<u>Paramount MyT – Part 4 – Guiding</u>

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Never go to excess, but let moderation be your guide.
-Cicero

As Richard Wright has said about guiding: "sometimes a necessary evil, but inherently it is a terrible thing to do." Sure, skipping the guide camera seems like a pretty obvious innovation. It reduces gear, cables and software. It removes the main impediment to using the LTI interface for all of your imaging needs. All manner of mounts are marketed with the idea that they don't need to be guided. Guiderless imaging is also incredibly trendy and the subject of considerable misinformation on both sides of the practice. At the end of the day, though, the vast majority of imagers (currently) use guide cameras, despite the public shame that these folks are forced to endure at the hands of the morally superior as well as those who simply can't get guiding to work.

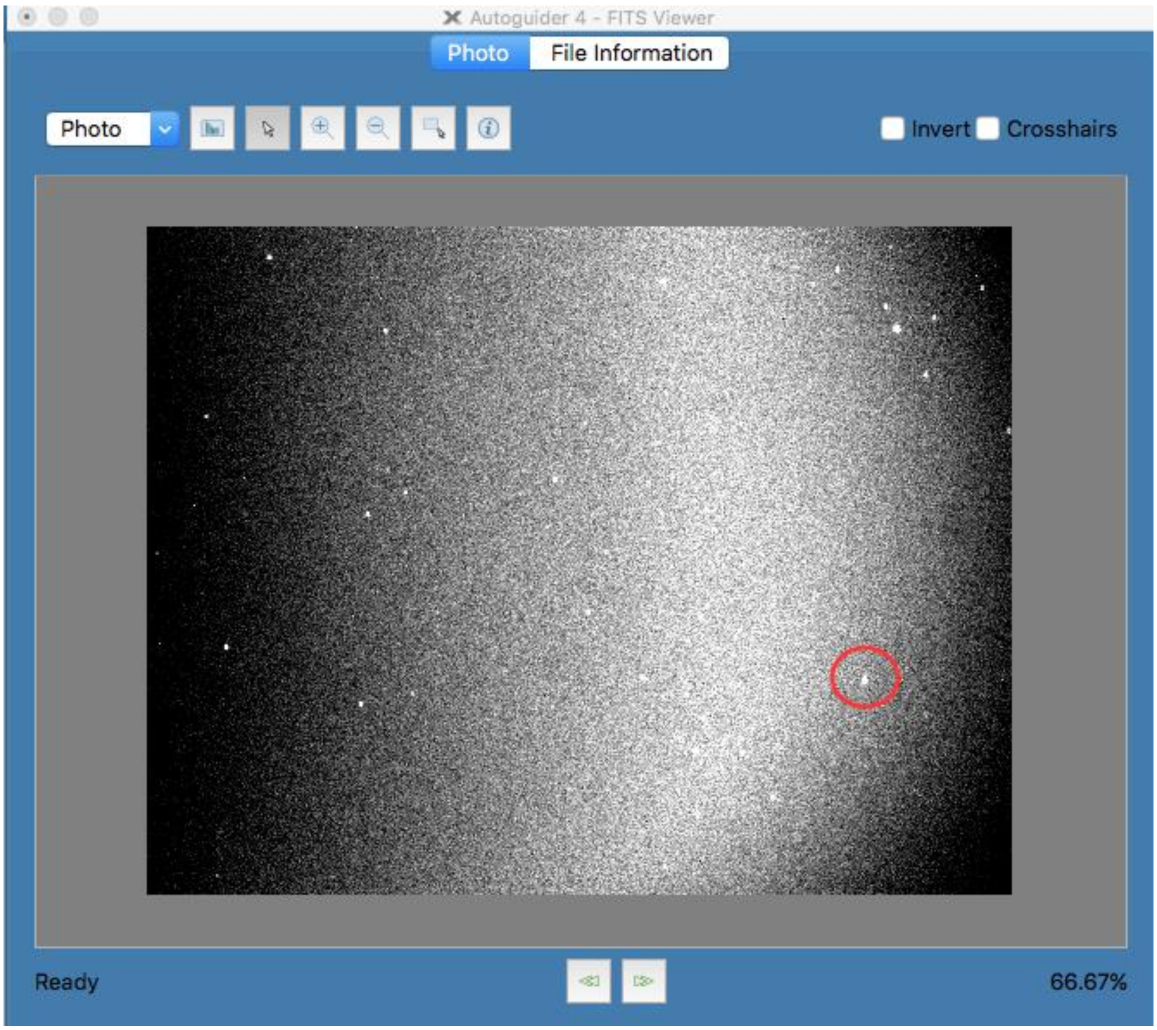
In addition to being gauche, guiding is relatively straightforward and proven. It keeps the mount pointing using a fairly obvious, and closed-loop, manner. It also helps compensate for mechanical challenges and other irregularities. While setting up guiding can present difficulties: much like meridian flips and filter wheels, the efforts people go to avoid it are sometimes excessive. Unfortunately, to get guiding going, you have to choose logical settings for your system and you must calibrate your guider.

The first thing that you have to understand about calibrating the guider in SkyX is that SkyX is not PhD. No seriously. SkyX is not PhD. SkyX's guider calibration is similar to the calibration process used for CCDSoft and has worked for many people over many years. Calibrating a guider in SkyX is fast and efficient, but it can be a little tricky, especially with noisy cameras. It is also difficult to calibrate if you don't understand how it works. Specifically, please don't think that SkyX works like PhD. One more time because nobody ever listens: SkyX doesn't calibrate a guider like PhD does. Really. It doesn't. SkyX isn't PhD. Now, go count the number of threads on the Bisque site started by people who think that SkyX calibrates guiders like PhD does.

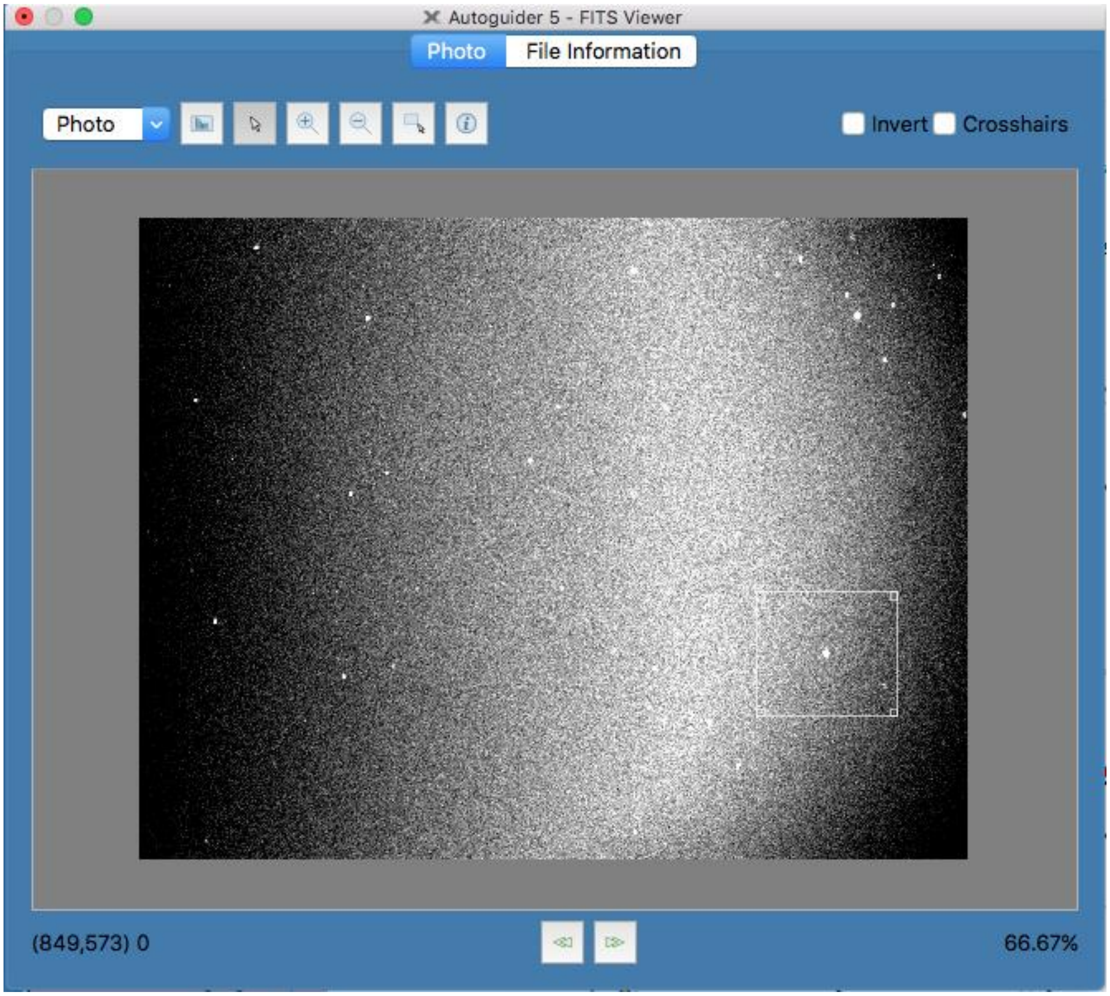
A great explanation of SkyX guiding and calibration is provided by Richard Wright in one of his many blog entries. The process has also been described in many threads on the Software Bisque support forum. The process of guider calibration can be seen in video format here, here and here (around the 47:39 point).

The basic idea behind guider calibration is that SkyX will take a picture and find the brightest thing in the FOV. This brightest thing is presumed to be the guide star. SkyX will then move the mount the requested distance (Paramount) or time (other mounts) in RA and take a second picture. It will then measure the distance moved by comparing the location of the brightest object found in the two images. The routine will then move the mount in the opposite direction in RA and measure that distance by comparing the second picture with a third picture. The routine will then move the mount in the declination axis the request distance/time and take a fourth picture. It will measure that distance. Finally, it will move in the opposite direction in declination and take a fifth image to measure the distance moved during the last move.

Let's try it. First, we'll slew to a location close to the celestial equator and snap a picture with the guide camera:

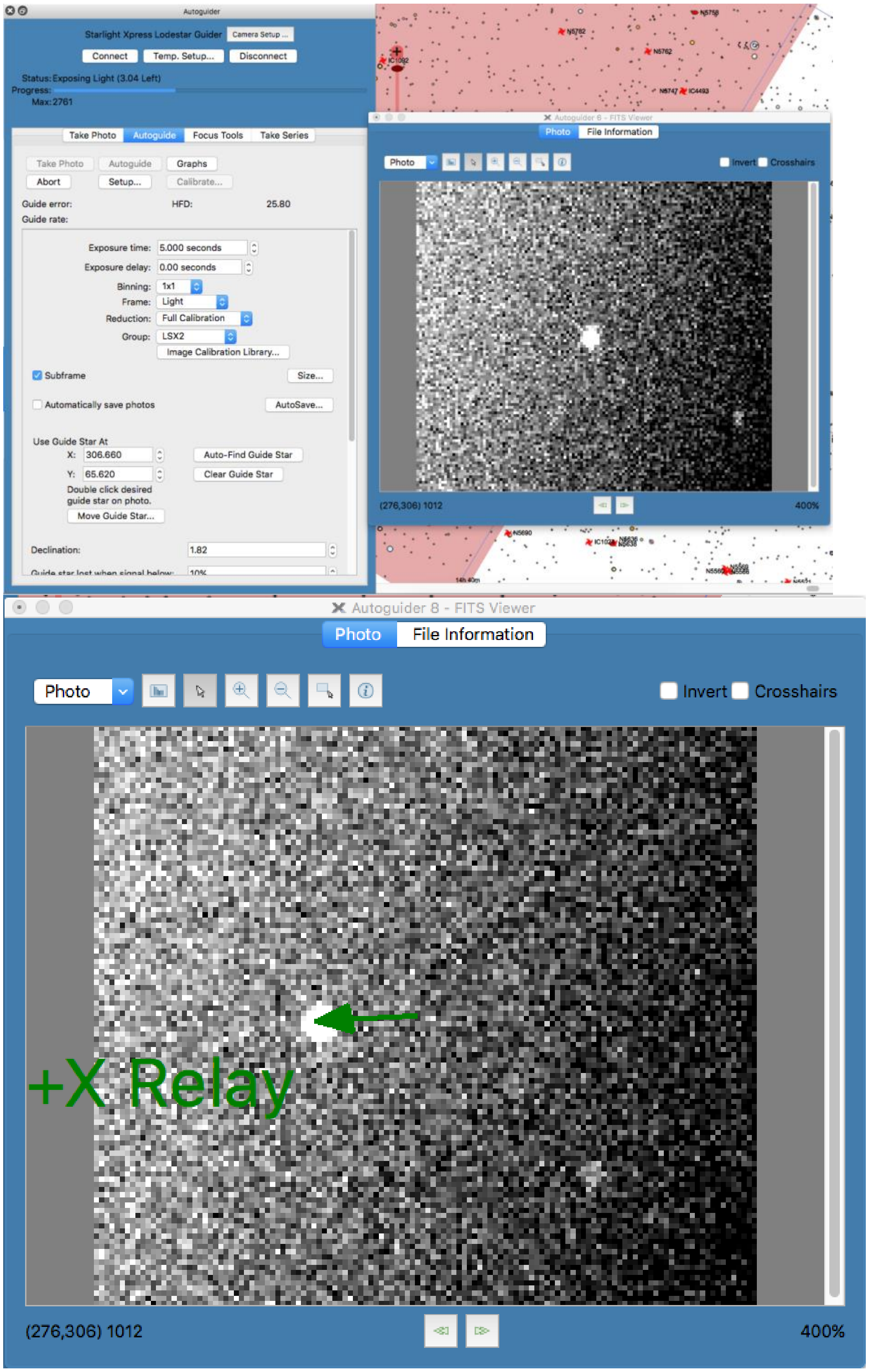


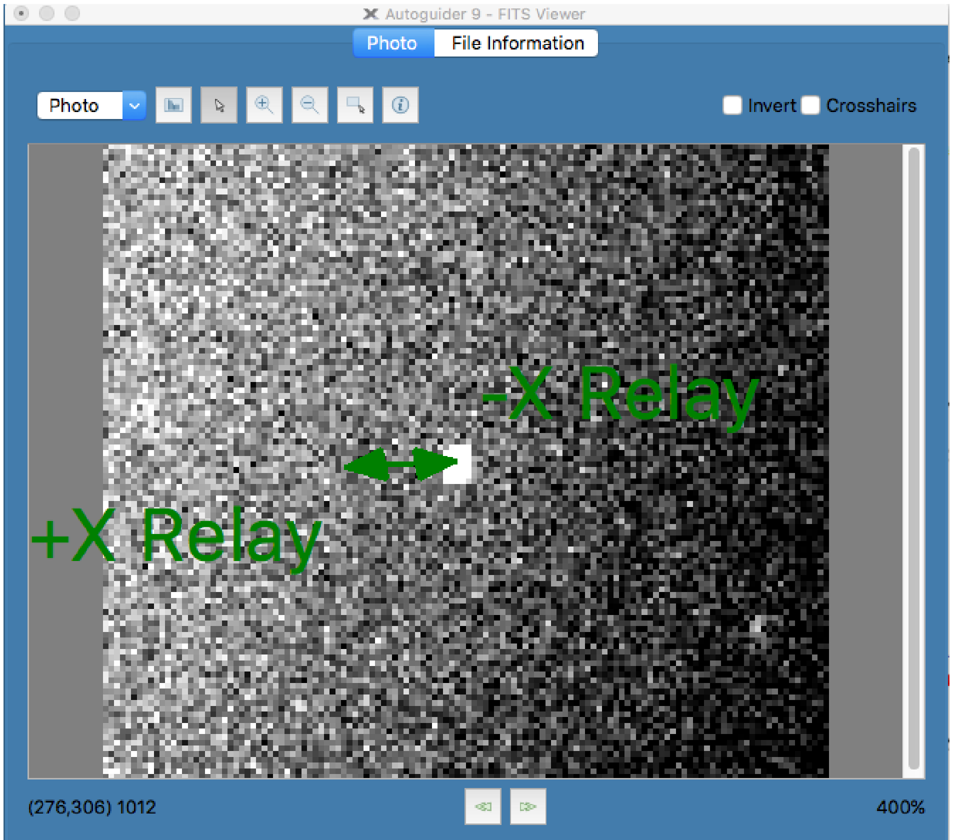
This is an ugly image because I recently rotated this Lodestar X2 camera and have not yet taken new flat frames for the camera. It is, however, calibrated with a dark master to mitigate any hot pixels and other noise. After looking over the FOV, I decided to calibrate on the star circled in red. That star is bright and fairly isolated from anything else of similar brightness. It is also far enough away from the edge of the image. I will now use the subframe selection tool (second button from the right, above the image) to draw a box around the star.



Note that I did not “select” the star by clicking on it. I simply defined a subframe around the star and SkyX will now measure the movement of the brightest thing within that subframe.

The next step is to press the “Calibrate…” button in the autoguider control pane. SkyX will ask me to then confirm my movement distances (60 AS, about 20 pixels, in this example), and the guider will go through the sequence of images & moves as described above. Note that it annotates the move as it goes:


Autoguider
Starlight Xpress Lodestar Guider
Camera Setup ...
Connect
Temp. Setup...
Disconnect
Status: Exposing Light (3.04 Left)
Progress:
Max: 2761
Take Photo
Autoguide
Focus Tools
Take Series
Graphs
Abort
Setup...
Calibrate...
Guide error:
HFD:
25.80
Guide rate:
Exposure time: 5.000 seconds
Exposure delay: 0.00 seconds
Binning: 1x1
Frame: Light
Reduction: Full Calibration
Group: LSX2
Image Calibration Library...
Subframe
Size...
Automatically save photos
AutoSave...
Use Guide Star At
X: 306.660
Y: 65.620
Auto-Find Guide Star
Clear Guide Star
Double click desired guide star on photo.
Move Guide Star...
Declination: 1.82
Autoguider 8 - FITS Viewer
Photo
File Information
Invert
Crosshairs
+X Relay
(276,306) 1012
400%


Autoguider 9 - FITS Viewer
Photo
File Information
Photo
Invert
Crosshairs
-X Relay
+X Relay
(276,306) 1012
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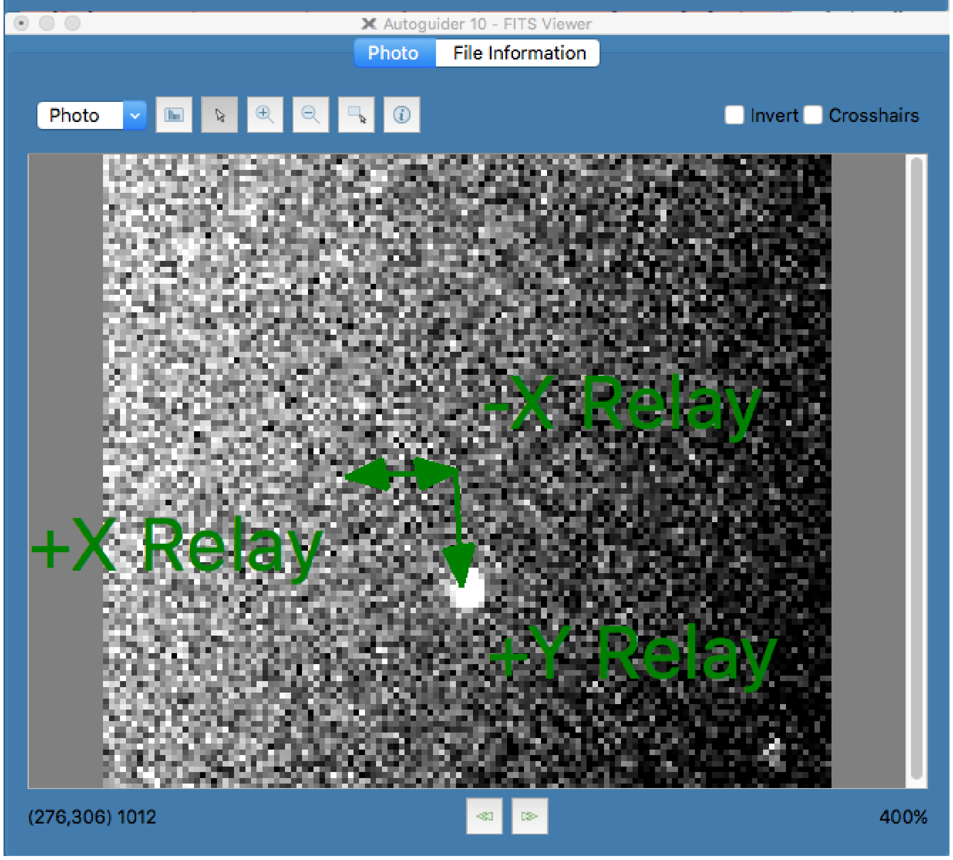
Autoguider 10 - FITS Viewer
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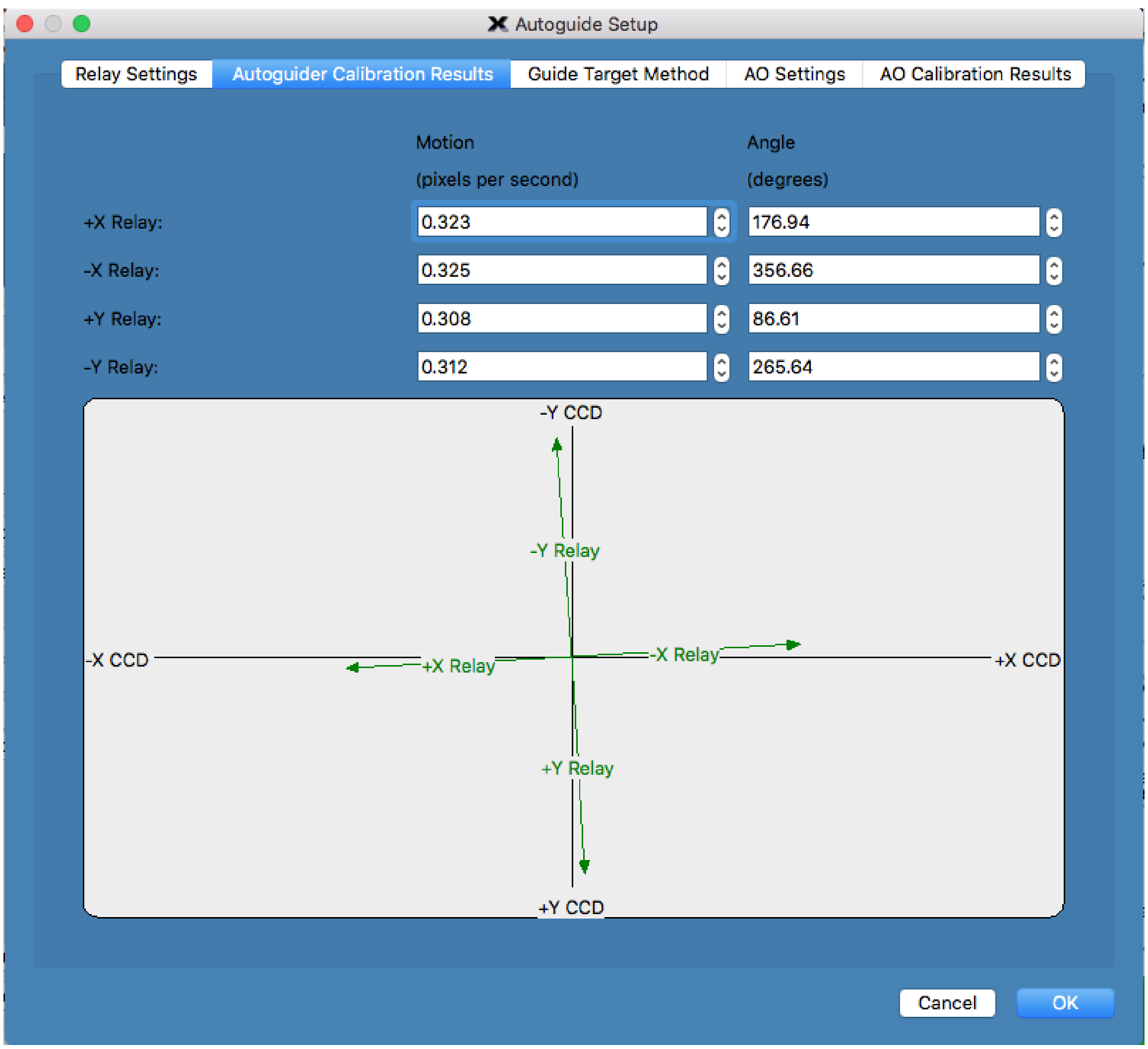
+X Relay
+Y Relay
(276,306) 1012
400%

The mount will then move the guide star back up to the original point with, in this case, a Y- move. Remember that the precise direction of movement will depend on your optics and camera orientation. Regardless, if all goes well, you will see the calibration star move in an "L" shape.

SkyX will then show you the calculated vectors (as shown below). These displayed vectors should be approximately 90 degrees from each other and approximately the same length. They need not be perfectly in line with the mount's axes, but it's conceptually simpler if they are close. If the mount moves at different rates in RA and DEC, you may find the vectors on one axis may be different than the distances moved in the other axis. This can also occur the farther you are from the celestial equator. If the vectors in the same axis have different lengths then your mount may have backlash.



While you're at it, check out the motion values. On a Paramount, you should use DirectGuide, which very conveniently describes mount movements in terms of arc distance rather than time. In other words, the distance column should more-or-less describe your guide camera's imaging scale. In the above example, I'm using a Starlight Xpress Lodestar that resolves approximately three AS per pixel. Sure enough, the guider calibration routine has determined that a mount movement of one AS matches a movement across the camera of approximately a third of a pixel. Moreover, the Lodestar uses odd rectangular pixels and that, too, is reflected in the calibration report.

So, what could possibly go wrong? Unfortunately, lots of things can go wrong. Some of these problems are a lot more common than others.

1.) Noise: If the guide camera is noisy (like a Lodestar…) then you can have hot pixels that show up in the frame. These hot pixels will distract the calibration routine. The calibration routine will then try to measure the distance moved by the hot pixel – which doesn't move – and come to the conclusion that the mount isn't moving. The routine will then suggest to you that you need to calibrate for a greater distance, but that won't work either.

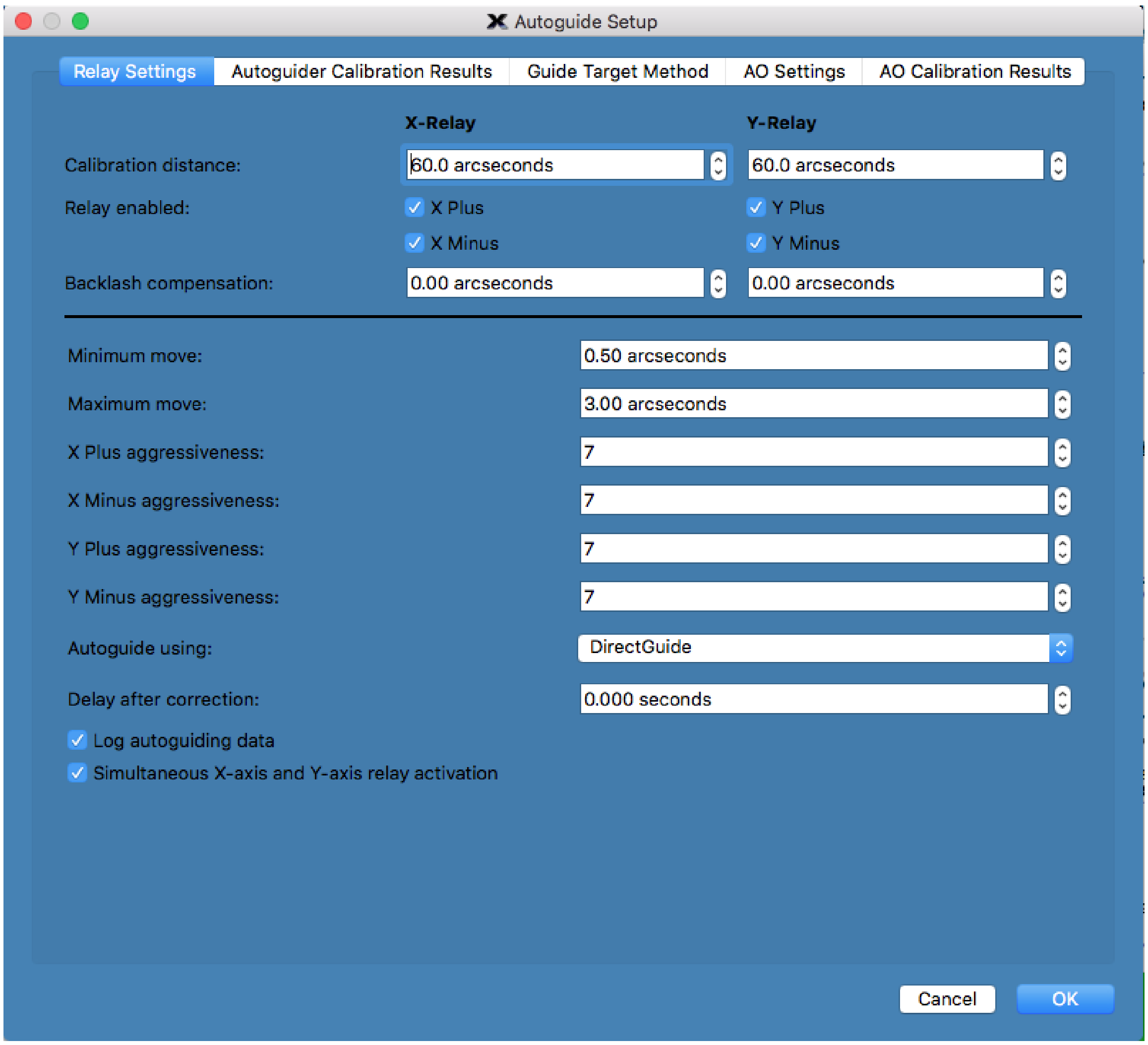
2.) Lurkers: If you aren't careful, there may be bright stars lurking just outside of the FOV. When the mount moves in that direction, if the lurking star is brighter than the calibration star then the calibration routine will measure the vector between the calibration star in the previous image and the newly intruding star in the current image. This, of course, gives you a bogus vector.

3.) Big moves or lop-sided sub-frames: While you want the mount's move to clearly show movement, you do not want the mount to move so far that the calibration star exits the field of view. Similarly, when defining a subframe around the calibration star, you don't want the box positioned such that the calibration star will easily exit the subframe.

4.) Incorrect "relay method" and cable confusion. Traditionally, guiders controlled a mount directly by means of an ST-4 relay cable. The cable transmitted simple on/off commands that were, not infrequently, tapped into the same wires that the hand controller used to slew the mount. More modern approaches send guiding commands through the mount control wire so that no ST-4 relay cable is required. One method is known as "Pulse Guiding" which is supported by most mounts under SkyX. For the Paramount, however, you will want to use a more sophisticated control system called "DirectGuide". Unfortunately, out of the box, SkyX defaults to guiding with an ST-4 style cable and "relay commands". To further add to the confusion, you can switch guiding on & off for each mount axis and the label next to these check boxes reads "Relay enabled".

Setup parameters:

In order to setup your Paramount for DirectGuide, ensure that "DirectGuide" is selected in the "Autoguide using" drop-down menu under the "Relay Settings" tab of the Autoguider settings control panel.



Let's discuss the settings in this control panel.

1.) The Calibration distance should be something sensible. You want the image to show clear motion but don't want to move the calibration star off of the chip. Think about the image scale of your pixels and the size of your chip.

2.) The Relays should be enabled for guiding. When you, later, record a tracking log for Periodic Error Correction, you will turn these off.

3.) There is no need for backlash compensation on a Paramount and there should be no need for RA backlash compensation on most properly functioning German Equatorial Mounts.

The other options require a little more thinking and can be confusing.

1.) Minimum Move tells the guiding system not to bother making a move unless this threshold is exceeded. The primary value is to prevent the mount from twitching back & forth for corrections that aren't really large enough to worry about but, whose movement, might setup instabilities.

2.) Maximum Move tells the mount that, regardless of the error calculated; don't move the mount more than this distance. It serves as a kind of sanity check to prevent the mount from making excessive excursions in case noise or a seeing-caused flutter causes the guider to want to chase a squirrel. A squirrel that will probably disappear in the next exposure.

3.) The aggressiveness values are there to prevent the mount from moving quite so rapidly to make a correction. For example, imagine that you had a heavy load and the mount made a sudden aggressive correction and over-shot slightly. In response, the guider would want to make another aggressive move in the opposite direction. This will then set up a see-saw effect.

    You should think of the aggressiveness as a percentage. An aggressiveness of ten will allow the mount to execute the fully recommended correction. An aggressiveness of five will execute half of that move.

4.) Delay after correction causes the guider system to pause before taking the next exposure. This may prove valuable if you want a longer delay between corrections but have a sensitive camera that might saturate if you force it to take a long exposure. This delay is independent of the camera delay value. In most cases, you can use either.

5.) Log Autoguiding data is useful for diagnostic purposes or for the creation of PEC curves. You can also switch it on or off from the main autoguider control pane.

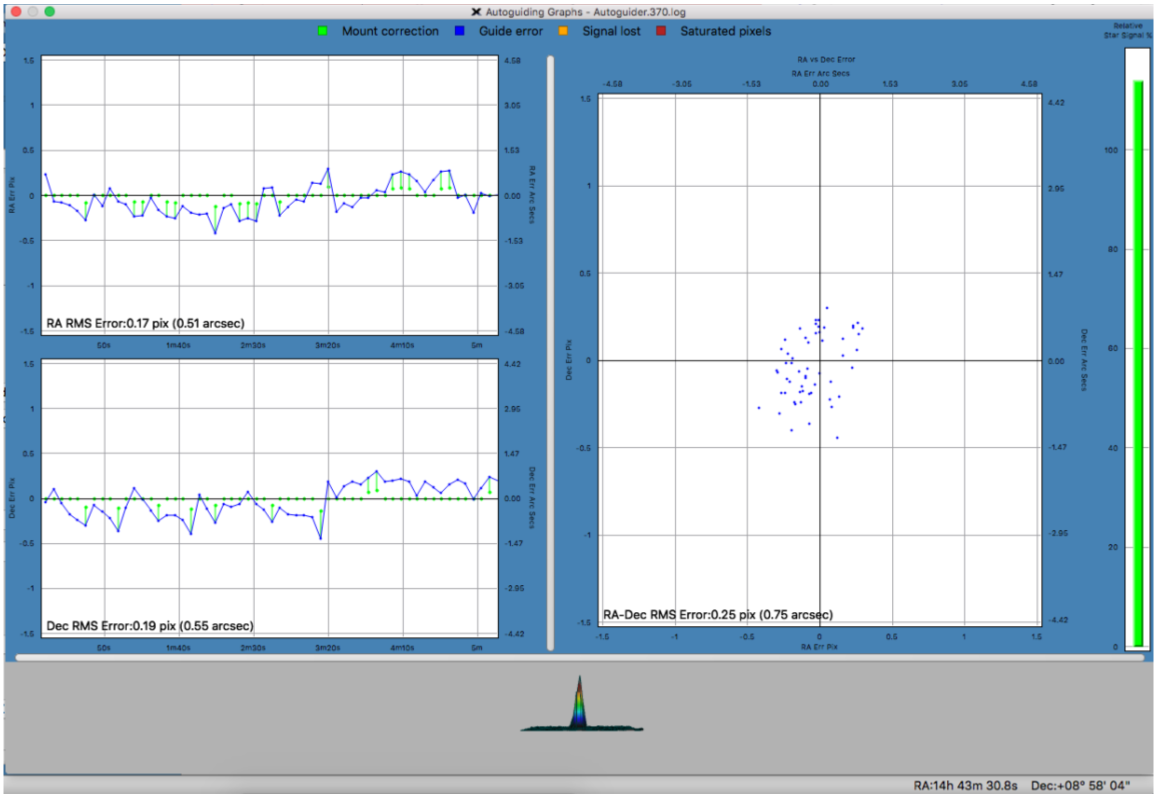
6.) Simultaneous corrections should be checked on a Paramount. Turning it off is for older mounts that can only handle a single movement at a time.

Typically, for a Paramount, the mount moves so smoothly that a lot of apparent guide star movement is caused by atmospheric conditions. The philosophy, therefore, is to move the mount as little as possible. By default, the Paramount already guides at a stately half sidereal rate. Most users find success by setting the aggression to five or six. The Minimum and Maximum move values will be dependent upon your camera's image scale. Take a look at this handy on-line calculator to find some decent starting values. Remember, even though conservative movements are favored, it is possible to become so conservative in your settings that the mount will correct sluggishly and might take a long time to dither when using "Take a Series" (of images). As always, you will have to experiment.

Once the guiding calibration is complete, remember that SkyX will remember the calibration vectors for the future and will also re-scale the declination vectors as you move the mount to different targets across the sky. In other words, so long as you don't remove the guider from the OTA or change its orientation, you will not have to recalibrate. Of course, this may not be possible with large instruments that are used in the field, especially with external guide scopes. Off axis guiders attached to rotating focusers may also require recalibration. Yet, many users are able to go months (or potentially years) between autoguider calibrations.

After you have a solid calibration, guiding itself is fairly simple. Take a picture of the FOV and choose a nice-looking guide star. Do not use the "auto find" button as that merely selects the brightest thing in the image, even if it's a hot pixel. Besides, sometimes the best guide star in the image may not always be the brightest. In particular, you should avoid saturated stars because the centroid-calculating algorithm requires non-saturated pixels in order to determine the true center point of the star. Unlike many mounts, the MyT benefits from a softer touch. When possible, longer guider exposures provide less incessant (and perhaps unnecessary) corrections and also help smooth out seeing-caused fluctuations.

For the purposes of this article, I chose to guide on the same star that I selected above for guider calibration. After five minutes of guiding, my guiding graph looked like this:



While I hope that many of you will achieve better guiding, here in Denver, that's not too bad. There are no strange patterns or wild jumps and the total RMS is about 57% of the imaging camera's pixel (1.3 AS/pixel). Also, if you have followed these guides in order then you have not, yet, performed an accurate polar alignment. As a result, you should see the guider pulling the mount to compensate for drift.

A final few thoughts about sampling: Modern guiding relies on calculating the centroid of a star. In order to do so, it must have a well-sampled star. In other words, the star must cover multiple pixels and not appear too "blocky". If the star is properly sampled, the centroid's location can be calculated to less than a pixel's resolution. This is how guiding can occur with a precision finer than the guide camera's image scale. In the real world, of course, there is a limit to "how low you can go" in terms of measuring a fraction of a pixel. Yet, contrary to popular lore, there isn't really such a thing as a "magic ratio" between the imaging image scale (or focal length) and the guider. You simply want a well-sampled guide star.

As with imaging, over-sampling a guide star may be less efficient, but you can always bin if you want to. So long as the guide star remains well sampled.

On the other hand, if the guider's image scale is so large that the star's image fits within a single pixel (it appears square) then it is impossible to calculate a centroid. Rather, what happens is that if the guide star moves from one pixel to another, then the camera will see this as a huge jump because the majority of the star's light will only fall upon a single pixel at a time. This is interpreted as a leap from the middle of one pixel to the middle of the next. The movement seen will be about the same as the guider's image scale.

New imagers sometimes fall prey to this phenomenon because it is somewhat self-reinforcing. They often purchase a short focal length finder-guider telescope for use as a guidescope because it's cheap, allegedly easy to mount (but not always solidly) and can find guide stars easily. They then may choose a large pixeled guide camera, such as the popular Lodestar (8+ micron pixels). Due to the Lodestar's interleaved readout, common advice is to bin the Lodestar. Of course, binning the camera also increases the camera's apparent "sensitivity" but at the usually unspoken cost of resolution.

If you combine all of these possibilities (an Orion 50mm finder-guider with a binned Lodestar X2) then the guide scope will have an image scale of 20 AS/pixel. Not only is it impossible to calculate a centroid at this imaging scale, it is almost three times more than the MyT's guaranteed peak-to-peak performance. In other words, this guider setup will do nothing – which will be reflected in the guide chart as a single central pixel and a flat line in each axis. Unfortunately, to an inexperienced newbie, that graph will be interpreted as confirmation of their awesome guiding performance.

In summary, SkyX's guider calibration routine does require some knowledge and care, but it's a proven technique that has been used by thousands of users for years. Keep in mind how it works and, if you have problems, you now have the knowledge to start to troubleshoot your issue.

Best of luck and, remember: The SkyX is not PhD.