrades
- USB port
- RJ-45 expansion port
- RJ-12 autoguider output

### Off-Axis Guider (OAG)

The SteadyStar has a built-in off-axis guider (OAG). It can accept several different guide cameras with T-threads or a 1.25" nosepiece.

The prism can be lowered or raised in the "Z" axis by loosening the small hex screw in the back of the unit (Figure 8), and gradually sliding the prism assembly up or down as needed.



**Figure 9.** The removable helical fine focus adapter is locked in place with a thumbscrew.

*Note: We do not recommend changing the prism spacing for normal use. The stock prism spacing has already been optimized to work with APS-C sized sensors such as the StarShoot Pro.*

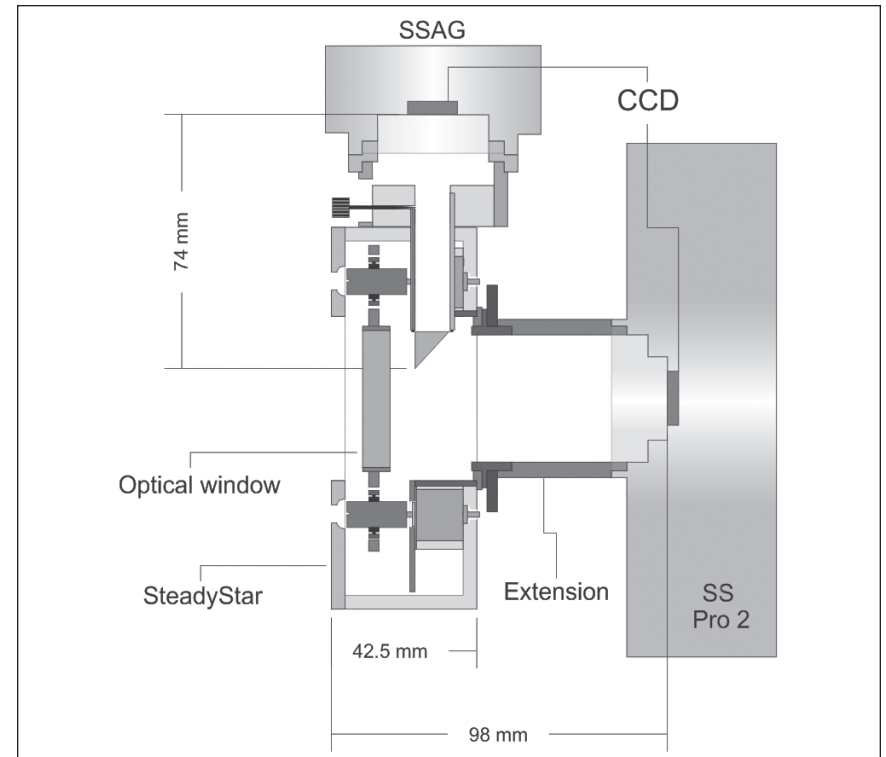
On top of the OAG, a small adapter allows finer focus adjustment (Figure 9). This adapter can be removed to achieve a smaller backfocus. The adapter is locked in place by tightening the thumbscrew.

The prism tilt knob allows the prism to be slightly tilted, therefore covering a wider FOV without moving the telescope.

#### **Adapters and Backfocus**

Figure 10 shows a cross section view of the SteadyStar. Although the SteadyStar can work with several different guide cameras and main cameras, to illustrate a possible combination of guide camera and main camera, the figure also shows the SSAG and SS Pro cameras (not included).

Although the SteadyStar only has 1.68" (42.5mm) of backfocus, the whole image train backfocus is larger and more complex to figure as it depends on the com-



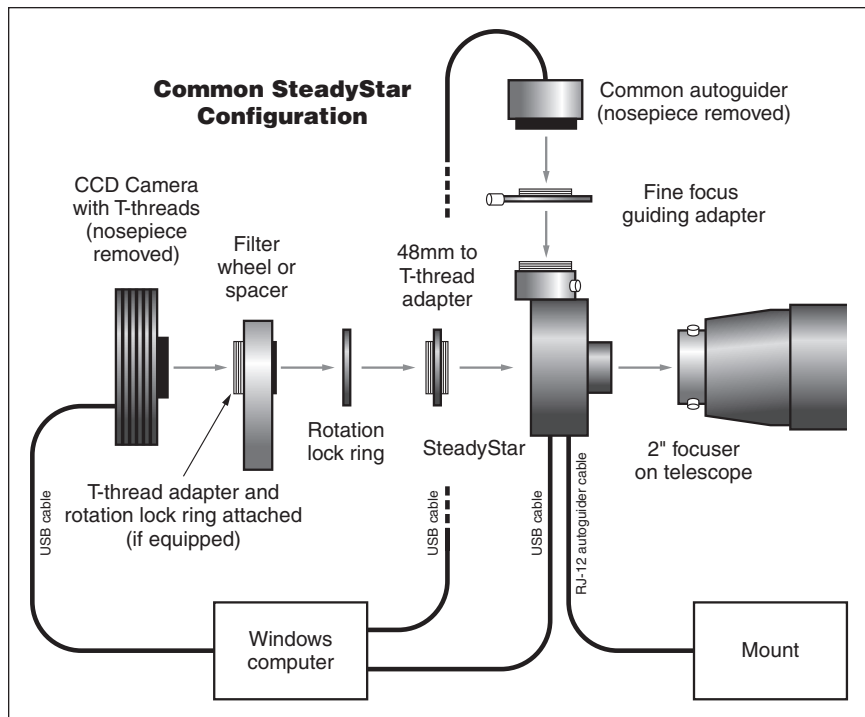
**Figure 10.** The SteadyStar cross section view with SSAG and SS Pro V2.0 (not included).

ination of guide camera backfocus, prism position, main camera backfocus, adapters, etc.

Figure 10 shows a combination that yields 98mm of backfocus. This distance was calculated knowing that the distance between the prism and the guide camera sensor is 74mm and the distance between the prism and the front of the SteadyStar is 24mm.

The backfocus can be reduced approximately 5mm if the OAG fine focus guiding adapter is removed.





**Figure 11.** Common SteadyStar configuration.

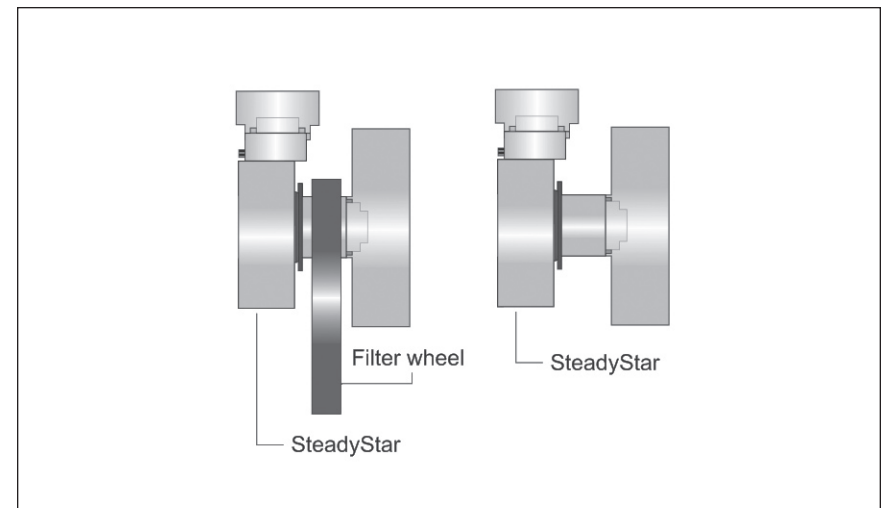
Refer to Figure 11 for a common configuration used with the SteadyStar.

This settles an approximate value for minimum mechanical backfocus at around **88mm**. Due to the refraction of the optical window, the optical backfocus is 2mm less than the mechanical backfocus, and therefore the minimum optical backfocus is  $88 - 2 = 86\text{mm}$ .

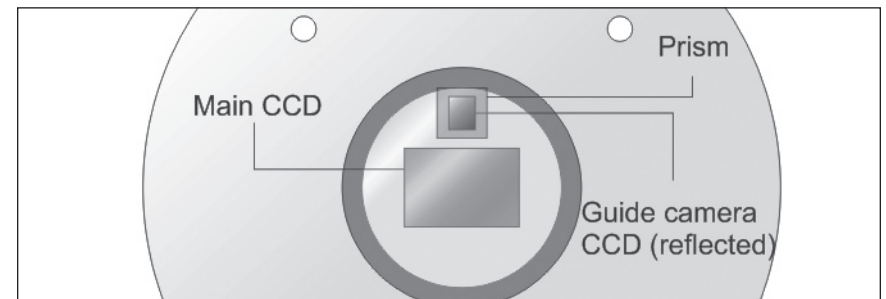
A rotation lock ring can (and should) be placed in the back side of the SteadyStar. Besides allowing the setting of a proper main camera angle (as seen in Figure 13), this rotation ring can also function as a variable spacer, which can be used for fine focusing, instead of using the OAG fine focuser.

Between the back side of the SteadyStar and the main camera, extension tubes must be placed to match the guider backfocus and the main camera backfocus. The big advantage on having the built in OAG is evident when looking at Figure 12. The backfocus is the same with or without a filter wheel. This also places the guide camera *in front* of the filters. Otherwise the guider sensitivity would be severely lowered.

Figure 13 shows a possible arrangement of the guide CCD (reflection on the prism) and the main camera. The main camera angle must be set with the rotation lock ring.



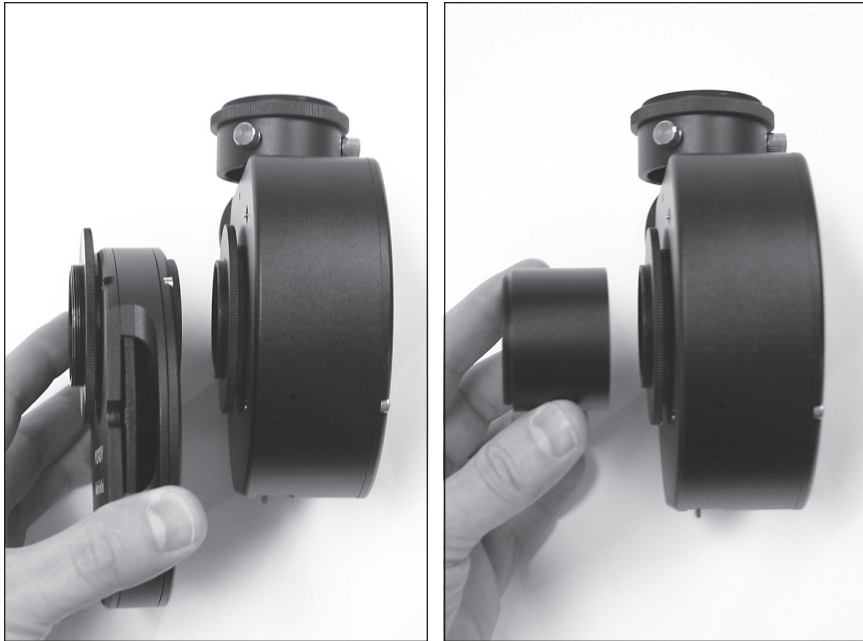
**Figure 12.** Backfocus with and without a filter wheel.



**Figure 13.** Guide and main camera orientation.

The guide CCD is shown with the shortest side facing down. This is a good option, as a bigger circle will be covered when rotating the whole image train to find a suitable guide star.

↳ **TIP:** To make both cameras parfocal, aim at the moon, as it is a very bright and large target. On most setups it will be possible to have the guide camera capturing one side of the moon and the main camera capturing the other side. Alternatively, you can focus on a bright open star cluster.



**Figure 14.1-14.2.** Thread the filter wheel or provided extension to the back of the SteadyStar.

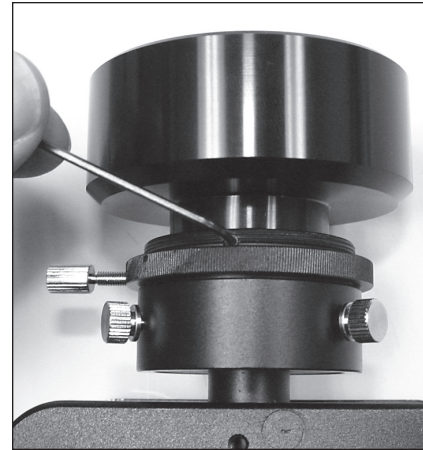
## 2.5. Attaching Your Imager and Autoguider to the SteadyStar

To attach your imaging camera to the SteadyStar:

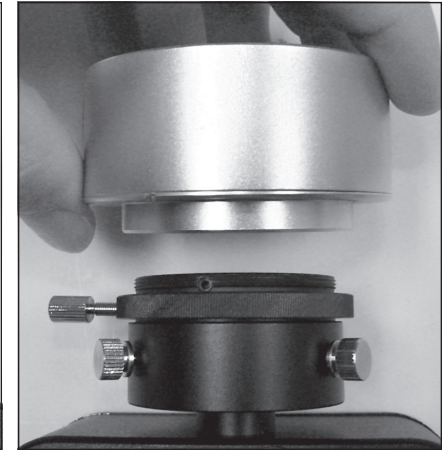
1. Ensure the 48mm to T-thread adapter and rotation lock ring is attached to the back of the SteadyStar body.
2. If you are using a filter wheel, thread the front of the filter wheel to the back of the SteadyStar. Otherwise, thread the required extension and imaging camera to the back of the SteadyStar (Figures 14.1-14.2). See Figure 11 for a typical configuration.

### *If using the StarShoot AutoGuider:*

- *The StarShoot Pro (V1 and V2) requires using the 30mm extension.*
- *The Parsec requires using the 17mm extension (with no filter wheel).*
- *If using the Orion Nautilus or manual Filter Wheels, no additional extension is required between the camera and SteadyStar, but the autoguider will require 7mm of extension when using the Parsec.*
- *DSLRs require approximately 7-10mm of extension. Start by using the provided 7mm extension and determine if more is needed for your particular camera.*



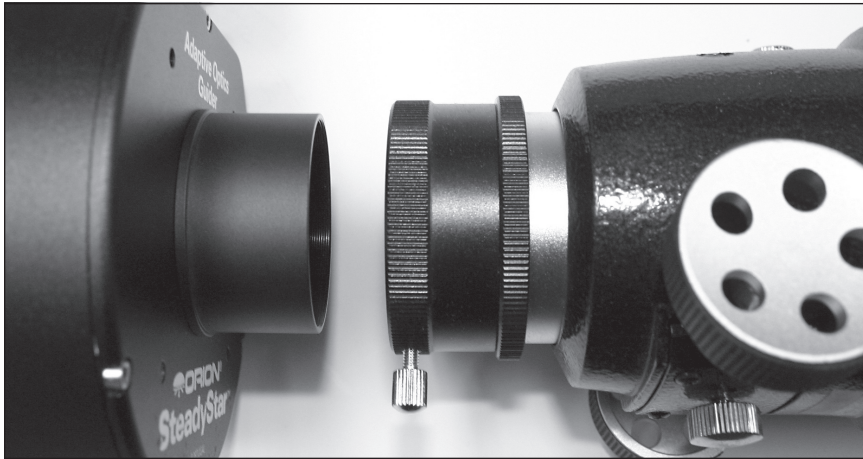
**Figure 15.** If your autoguider's nosepiece is not removable, insert the autoguider into the OAG's fine focus adapter and secure it with the provided hex key.



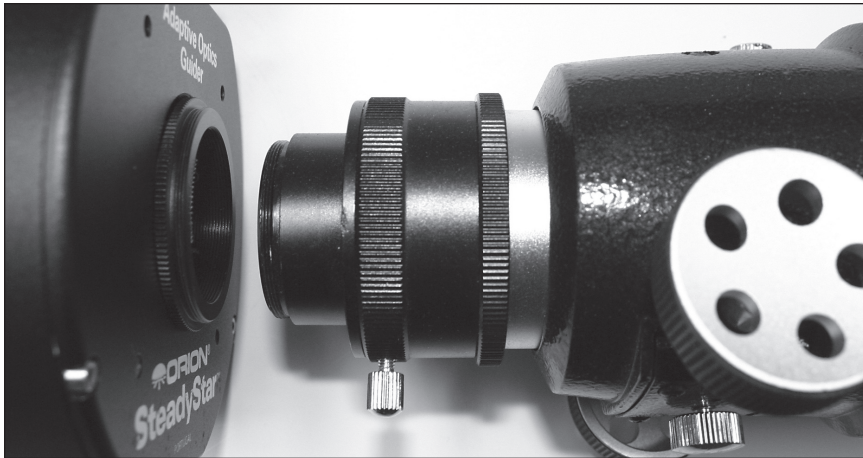
**Figure 16.** Thread the autoguider to the OAG on the SteadyStar.

To attach your autoguider to the SteadyStar:

1. Ensure the fine focus adapter is attached to the Off-Axis Guider (OAG).
2. Remove the nosepiece from your autoguider to allow direct T-thread attachment to the SteadyStar. If your autoguider does not have a removable nosepiece or T-threads, then insert the camera's nosepiece into the OAG's fine focus adapter and secure it with the provided hex key (Figure 15). Note that the autoguider nosepiece will consume more backfocus and require additional extension between the imaging camera and SteadyStar to reach focus.
3. Thread the autoguider to the OAG on the SteadyStar (Figure 16).



**Figure 17.** Insert the SteadyStar into the 2" eyepiece holder on your telescope.



**Figure 18.** Thread the SteadyStar onto your telescope.

## 2.6. Attaching the SteadyStar to Your Telescope

1. Ensure the 2" nosepiece is securely attached to the front of the SteadyStar.
2. Insert the SteadyStar (with the camera and accessories already attached) to the 2" eyepiece holder on your telescope (Figure 17). Firmly tighten the thumb-screw on the 2" eyepiece holder.

If your telescope has T-threads for direct attachment, a more secure connection can be made:

1. Unthread the nosepiece from the SteadyStar.



**Figure 19.** The SteadyStar software Setup tab.

2. Thread the 48mm to female T-thread adapter to the front of the SteadyStar.
3. Thread the SteadyStar onto your telescope (Figure 18).

## 3. Software Walk-Through

### 3.1. How the Software is Structured

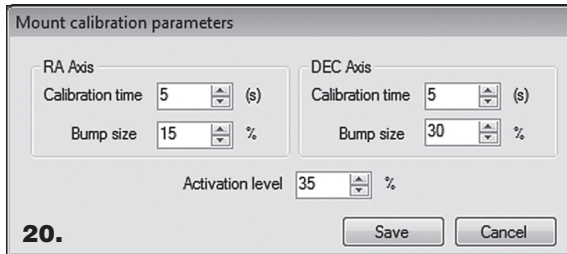
The SteadyStar guiding software structure is very simple. It is divided in three main areas, each one on a separate tab.

### 3.2. The Setup Tab

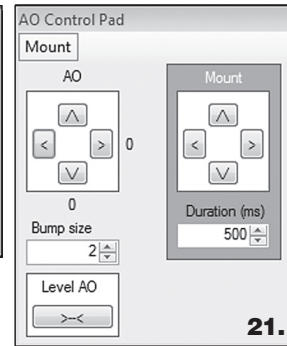
When you start the stand-alone SteadyStar guiding software, you will see a screen similar to the one depicted in Figure 19. The top of the window shows three tabs; **Setup**, **Locate** and **Guide**. The **Locate** and **Guide** tabs only become accessible after a connection has been established with a guide camera.

On top of the setup tab there is an area called **Camera** (Figure 19). This area allows camera choosing and setup. By default, the selected camera is **Orion StarShoot Autoguider**. With this camera selected, only the **Connect** button is enabled.

If the **ASCAM** camera is chosen, the **Choose** button becomes enabled, allowing the user to choose the wanted camera. The **Connect** button becomes enabled after a valid pick.



**Figure 20.** Mount calibration parameters



**Figure 21.** The AO Control Pad

If **Video camera** is chosen, the **Choose** button becomes enabled, allowing the user to choose the wanted camera. Clicking it shows a dialog box with all the view-capable cameras connected to the computer. You must also choose the proper resolution. The **Connect** button is enabled after a valid camera selection. The setup dialog is also enabled to allow direct access to the camera driver configuration.

Below, there is an area called **AO unit** (Figure 19). This area allows you to check the current status of the SteadyStar. It also allows reconnection without having to restart the application.

If the unit is connected, the internal temperature can be measured. To avoid USB delays during calibration and guiding, this update is only done by request, by pressing the refresh button. It is also possible to allow the unit to control its temperature. If the internal temperature is below 15°C, the unit will adjust its power management to warm up. This will increase the current to 0.75A.

The **Mount** section (Figure 19) of the **Setup** tab allows connection to an ASCOM compatible mount for DEC, RA, side of pier and latitude retrieval.

The **Configure Guiding** button allows the setting of mount guiding and calibration parameters. For this topic, refer to “Mount setup” in this section.

The **3rd Party Interface** section allows integration with MaxIm DL for dithering purposes. Click **Connect to Maxim** and MaxIm DL shall be launched (MaxIm DL is not included). If it is already running, connection will be made. If for some reason Maxim is closed, the user can check the status and reconnect.

The section at the bottom named **Rotator** (Figure 19) allows the connection to an ASCOM rotator.

### Mount Setup

Click **Configure Guiding** in the **Setup** tab in the **Mount** section (Figure 19). This window (Figure 20) sets the calibration values for the mount calibration.

The calibration time for each axis must be set so that the value is greater than the known backlash reversal time.

The activation level varies from 10% to 50%. This means that if any of the AO axis is over the activation level, an autoguide command to the mount shall be issued. Recommended values are between 25% and 35%.

The **Bump size** value is the correction amount, in percentage of the AO movement amplitude that the mount command will correct. We recommend a value of 10%-20% for the RA and 15%-50% for the DEC. If exposure time is over 250ms, these values should be lower, to allow the AO to compensate for the mount movement.

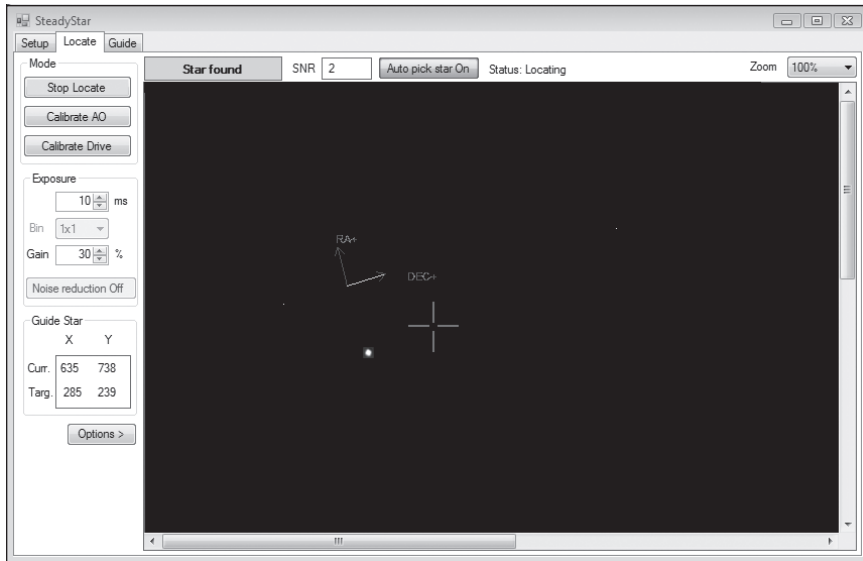
### 3.3. The AO Control Pad

This floating window is a useful tool that allows independent control over the AO unit and the mount. It is automatically launched after a successful camera connection.

On the left, we have an AO cursor. Each cursor click will tilt the AO optical window by the number of steps defined in **Bump size**. If one of the cursor button's has a red background, it means that the AO cannot move any further in that direction and that is already touching the “end of line” switch.

Below, there is the **Level AO** button. This should be used when the optical window is misaligned or jammed.

If you press the **Mount** button, a new cursor will be displayed on the right side (Figure 21). This allows direct commands to be sent to the mount. This is useful for centering the star, for example.



**Figure 22.** The Locate tab.

### 3.4. The Locate Tab (Figure 22)

This tab allows several operations:

- Set the exposure parameters
- Search for the guide star on the covered sky area
- Select a proper star envelope size
- Define a minimum SNR value
- Calibrate the AO unit
- Calibrate the mount
- Create and load a dark frame
- Create and load a hot pixel map

#### Setting the Exposure Parameters

The exposure area is only available if the chosen camera is not a video camera. Also some of the controls might not be available for all cameras.

The “Bin” control should only be used when the camera is not exposing. Except for this control, all the others are changeable in real-time.

AO operations require a bright star for fast corrections. The user should plan the session in order to find the best suitable guide star for each target.



**Figure 23.1-23.3.** Setting the correct star envelope size is important to ensure the most accurate guiding.

#### Search for the Guide Star on the Covered Sky Area

After a proper exposure setting, you should find and center the guide star by moving the telescope mount directly or by using the mount control pad. Also, you might have to rotate the whole camera plus AO unit assembly. This can be accomplished by using a telescope built-in rotator, a focuser with rotator, or manually rotating the whole assembly inside the telescope’s 2" eyepiece holder.

Contrary to other AO units in the market, no special care must be taken to align mount axis with AO axis and camera axis. The guiding algorithms for mount and AO are *completely independent of camera-AO-mount angles*.

The guide star should be positioned near the center of the screen, especially if the user wants to calibrate the mount.

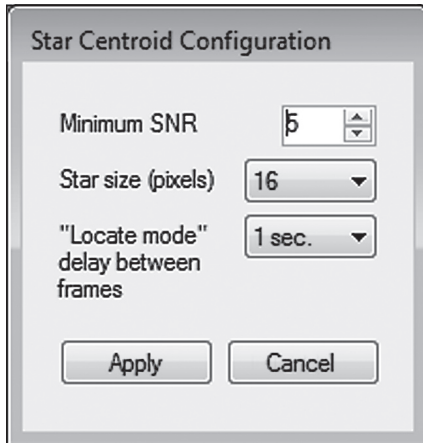
**TIP:** To avoid slow refresh, uncheck the **Auto pick star** button. This button must be checked later in order to calibrate or guide.

#### Select a Proper Star Envelope Size

Once the star has been found, the next step is to adjust exposure, envelope size and minimum SNR. While it is useful to have a long exposure for star location, the user should reduce the exposure for faster operation, while maintaining a reasonable SNR. Calibration should be done with a high SNR but guiding can work with much lower SNR.

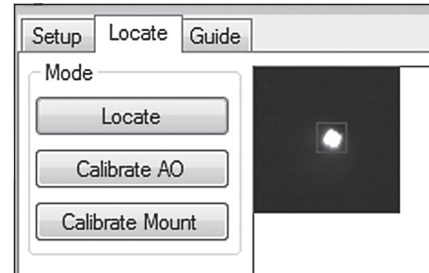
To set the correct envelope form, see Figures 23.1-23.3.

Figure 23.1 shows a star with a very small envelope. This is the most undesirable situation, as the tracking box (blue box) will mistake the corners of the star with its center. This leads to a very unstable guiding and to a bad calibration. Figure 23.2 shows an envelope that is too large. While this can be helpful in a very turbulent night, it should be avoided because noise will affect centroid calculation. Figure 23.3 shows a tight envelope around the star. This is the correct envelope size on a night with average to good seeing. If the seeing is very turbulent, increase the envelope size slightly.



**Figure 24.** The Star location setup.

**Figure 25.** The AO calibration window



To access these parameters, click on the **Options** button and then choose the **Star location setup** submenu (Figure 24). **Minimum SNR** should be set to a high level (>20) for calibration purposes and to a low-level (5-15) for guiding purposes. If there is severe turbulence, very low levels should be avoided.

The **Locate mode delay between frames** is only available for video camera capture. It reduces the number of processed frames per second, which is useful during star location.

### Calibrate the AO Unit

This operation only needs to be executed once for the imaging session. Repeating it is only necessary if:

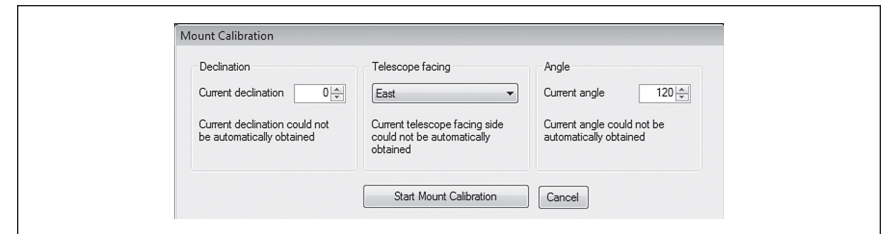
- The guide camera was rotated (not the SteadyStar unit)
- The built-in OAG (Off Axis Guider) was rotated to achieve better focus
- The guide camera was swapped by another camera

Follow these steps (see Figure 25):

1. Make sure that you are in **Locate** mode.
2. Make sure that the **Auto Pick Star** button is checked.
3. Make sure that the star is not very close to the edge of your autoguider's field of view.
4. While on **Locate** mode, click on the star. A green crosshair will be displayed on the clicked position. This is required to avoid a hot pixel from automatically being selected.
5. Click the **Calibrate AO** button.
6. Wait until a message box signals a successful or unsuccessful calibration.

If the calibration fails, please look at section 6, "Troubleshooting".

For permanent setups, AO calibration only needs to be done once.



**Figure 26.** The Mount Calibration dialog

It is a good practice to save calibration parameters at this point. Refer to the section, "Saving and loading calibration sets".

### How to Calibrate the Mount

The mount calibration must be executed each time:

- The mount guiding speed is changed
- The focal length is changed
- The guide camera pixel size is changed
- The guide camera rotation is changed
- The AO unit is rotated\*
- The DEC is changed\*\*
- The mount crosses the zenith\*\*

\*This can be skipped by allowing user to manually enter a rotation angle or, automated, if the AO unit has a built-in rotator.

\*\*This can be skipped by allowing the user to manually enter a new DEC value/choosing telescope facing side or by retrieving DEC/pier flip information from the mount ASCOM connection.

To calibrate the mount, follow these steps (see Figure 26):

1. Make sure the previous step "Calibrate the AO unit" has been performed at least once.
2. Make sure that you are in **Locate** mode.
3. Make sure that the **Auto Pick Star** checkbox is checked.
4. Make sure that the star is near the center of the screen.
5. While in **Locate** mode, click on the star. A green crosshair will be displayed on the clicked position.
6. Click the **Calibrate Mount** button.
7. The dialog shown in Figure 26 is displayed. You can leave the default values.
8. Click **Start Mount Calibration**. Wait until a message box signals a successful or unsuccessful calibration.

If calibration fails, have a look at section 6, "Troubleshooting".

## Create a Dark Frame

Dark frames are useful to reduce noise and to remove hot pixels. They can effectively allow an exposure 3 times shorter while maintaining a good SNR.

To create a dark frame, press the **Options** button on the **Locate** tab and click on the **Take dark frame** menu item. The application will ask you to cover the guide camera. Next, the application will take 31 sub frames, calculate the median and finally ask the you to uncover the camera. Subsequent frame capture will use dark frame calibration. Keep in mind that if you change bin, exposure time, gain, noise reduction or any other setting that influences the exposure, the application will automatically discard the previous dark frame.

## Create a Hot Pixel Map

Although dark frame calibration removes hot pixels, it requires covering the camera which is not always convenient; and the calibration is lost once the exposure time is changed.

The alternative is to build a hot pixel map. This only needs to be done once. The hot pixel map should be done with exposures of 2000ms. After a successful creation, the user can save the hot pixel map into a XML file. That file can be loaded in future sessions.

The big advantage of hot pixel maps is that the same map can be used for any exposure time. But although hot pixel map is a good tool for star location and calibration, for guiding purposes it is always recommended to use a dark frame.

## 3.5. The Guide Tab

Certain conditions must be met before you can start guiding:

- The AO unit must be calibrated.
- The user must click over the Star while on **Locate** mode. This will put a green crosshair target over the star.
- The **Auto Pick Guide Star** button must be checked.

After all these conditions are met, you can go to the **Guide** tab (see Figure 27).

On the top left, there is a small area called **Guide Values**. This area provides real-time information for the AO position (-50% to +50%), the measure error and the last performed correction.

On top mid, there is a black box showing the guide star. Below, two buttons are visible: **Guide** and **Stop Guide**.

On the top right, there is an area called **Guiding Parameters**, which contains all the real-time-adjustable parameters.

The aggressiveness parameters allow you to adjust the percentage of error to be corrected. 10 equals 100% and zero equals 0%. If the calibration is accurate, the recommended value is 10. But if there is too much turbulence, the value should be reduced to seven or less. If very fast guide rates are being used (over 15Hz), a more complex scenario emerges and motor speed plays a limiting role and the recommended aggressiveness is 4-7.

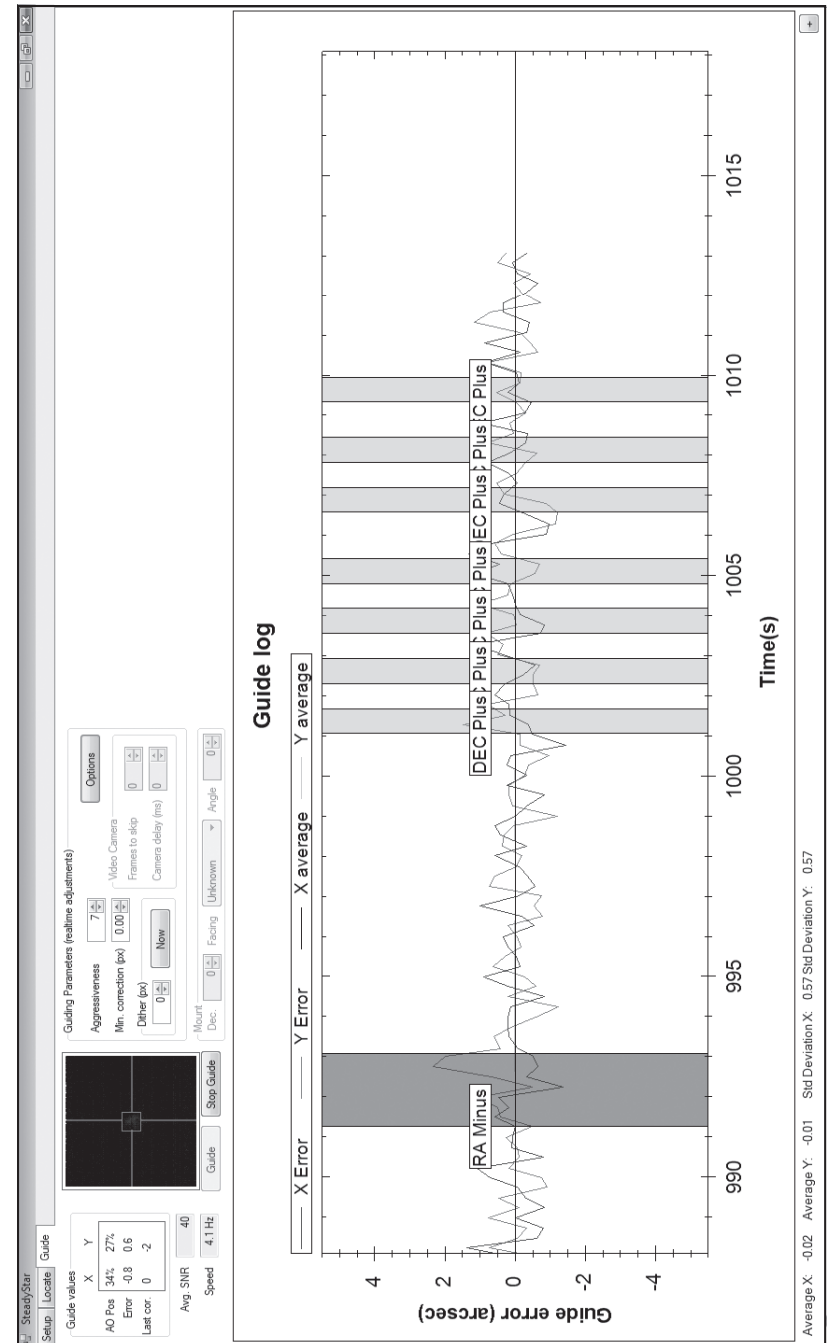
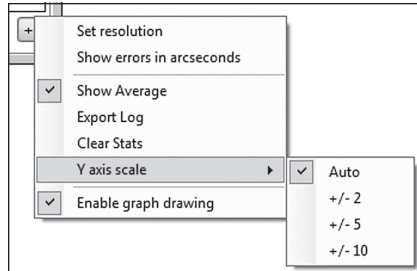


Figure 27. The Guide tab

The **Min. correction (px)** is a threshold that defines the lower limit for corrections. If the star distance to guide target is less than the threshold, no movement will be made. The recommended value is between 0.15 and 0.5 pixels. Less than 0.15 is not useful because the associated centroid error is around 0.15 pixels (depends on SNR and star deformation).



**Figure 28.** Tracking error graph options

The minimum correction might be limited by other factors, like the optical window thickness and pixel size in microns. Leaving the field with zero is the default.

**Frames to skip** and **Camera delay** are parameters only useful for video cameras, which have a fixed number of frames per second. These parameters define the number of milliseconds or frames to be discarded after an AO correction. This prevents instability. When using video cameras, **Frames to skip** should be at least 1. Or leave it with zero and insert a value in **Camera delay** that is equivalent to the exposure time.

### Dither

Dithering is set by a positive value in the dither box. After that, there are two ways to trigger dithering:

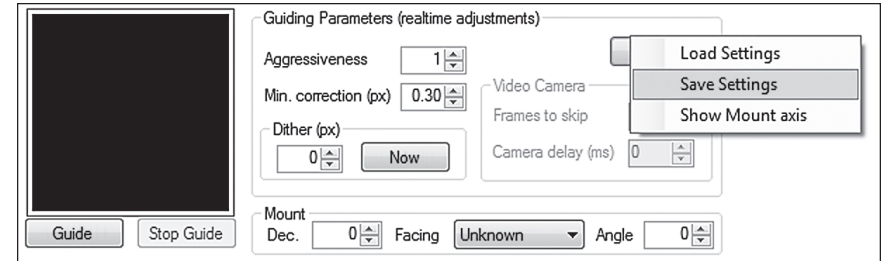
- Press the **Now** button
- Press **Connect to MaxIm** in the **Setup** tab, then go back to the **Guide** tab and select the pixel value in **Dither**.

Dithering instructs the application to shift the current guiding center by a random distance with a maximum value defined in the dither box. The new guiding center will be reached in less than a second.

### The Tracking Error Graph

The lower half of the screen shows a graph that helps the user to fine tune and troubleshoot guiding (see Figure 28).

The error is displayed in pixels, but it can also display the error in arc seconds.



**Figure 29.** Saving calibration sets.

Average X and Y should be around 0.1 pixels or less. RMS errors depend on several factors, turbulence being the principal. The lower, the better. Adjust **Aggressiveness** for each session to reduce these values.

The graph values can be saved to a CSV file for later analysis. For performance reasons, the graph might not hold all the corrections made.

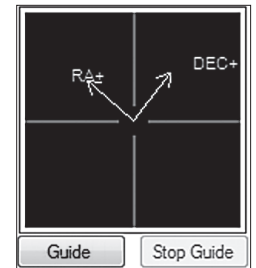
### Saving and Loading Calibration Sets

On the top right part of the **Guiding Parameters**, there is a button that allows the user to save and load calibration sets (see Figure 29).

This is useful if the user has several setups and wants to switch between them quickly.

It is also recommended to save the parameters after a successful calibration. If the application crashes, the user can resume guiding without having to redo calibration.

Another useful feature is the possibility to see the mount axis in relation to the camera axis. To use this feature, press the **Options** button on the **Guide** tab and click the **Show Mount axis** menu item (see Figure 30). This is also useful to troubleshoot mount calibration.



**Figure 30.** Plotting the mount axis.



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## 4. Quick Start Guide

After you have successfully installed the SteadyStar software and configured the hardware to your telescope and imaging equipment, follow these basic steps to begin using the SteadyStar. The Quick Start Guide is intended only as a brief overview of the SteadyStar operation. Please read section 3, “Software Walk-Through” for more detailed information about the software usage and functions.

1. Connect the SteadyStar to your computer’s USB port.
2. Plug the SteadyStar into your power source using the provided 12VDC cable.
3. Connect the provided RJ-12 autoguide cable from the SteadyStar to your mount’s compatible autoguide port.
4. Connect the autoguider camera to your computer’s USB port. Make sure the autoguider camera is properly installed recognized by your computer.
5. Open the SteadyStar software.
6. Select your autoguider camera in the **Camera** selection pulldown menu. If you are using a video or web camera, select **Video camera** then click **Choose** to select your camera.
7. Click **Connect** and the autoguider and SteadyStar will connect at the same time.  
*Note: You must be connected to the autoguider camera in order to connect to the SteadyStar.*
8. Level the AO when asked upon connecting to the SteadyStar and autoguider. You will hear a chatter as the stepper motors move to level the AO. This will reset the AO and establish its starting position. Leveling the AO is the most common method of resetting its tilt position. When in doubt, level the AO!
9. Click the **Locate** tab and the screen will be showing a live image of your autoguider camera. If you are using the StarShoot AutoGuider, the default exposure time is 250ms.
10. Take a dark frame by clicking **Options** and selecting **Take dark frame**. Cover the telescope at the prompt and wait for the dark frame calibration to finish. This will significantly improve your camera’s signal to noise ratio (SNR) and increase the chances of finding a guide star.
11. Select **Auto pick star On** at the top of the **Locate** tab.
12. Click on a star with a red box around it and green crosshairs will appear over the star and red box. If you do not see any star or red box, you will need to keep searching for a guide star or increase the exposure time.
13. Click **Calibrate AO** and wait for the calibration process to finish. You should be prompted with a “calibration successful” message.
14. Click **Calibrate Mount** and wait for the calibration process to finish. This process can take a couple of minutes depending on your mount’s settings. You should be prompted with a “calibration successful” message. See section 3.2 “Mount Setup”.

15. Make sure the green crosshairs are still over the star and red box; if not, click on the star again.
16. Click the **Guide** tab and click **Guide** to begin autoguiding with the AO. The tracking error graph will plot the tracking error and corrections shown by the AO and your mount.

## 5. Advanced Topics

### 5.1. Why Fast Guiding?

Let’s start by pointing out the main objective: obtain high resolution images.

Keeping the telescope centered on its target for several minutes is not an easy task. Any small disturbance will blur the image. One of the approaches is trying to reduce the origin of disturbances by using a high end mount. But even high end mounts have small errors. Add atmospheric turbulence, wind gusts, mirror shifts, misbalanced telescope and other factors and the final image will not use the full potential of the telescope.

So, if it is difficult, or expensive, to reduce disturbances, the other option is to correct them as soon as they are detected. Fast guiding approach just accepts the fact that disturbances will occur and the best way to correct them is to measure the guide errors several times per second and correct them as fast as possible.

### 5.2. How to Achieve High Number of Corrections Per Second

There are several factors that limit the number of corrections per second. Data communication, processing, motor movements and, most important, exposure time limit the number of corrections per second.

The SteadyStar was made to tackle each of these factors. Below there is a list of factors that limit performance.

Factor	Performance
Exposure time	Depends on guide star brightness and camera sensitivity
Image upload from camera to the PC	Depends on the camera USB speed
Processing time (star centroid calculation, error correction calculation, etc)	Less than <b>30µs (!)</b> in any laptop bought after 2007
Communication time (transmitting information through USB)	Around 0.5ms
Sending commands to move motors	Around 1µs
Moving motors	1.25ms per step

Taking in consideration that a normal correction requires 3 motor steps, the total overhead is  $0.03 + 0.5 + 0.001 + 3.75 = 4.281\text{ms} \approx 4\text{ms}$ .

This is important because it means that the system performance is not limited by the AO unit. Any measured error is corrected immediately.

Although an overhead time of 4ms meant that it would be possible to guide at 250Hz, the most limiting factor is the exposure time.

Exposure time is mostly dependent on the camera electronics and on guide star brightness.

The goal is to obtain the smallest exposure times while maintaining a reasonable Signal to Noise Ratio (SNR) for a proper star position calculation.

### Camera Characteristics and Exposure Time

The SteadyStar supports a wide variety of guide cameras.

Camera	Pro	Cons
Orion SSAG	<ul style="list-style-type: none"> <li>• Large area</li> <li>• Fast uploads</li> <li>• High QE</li> <li>• Value for money</li> </ul>	Small pixel size (good resolution, but low sensitivity)
Video cameras	<ul style="list-style-type: none"> <li>• Fast uploads</li> <li>• High QE (for mono cameras with a Sony CCD)</li> <li>• Value for money</li> </ul>	Impossible to control exposure start time
ASCOM cameras	<ul style="list-style-type: none"> <li>• Any camera with ASCOM driver is supported</li> </ul>	Might have slower upload
Lodestar	<ul style="list-style-type: none"> <li>• High QE</li> <li>• Bin capable</li> <li>• Low noise</li> <li>• Large pixels</li> </ul>	More expensive

### Exposure Time vs. Guide Star Brightness

As the SteadyStar responds in 4ms, the overall performance is mostly dependent on exposure time.

Exposure time should be as short as possible, while maintaining a minimum Signal to Noise Ratio (SNR) so that the star centroid can be calculated. But how do we determine minimum SNR? Figure 31 shows a guide star with low SNR.

Although the SteadyStar can work with stars as faint as this one, centroid

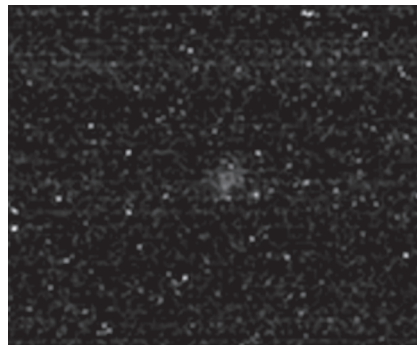


Figure 31. Star with low SNR

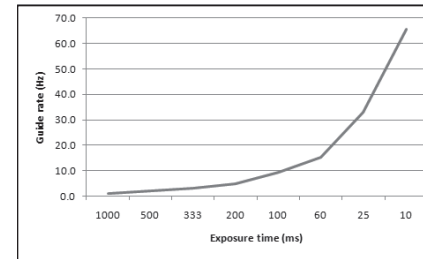


Figure 32.1. Guide rate vs. exposure time

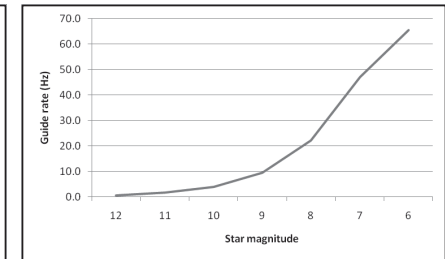


Figure 32.2. Guide rate vs. star magnitude

accuracy might not be the best. Also, on bad seeing nights, this star will have a great variation in SNR from frame to frame. This means that most exposures will be invalid. So, in this case, exposure time should be increased. Try to obtain a SNR of at least 30 or higher.

### Computer

The computer that is running the SteadyStar standalone guiding software must be fast and “clean”, i.e., not having other applications running in the background that constantly demand CPU. For example: a test was made with a very bright star and the SteadyStar was running at 65Hz. A video grabber application was started to record the session and because it was intensively using the processor, the guide rate lowered to 25Hz.

### Summary

Adding all the factors, we can create a relation between exposure time and guide rate.

How does this relate to star magnitude? As said before, it depends a lot on the camera, pixel size, telescope size, etc. Refer to Figures 32.1-32.2.

### 5.3. Finding a Suitable Guide Star

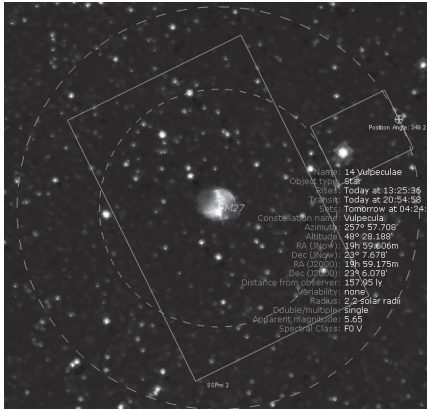
Although there are over 600,000 stars with magnitude 10 or brighter (1.8 million with mag. 11 or brighter), it is not always easy to find one close to our target. And finding one in the FOV of our guide camera is even harder.

So **finding a good guide star is by far the most difficult task when using the SteadyStar**. It is not as easy as having a 400mm FL guide scope that can guide with virtually any star that pops in the current FOV. It is not something that can be done by just moving around the scope. It requires some pre-imaging session preparation.

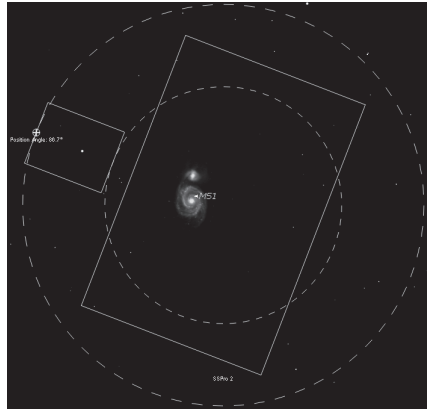
### Determining the Focal Length

The first thing that you need to do is to estimate your focal length.

The best way to estimate your sampling is to do a plate solving. Plate solving compares one of your main camera images of a star field with a huge star data-



**Figure 33.1.** FOV indicator in Starry Night.



**Figure 33.2.** M51 de-centered in the FOV indicator

base and gives very accurate information about precise location, camera rotation angle, focal length and sampling.

You can also use your telescope advertised focal length, although that is not a correct value as the image train length will affect focal length. For example, a f/10 8" SCT with advertised 2000mm focal length might end up with 2150mm focal length due to the size of the image train.

### Creating a Field of View (FOV) Indicator

The next step is creating a FOV indicator in a planetarium application.

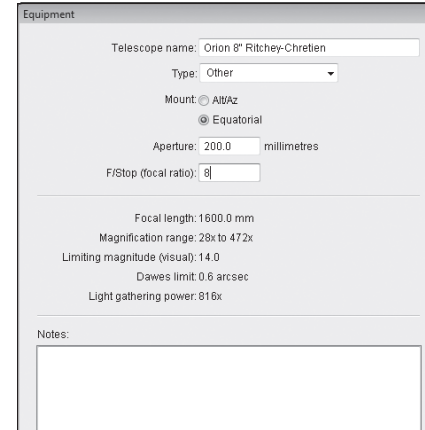
Here are some applications that allow the setup of a FOV indicator:

- **Starry Night Pro, Starry Night Pro Plus or Starry Night Astrophoto Suite**
- **MaxIm DL 5** (any version that has the built-in Planetarium)
- **TheSky6**
- **Cartes du Ciel**

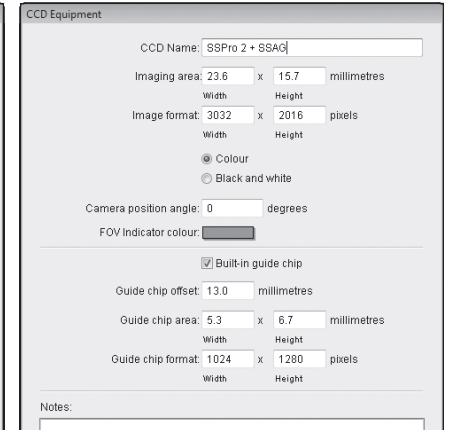
A good FOV indicator is constituted by:

- Placing the main camera CCD on the center of the FOV, with correct rotation
- Placing the guide camera CCD with an offset relative to the center, with correct rotation
- A circle with radius equal to the minimum distance between the guide camera and the FOV centre
- A circle with radius equal to the maximum distance between the guide camera and the FOV centre

The zone between the two circles is the zone where guide stars can be found.



**Figure 34.1.** Creating a telescope in Starry Night.



**Figure 34.2.** Creating a CCD in StarryNight.

Figure 33.1 shows an example taken from Starry Night, using the StarShoot AutoGuider (SSAG) as a guide camera and the StarShoot Pro as the main CCD. The whole FOV was rotated so that the brightest star (mag 5.65) in the guide radius was inside the FOV of the guide camera.

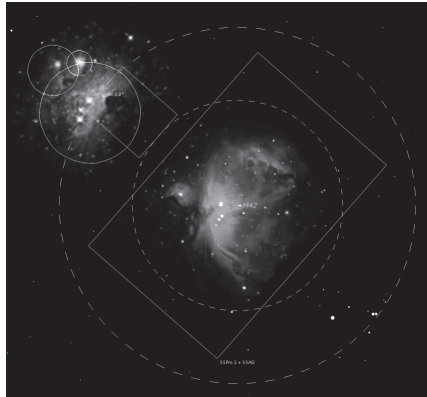
The guide CCD was placed “upward” in relation to the center. This is a possible solution that has the advantage of allowing a wider area to be covered when rotating the assembly.

The OAG prism can be slightly tilted to allow the usage of guide stars close to the borders.

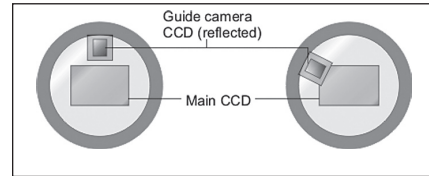
If there is not suitable guide star between the two circles, the telescope can be slightly de-centred from the target, as seen in Figure 33.2.

To create a FOV indicator, follow these instructions (Starry Night):

1. Go to the **Edit** menu and click on the **Edit equipment list...** sub item.
2. Make sure that the top left drop box has **Telescopes** as the selected item.
3. On the bottom, click **New**. Fill the fields as seen in Figure 33.1 or with the specs from your own telescope.
4. Click **OK**.
5. On the top left drop box, select **CCDs**.
6. On the bottom, click **New**. Fill the fields with the specs from your imaging setup.
7. Click on the **OK** button.
8. Click on the **OK** button to return to the main screen.
9. On the left panel of the main screen, click on the **FOV** tab.



**Figure 35.** StarryNight FOV.



**Figure 36.** Issues with an OAG independent rotation.

10. The top ribbon should display **Orion 8" Ritchey-Chrétien** (for example). Click on the associated **+** button.
11. A checkbox should now be visible with the label **SSPRO 2 + SSAG** (for example). Check it.
12. The FOV will appear on the main screen, as seen in Figure 35.

### Rotating

If you look at Figure 35, you will notice that the guide CCD only covers some 15% of the area between the two circles. This means that the best guide star will most likely not be readily accessible when you mount the image train.

***This leads to a conclusion: to find a suitable guide star, the whole image train must be rotated.***

With firm hold of the SteadyStar AO Guider, loosen your telescope's 2" eyepiece holder setscrew slightly and rotate the whole assembly within the 2" eyepiece holder of your telescope, then firmly retighten the set screw.

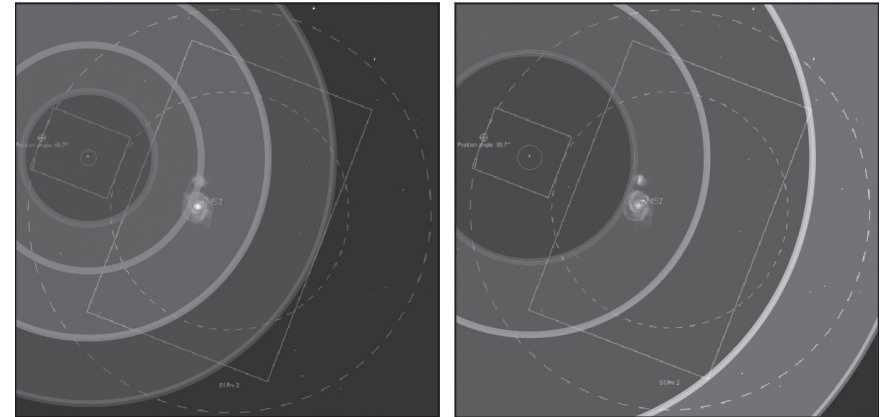
If you are using a Field Rotator you can simply select the desired angle in the **Setup** tab under the SteadyStar Rotator unit.

The SteadyStar maintains the OAG prism in the same orientation in relation to the main camera, thus avoiding the problem described in Figure 36.

## 5.4. What to Expect from AO Guiding

### Mount

There is one basic thing that the SteadyStar guarantees: excellent guiding with round stars, even on low budget mounts. It will compensate for any mechanical flaw, wind gusts, unbalanced mount, etc. Even a low budget mount can guide at very long focal lengths with the SteadyStar. With a modest mount, the difference is between perfect guiding with the SteadyStar and highly trailed guiding without.



**Figure 37.1-37.2.** Fast guiding effectiveness with high (left) and low (right) turbulence.

For high end mounts, the difference is not as significant, but some marginal improvement can be obtained. Also, on windy nights, it can make a big difference. Tests conducted showed that even wind gusts that displaced the image by 15 arc seconds were successfully corrected by the SteadyStar.

### Focal Length

The performance of the SteadyStar is best seen with long focal length telescopes.

The SteadyStar also works with medium focal length telescopes. Guiding is still nearly perfect, but the increase in resolution is not as evident as in long focal lengths. This is because the distance between the guide star and the main CCD is longer (in arc-seconds) therefore suffering the same effect as seen in Figure 37.1-37.2 (uneven turbulence across the FOV).

### Aperture

The only relation between aperture and AO guiding is that larger telescopes will provide brighter guide stars, therefore increasing the number of updates per second.

### Guide Rate

For an increase in image resolution, a high guide rate must be obtained. Anything below 3Hz will still provide excellent guiding (better than traditional autoguiding) but resolution improvement will not be evident. The goal is to guide over 7Hz.

### Seeing

Does the SteadyStar improve resolution by reducing the effect of seeing (atmospheric turbulence)?

Yes, but only to a certain degree. As with professional AO systems, good seeing is required. There are several reasons for this. One reason is that under bad

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seeing the guide star is oscillating faster than the motors (and the whole system) can compensate.

The SteadyStar is very fast, it can correct one step in only 1.25ms. But there is still a limit. As it can be seen in Figures 37.1-37.2, the farther away the target is from the guide star, the worse the correlation gets. So, even if the SteadyStar could measure and correct the error in zero time, that would not lead to a resolution improvement across the whole FOV. Some areas would be excellent while others (further away from the guide star) would not experience improvement and even degrade a bit, as turbulence would be **uneven** across the FOV.

Under bad seeing, the SteadyStar will continue to provide round stars, but not much resolution improvement is to be expected. Also, the aggressiveness must be kept low to minimize the effects of the uneven turbulence across the FOV.

There is, however, a turning point. On nights with average to good seeing, the SteadyStar will give improved resolution images.

## 5.5. Dithering

The SteadyStar stand-alone software allows manual dithering. As the SteadyStar does not control the main camera, it does not know when to dither, so a special control was placed to allow manual dithering. One basic way to dither is to click the **Now** button in the **Dither** section (in the **Guide** tab) between main camera exposures. The SteadyStar will shift the guide center by a small number of pixels, randomly picked between zero and the maximum dither size.

Dithering is performed very quickly, usually the new position is reached in less than half a second.

Remember that the dither size is measured in guide camera pixel size and not main camera pixel size. The StarShoot AutoGuider, for example, uses 5.4 micron pixels whereas the StarShoot Pro has 7.8 micron pixels. Make sure the dither size is great enough to make at least a 3 pixel movement (or more) in the imaging camera.

## 5.6. Integration with MaxIm DL for Automatic Dithering

MaxIm DL is a powerful capture and processing application. The SteadyStar can establish a connection with MaxIm DL and capture exposure stopping events, therefore dithering at the correct moment.

To enable dithering through MaxIm DL, follow these steps:

1. Go to the **Setup** tab.
2. Locate the **Connect to Maxim DL** button and click it (if MaxIm DL is not running, a new instance will be automatically launched).

- 
3. In MaxIm DL, create an exposure sequence but disregard the built-in dither controls.

Nothing more is needed for dithering. While guiding, the SteadyStar will automatically dither when it receives an exposure stop event from MaxIm DL.

*Note: Automatic dithering is not possible with MaxIm LE version or any other version that does not support automation.*

## 5.7. Mount Guiding

The optical window tilt has its limits. Either by bad polar alignment, poor mount tracking speed or high periodical error, the SteadyStar has a range limit. The most common is declination drift as a result of poor polar alignment. Even a slow and gradual Dec drift will eventually exceed the optical window tilt limit of the SteadyStar.

The solution is to send “bump” commands to the mount before the SteadyStar is near the limit.

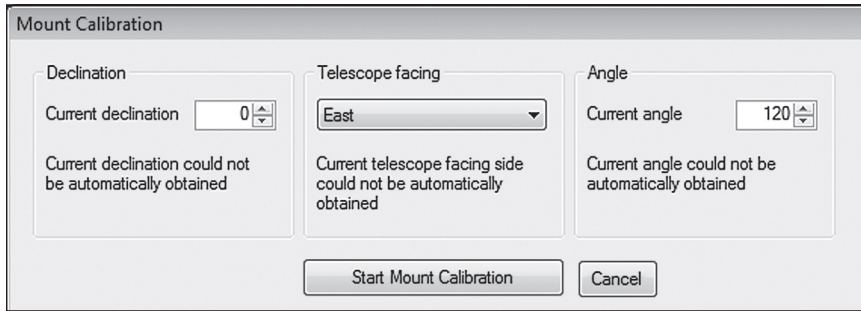
This adds a lot of complexity to the system, because a match must be made between guide camera axis, the SteadyStar axis and mount axis. Fortunately, the SteadyStar takes care of all these details and you don’t need to bother aligning the above mentioned axis.

Similar to the SteadyStar calibration, a mount calibration calculates all the necessary parameters.

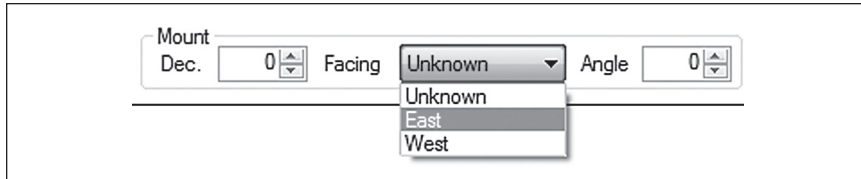
The SteadyStar goes a step further. Instead of calibrating the mount for each guide star, it is possible to make a single mount calibration that works for the whole sky.

If you want to do an “all sky calibration”, you need to do the following steps:

1. Choose a bright star (magnitude 8 or brighter) near declination zero.
2. (Optional) Connect the SteadyStar software with your mount’s ASCOM driver. For this, go to the Setup tab and click **Connect** on the **Mount** section. This allows the SteadyStar to retrieve Declination and telescope pier side (facing west/east).
3. (Optional) Connect the SteadyStar software with your rotator ASCOM driver. For this, go to the Setup tab and click **Connect** on the **Rotator** section. This allows the SteadyStar to retrieve the image train angle.
4. When starting the calibration, the dialog shown Figure 38 will appear if one of the parameters cannot be automatically obtained. Fill the parameters that could not be automatically obtained. Leaving **Telescope facing** with **Unknown** means that no compensation will be done when switching meridians.



**Figure 38.** Mount Calibration dialog



**Figure 39.** Mount compensation

- Before starting guiding, fill the required parameters as shown in Figure 38. The SteadyStar will recalculate the calibration to take in account the change of these parameters.

Which factors normally force a new mount calibration? Can they be compensated?

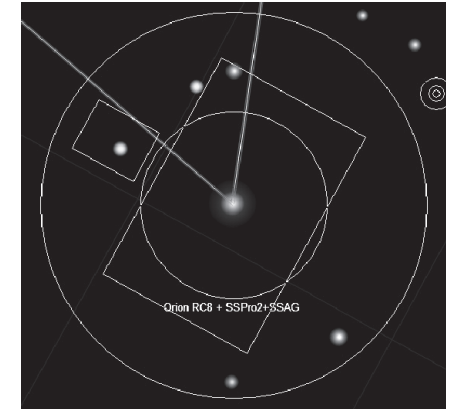
Change	Compensation
1) Declination change	Affects RA gain. Can be compensated
2) The SteadyStar rotation in relation to telescope	Rotates the mount axis in relation to the camera. Can be compensated
3) Guide camera rotation (focus)	Cannot be compensated. Requires full calibration
4) Change of meridian (east to west, for example)	Inverts RA gain. Can be compensated
5) Mount guiding speed and anti-backlash are changed	Cannot be compensated. Requires a new mount calibration
6) Focal length of telescope is change	Cannot be compensated. Requires a new mount calibration
7) Guide camera swap	Cannot be compensated. Requires full calibration

## 5.8. Using a Different Optical Window

The SteadyStar accepts different optical windows. These can be:

- Wider, up to 2" (50mm)
- Thicker or thinner, which changes resolution
- Special coated, for special types of imaging projects

The OAG prism can be moved up in the “Z” axis when the optical window is wider. Larger optical windows are available from Orion. Please contact [support@telescope.com](mailto:support@telescope.com)



**Figure 40.** Sulafat (Lyra) with 5 bright stars around it.

## 6. Troubleshooting

### 6.1. I Can't Find a Suitable Guide Star

Finding a suitable guide star is perhaps the only difficult task when using the SteadyStar. It is easy to become frustrated, because contrary to a small focal length guide scope, finding one by just panning around does not work.

Here are the key factors to find the guide star:

#### Having a FOV Indicator With a Correctly Calculated Focal Length

Please refer to section 5.3, “Creating a Field of View (FOV) Indicator” to see how to create a FOV. Figure 40.3 is also a good example of a suitable test to verify focal length and camera placement.

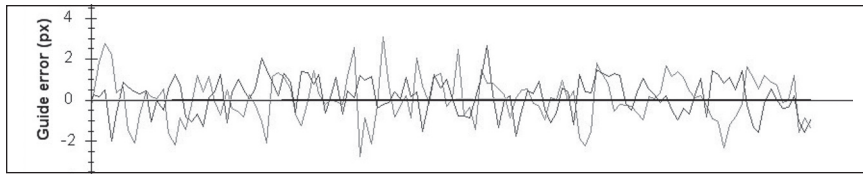
#### Having Set the Correct Angle Between the Two CCDs

This is easy to do. Just look straight to the front of the SteadyStar. The placement should be something as seen in Figure . Adjust the main camera angle with the rotation lock ring if necessary.

#### Having a Good Measure of the Angle Between the SteadyStar and the Telescope

Although the FOV indicator can assure that a suitable guide star is available, the whole image train must be rotated. You can do this by trial and error, i.e. rotating 15° each time and checking if the guide star is there. But it is much easier if you just take note of the angle provided by the FOV and rotate the whole assembly directly to the target. If all steps were carefully done, the star should appear on the FOV of the guide camera.

There is a small detail: depending on telescope type, the image might be reversed, so the correct angle might have to be “mirrored”. For example, 350° should be 10°.



**Figure 41.** Tracking error graph.

Figure 40 shows a good technique to find the correct angle direction. Center the telescope on a bright star. This makes it easy to make sure that the telescope is well centered. Choose a star that has several suitable bright guide stars around. Rotate the SteadyStar to determine if the direction is correct and the “zero” position is correct.

## 6.2. Guiding is Very Unstable

When working at long focal lengths, it is easy to mistake guiding instability with turbulence.

To rule out pure turbulence, there are two easy methods:

- a) Go to the **Locate** tab, press the **Locate** button, make sure that the **Auto pick star** feature is not enabled (to have fast updates) and check if the star seems as unstable as during guiding
- b) While guiding, set the **Aggressiveness** to zero. Check if the star seems as unstable as during normal guiding. Looking at the graph might help

If the star seems to be jumping around as much as during guiding, this is not instability; it is turbulence that the SteadyStar will try to compensate as much as possible.

Figure 41 shows a typical guide error graph. It might look that is very unstable, but it is not, it is a matter of scale. This error graph was obtained in an average seeing night with a setup that provided a sampling of 0.42 arcsec/px for the guide camera. Most of the errors are below +/-1px and the larger errors go around 2.5 pixels. This means that most of the error is below 0.42 arcsec/px and that the peaks are around 1 arcsec.

Instability due to turbulence will probably be more noticeable at shorter exposure times, but that is expected.

If the instability is not (only) caused by turbulence, it might be caused by:

Cause	Solution
Bad AO calibration	Re-calibrate AO
Guide rate is over 15Hz and aggressiveness is bigger than 7	Reduce aggressiveness to 7 or less
Star centroid box is too small. This is easy to spot, as star is often seen stretching beyond the centroid box. See section 1.4, “Select a Proper Star Envelope Size” For correct star centroid box size	Increase star centroid box size
Star SNR is too low and centroid calculation has a large error	Increase exposure time

## 6.3. The Star Rapidly Drifts When It Is Near the SteadyStar’s Limits

If you have performed mount calibration and you experience such behavior, it means that mount corrections are incorrect. This can be caused by a bad mount calibration or because the performed mount calibration is incorrect for this guide star (for example due to a field rotation, meridian flip or declination change). Re-calibrate the mount and ensure that you get a successful calibration.

## 6.4. AO Calibration Fails

AO calibration can fail mainly due to these reasons:

1. There is no star in the region of interest. Make sure that the green crosshair is over a star before starting the calibration.
2. The star is too close to the borders. Make sure that the green crosshair is over a star before starting the calibration.
3. Some wind gusts occurred during calibration.
4. The SteadyStar is jammed. See section 6.6, “The SteadyStar Seems to be Jammed”.
5. The star SNR is too low. Try increasing the exposure time.

## 6.5. Mount Calibration Fails

There are two main reasons for mount calibration to fail:

- a) Mount commands are not being received by the mount

To troubleshoot this issue, please follow these steps:

1. Check if the autoguide cable is connected between the SteadyStar autoguide output and your mount’s autoguider port.
2. Make sure that your mount is correctly configured to receive ST-4 standard autoguiding commands.
3. Use the **AO Control Pad** (see section 3.3), click the **Mount** button (the mount side control is shown).

4. While having a guide star on screen, set the bump time to 4000ms and click on one of the mount command buttons.
  5. Wait 4 seconds and click on the same button (to make sure backlash is not interfering).
  6. Check if the star has moved in the screen.
  7. If it moved, repeat step 4 through 7 for each of the 4 directions.
  8. If any of the movements failed, the autoguide cable might be damage or your mount is not responding as it should (for example due to a weight balance issue).
- b) The other major reason for mount calibration failure is incorrect calibration parameters

Usually, mount calibration fails if either RA or DEC calibration times were not enough to completely overcome backlash. The calibration report usually gives some hints on which axis calibration time was incorrect.

There is an easy method to estimate the backlash time for each axis:

1. Make sure that you are on “Locating” mode with a guide star on the center of the field
2. Use the **AO Control Pad** (see section 3.3), click the **Mount** button (the mount side control is shown)
3. Set the bump time to 4000ms and click on one of the mount command buttons (for example RA+)
4. Wait 4s and click on the same button (to make sure backlash is not interfering)
5. Check if the star has moved in the screen
6. Now click on the star (a green crosshair will appear over it)
7. Set the bump time to 500ms and click on the opposite mount command button (for example RA-)
8. Wait 0.5s and check if the star moved. If it did, your backlash for that axis is 500ms x nr. Of times the button was pressed. If the star did not move, repeat step 7 and 8
9. Repeat step 3 through 8 for the RA and DEC axis. Remember that calibration time should be larger than the backlash time on at least 25%. So, for a backlash of 4 seconds, calibration time should be at least 5 seconds.

There are other situations where mount calibration can fail. For example, if a second star with similar brightness is in the FOV, the star detection algorithm might jump between the two. A hot pixel can have the same effect. It can also fail if the guide star is too close to the edge.



**Figure 42.** Use a flat head screwdriver to turn the jammed motor until it turns freely.

## 6.6. The SteadyStar Seems to Be Jammed

Although it does not occur often, the unit can jam. This is noticeable if:

- The optical window does not tilt
- While guiding, the unit reaches the limit in a few seconds or at most a minute (this can also occur due to bad calibration)
- An optical window level alignment command fails at least twice in a row

To un-jam the unit, please follow the described steps:

1. Try to level the unit. If levelling works, the unit is functioning properly.
2. If step one fails, a reset might be required. Disconnect the 12 V cable and the USB cable.
3. Reconnect the unit and try to level it again. If levelling works, the unit is functioning properly.
4. If step three fails, disconnect the 12VDC cable and the USB cable .
5. Remove the four cover plugs on the front side of the SteadyStar and locate the four motor holes inside the unit
6. With a flat-head screw driver, try to find the motor which seems to be more stuck and rotate the screw driver until it feels free (Figure 42). If it feels excessively stiff, try another motor first.
7. Now check if one of the other three is still stuck and try to loosen them up. Only a partial turn may be needed.
8. Plug-in the USB and the 12VDC cable.
9. On the **Setup** tab, click **Refresh Status** then **Connect to AO**.
10. Try to level the unit.



## 7. Care and Maintenance

Keep the SteadyStar stored in its hard carrying case when not in use. The SteadyStar was built to last, but please handle the unit with care, especially while transporting it to your imaging session. No collimation is necessary, but the internal optical window, tilt mechanism, and off-axis guider are sensitive components.

The SteadyStar was designed to operate in extreme conditions including sub-freezing temperatures and climates with heavy dew. Frost or dew accumulation on the optical window should not typically occur, since the SteadyStar will warm the window if the internal temperature drops below 15°C (59°F). If frost or dew does occur, leave the unit uncapped after use and wait for it to dry.

Do not touch the optical window. If you need to clean it, use microfiber cloth with a drop of lens solution applied to the cloth. Make sure the lens solution is safe for multi-coated glass.

While the SteadyStar is in use, do not allow anything to touch end of the stepper motors that are seen on the back side of the unit.

## 8. Messier Catalog Guide Star Suggestions

Finding a suitable guide star can be challenging. But you will find that most celestial objects of interest have an appropriate guide star at a given angle. Refer to the Messier catalog guide star suggestions to get an idea of how to plan your guide star selection before the imaging session.

The guide star angle is relative to the SteadyStar being parallel to the Declination axis at the 0° position.

Target	RC8		C11	
	Best star	Angle(°)	Best star	Angle(°)
M1	7.03	92	9.19	77
M2	9.16	189	9.77	287
M3	6.23	228	8.3	159
M4	6.61	95	8.92	10
M5	5.05	150	5.05	150
M6	7.85	121	7.91	60
M7	5.84	320	5.88	268
M8	7.2	70	5.37	294
M9	7.83	171	9.83	110
M10	8.33	128	9.73	352
M11	5.99	314	8.66	240

Target	RC8		C11	
	Best star	Angle(°)	Best star	Angle(°)
M12	8.97	311	9.43	66
M13	8.69	100	6.86	77
M14	7.43	353	7.43	353
M15	8.15	80	6.1	95
M16	8.98	88	7.91	5
M17	5.39	335	7.9	120
M18	7.31	222	8.08	100
M19	8.1	220	9.5	138
M20	7.2	62	5.77	340
M21	5.77	240	6.73	230
M22	5.49	258	9.73	337
M23	8.78	235	6.48	310
M24	6.6	198	6.54	255
M25	5.63	313	6.8	332
M26	8.46	320	9.51	55
M27	5.68	344	7.67	92
M28	8.81	265	9.44	320
M29	7.63	220	8.78	15
M30	5.2	100	10.87	90
M31	7.03	193	9.15	83
M32	7.18	116	7.03	215
M33	5.84	240	8.11	70
M34	8.34	178	7.33	156
M35	5.83	83	7.55	122
M36	8.11	279	8.86	297
M37	6.28	200	8.77	195
M38	6.17	223	8.84	68
M39	7.59	271	6.83	125
M40	8.19	145	5.54	223
M41	6.07	140	6.07	140
M42	3	175	6.56	137

Target	RC8		C11	
	Best star	Angle(°)	Best star	Angle(°)
M43	4.61	353	8	210
M44	7.65	185	6.77	118
M45	3.72	270	4.13	228
M46	4.98	216	8.99	300
M47	7.6	306	7.94	213
M48	7.89	243	8.19	330
M49	6.05	135	11.01	151
M50	5.96	269	8.94	293
M51	7.06	82	7.06	82
M52	6.6	160	7.82	143
M53	6.1	7.5	9.63	223
M54	6.64	243	8.98	344
M55	8.27	210	9.26	167
M56	9.22	125	5.88	324
M57	7.66	140	8.69	71
M58	9.06	337	8	273
M59	10.36	44	9.17	62
M60	8.64	173	9.17	326
M61	7.64	19	8.19	287
M62	7.39	355	8.48	237
M63	9.25	92	9.88	335
M64	7.21	52	10.08	174
M65	10.05	310	7.12	12
M66	7.12	326	10.44	90
M67	7.8	308	7.8	0
M68	5.4	224	8.59	327
M69	8.52	222	8.61	139
M70	8.08	185	7.78	251
M71	6.24	252	6.24	252
M72	9	274	8.28	25
M73	6.61	150	8.92	322

Target	RC8		C11	
	Best star	Angle(°)	Best star	Angle(°)
M74	9.52	177	10.44	88
M75	6.44	234	7.99	23
M76	8.82	315	6.66	105
M77	7.59	343	8.96	48
M78	8.73	255	9.71	254
M79	5.44	245	8.87	116
M80	7.51	123	8.4	222
M81	7.73	163	9.26	141
M82	8.46	0	7.92	308
M83	5.81	50	7.15	85
M84	8.92	247	9.97	12
M85	8.19	338	8.59	207
M86	9.84	260	9.97	314
M87	8.09	150	8.09	150
M88	7.28	290	9.38	314
M89	8.22	42	8.94	242
M90	9.02	162	8.22	145
M91	8.93	125	8.84	300
M92	8.53	30	8.65	50
M93	6.73	142	9.85	43
M94	8.75	114	9.56	168
M95	9.92	175	9.98	126
M96	9.98	234	9.73	77
M97	7.73	336	6.63	247
M98	5.09	88	9.4	257
M99	7.11	150	8.17	275
M100	6.47	241	8.81	131
M101	9.36	20	8.01	350
M102	9.36	20	8.01	350
M103	7.29	227	7.65	185
M104	7.82	285	8.77	285

Target	RC8		C11	
	Best star	Angle(°)	Best star	Angle(°)
M105	6.9	295	9.59	273
M106	6.33	103	10.73	240
M107	7.41	25	7.63	33
M108	7.73	131	8.5	278
M109	2.41	300	8.59	200
M110	8.65	243	9.15	320
average	7.37		8.30	
max	10.36		11.01	
min	2.41		4.13	

*This device complies with Part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) this device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.*

*Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.*

*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 equipment and receiver.*

*Connect the equipment into an output on a circuit different from that to which the receiver is connected.*

*Consult the dealer or an experienced radio/TV technician for help.*

*A shielded cable must be used when connecting a peripheral to the serial ports.*

### **One-Year Limited Warranty**

This Orion SteadyStar Adaptive Optics Guider is warranted against defects in materials or workmanship for a period of one year from the date of purchase. This warranty is for the benefit of the original retail purchaser only. During this warranty period Orion Telescopes & Binoculars will repair or replace, at Orion's option, any warranted instrument that proves to be defective, provided it is returned postage paid to: Orion Warranty Repair, 89 Hangar Way, Watsonville, CA 95076. If the product is not registered, proof of purchase (such as a copy of the original invoice) is required. This warranty does not apply if, in Orion's judgment, the instrument has been abused, mishandled, or modified, nor does it apply to normal wear and tear. This warranty gives you specific legal rights, and you may also have other rights, which vary from state to state. For further warranty service information, contact: Customer Service Department, Orion Telescopes & Binoculars, 89 Hangar Way, Watsonville, CA 95076; (800) 676-1343.

**Orion Telescopes & Binoculars**  
**OrionTelescops.com**

**89 Hangar Way, Watsonville, CA 95076**

**Customer Support Help Line (800) 676-1343**