

What to do When PHD Guiding isn't Push Here Dummy

Craig Stark

I designed [PHD Guiding](#) to be as simple as "Push Here Dummy". When everything works, it's great (and quite often that's the case!). But, what do you do when it doesn't work? What do you do when you've spent night after night trying to get it going, only to meet frustration at every turn? One option is to throw in the towel. Let's cross that one off the list. Another is to turn to Internet groups like the [forums here on Cloudy Nights](#) the [Yahoo Group](#), or send me an e-mail. Both are solid options. A third option is to diagnose it yourself. The articles here are designed to let you do just this. If they don't get you going, you'll at least know a lot more about your problem making it easier for others to help. While I can't ensure you'll get sub-arcsecond accuracy with perfect stars every time, I can say that I've never tried to help someone that didn't get guiding up and going. I've helped a lot of people along the way and odds are pretty good that your solution will be somewhere in here. I should note at the outset that many of these apply to any of the other excellent guide packages out there as well. So, let's dive in!

The first thing to know is that there are a number of reasons why you might not be getting round stars that have nothing to do with PHD Guiding itself. Before diving into various settings, we need to make sure that PHD is actually anywhere near the problem. Having now helped hundreds of people with their guiding, I can say that the vast majority of the time, the issues don't stem from various parameters to set in PHD. I know what you're thinking - "Not me! It must be the parameters!" Do yourself a favor and let's walk through the other options first as to why you might get poor performance or calibration issues that have nothing to do with hysteresis, aggressiveness, etc. Read through each of these to try to determine which lines up with your issues the best. Only once you've ruled out any of the options below should you turn to tweaking with the parameters.

Calibration works but all my stars are oblong

Now if all your stars are oblong and all the non-roundness is in the same direction, you could very well have guiding issues that parameters would help with. Before you dive into this, though, there is a very important check to make and that is to determine that it's not coming from something in your optical chain or something mechanical. The first step in this is to make sure that your collimation is good. If you throw a high power eyepiece (you know that thing you actually put your eyeball up to!) and look at a bright star defocused a touch, do you see nice concentric circles or are they off-center? Rack to the other side, do you get the same thing or was it oblong one way on one side and now oblong another way on this other side? Non-concentric circles point to mis-collimation and different orientations of footballs point to astigmatism. If you don't have points of light hitting your sensor, PHD won't help. Work on those optics.

If the optics look good, head on to a bright star but one not straight up in the sky and take a short exposure with guiding off. Now rotate your camera 90 or 180 degrees and take another one. In a second or so worth of exposure, your mount shouldn't have much error (if it does, it's time to think about a new mount!). If exposures here are showing oblong stars, you've got an issue with your sensor not being lined up with the focal plane. Examine the direction of the problem in one image and then in the one where you rotated the camera. Does the problem go in the same direction or did it move? If it moves, it likely means the error is wherever "down" is, physically. Gravity is doing what it does best and is pulling on your rig. Any flex in drawtubes, focusers, adapters, etc. will pull your sensor out of square. If the problem though is always in

the same direction relative to the sensor even though you rotated the camera, you're looking at your sensor not being square relative to its mounting (i.e., relative to the camera body, it is tilted). Again, there's not going to be anything better guiding can do about this.

My stars are oblong and PHD's graph shows jumps in RA or Dec

On each sample of the star, PHD tries to figure out where the star is relative to the lock position and it then sends a correction to the mount to reduce the error. If a big jump happens, it'll be because the star moved a bunch without PHD doing anything, because one of PHD's commands made the mount move more than it should, or because PHD's demonically possessed. For now, let's throw out the last option. Bugs do happen in code, but this part of the code has been stable for so long, the odds are it's something else. What could it be?

It might seem odd to think that the star moved without PHD's intervention, but that actually does happen to people with some frequency. How? Slop in the gears is a prime culprit. Gears never mesh perfectly and the small gap will give the gears space to rock back and forth. As this happens, the scope moves and thus, to PHD, the star moves. Remember, one arcsecond is 1/3,600th of a degree or about 1/7,200th the width of your thumb at arms length. That's not much! Why would it rock in the gears? Typically, this comes from people being a bit obsessive about balance. If your scope is perfectly balanced, it's very easy to push it to one side and then the other in the gears. Unbalance it a bit and it's biased towards one side (east is better than west for RA). Now, a light touch or a light breeze is much less likely to bring on this mechanical problem. Both axes should be moderately imbalanced.

A second issue that comes up is crud (technical term) in your gears. This can cause far more rapid motions than are expected, leading to a clear jump (the bits of metal change the shape of the gears as you ride over them). Cleaning them out or ignoring these occasional jumps are your only real fixes. You'll know if you have them if you generate a periodic error (PE) curve (see below).

I watch PHD's graph and display and all looks great but my stars are still oblong

So, PHD's graph shows small errors that are routinely fixed. When you watch it, the star stays in on or very near the crosshairs. Thus the box (where PHD thinks the star is) is routinely nicely lined up with the crosshairs (the lock position). Yet your main image shows issues. One is great, while the other is not.

PHD is doing its job keeping the guide star in place. All your data - the graph, probably small errors show in the log file, the display - say that guiding is good. There are two options here to consider.

First, you must consider if you're asking too much of your guiding. If you're using a very short guide scope and trying to image on a 14" f/10 primary scope, you're pushing the notion of "guider focal length doesn't matter" a bit far. A longer focal length guide scope or a shorter focal length image scope is probably in order. With that focal length on your main scope, you're probably even below a half an arcsecond per pixel there. Unless you've got a very nice mount and steady skies or really know how to work your gear perfectly, think long and hard about cutting that focal length down. If you're just starting out at this, get that focal length down considerably as guiding well below an arcsecond of error is not trivial. We'll come back to this later.

There's another real possibility here, though, and that is flex. Determining if it's flex or poor guiding can be fairly simple. One way is to just take a 30 minute or so series of fairly short exposures (1 minute or less) and scroll through them (e.g., using Nebulosity's Preview tool). Does the drift you see go back and forth in one direction (RA) only? If so, your mount's periodic error isn't being taken care of despite the seemingly good behavior by PHD (are you imaging at very long focal lengths?).

If not, and if the drift all seems to be in one direction, odds are you've got flex. Remember, all data pointed to PHD controlling both the RA and Dec error and yet your main image is showing this steady migration of the stars across frames. The guide star is stable, but the main image moved. The answer is that they are moving relative to each other and the only way that's going to be happening is if something mechanical is causing it. Your focusers, rings, and even OTAs themselves can be distorting. As the mount turns, the direction gravity is pulling and the load it's placing on the gear changes, leading to this differential flex. No matter how well PHD holds the star in place, you'll get this error and there is nothing PHD can do about it. You need to work on getting things more sturdy. (Note, off-axis guiders are very unlikely to suffer from this problem.)

My stars were great for one target and poor on another in the same night

PHD works by knowing how the star moves for given amounts of RA and Dec motor activity. If you slew to a different portion of the sky, the vectors PHD uses must be updated by running the calibration again. You'll need to check "Force calibration" in the Advanced, select your new star and hit "Guide" to have PHD recalibrate. If you've done that, start thinking about balance and flex again.

Box 1: Interpreting PHD's log file

If there is any place that will hold all the secrets to your guiding woes, it's PHD's log file. In there, you can find clues to the source of most any problem. You still need to do your detective work, but it has invaluable information to help you. So, what's in there and how do we decipher it?

The first thing to do is to make the log file. Before you calibrate on a star, enable logging either via the Advanced panel or via the Tools menu. Personally, I leave logging enabled at all times. A small amount of hard drive space is all it will cost you and the data can be invaluable.

With that out of the way, we can start to look at it. The log file is a simple text file you can open up in any text editor (Word, WordPad, NotePad, TextEdit, etc.) The best way to open it though is in a spreadsheet program (Excel, OpenOffice, etc.) or one of the various log file analyzers. If you're using a spreadsheet, tell it that the file is a "CSV" or "txt" file and that it's "delimited" with commas (CSV = Comma Separated Values).

With the file open now, you'll see a top section that has your calibration data (see Box 2 for more on this). After that, you'll see a long list of values. Each row is a separate time point (a separate guide frame) and its associated error and corrections. At the top of this list is the name for each column.

1. Frame = image number
2. Time = Seconds since guiding began
3. dx = Number of pixels the star is from the lock location in the horizontal axis
4. dy = Corresponding number for the vertical axis
5. Theta = Direction of error (radians)
6. RADuration = Milliseconds the RA motor was turned on to correct for this frame
7. RADistance = Amount of error specifically in RA (in pixels)
8. DECDistance = Milliseconds the DEC motor was turned on to correct for this frame

9. DECDistance = Amount of error specifically in DEC (in pixels)
10. StarMass = Summed brightness of the guide star.

The RADistance / DECDistance and the RADuration / DECDuration columns are the ones to focus on the most as they show the error and corrections PHD made that we care about. Are these errors continually small and yet you have drift in the main image? Think about flex. Are the errors building up despite PHD sending large durations? Think about whether the guide signals are getting through (or whether you're limiting them too much). Are there sizable errors building up but the distance columns are zero? Check your minimum motion parameter. Are there lots of Dec corrections in the same direction? Odds are your polar alignment is off. Did guiding go bad at some point and the StarMass column showed a real drop? Think about whether clouds could have obscured the star.

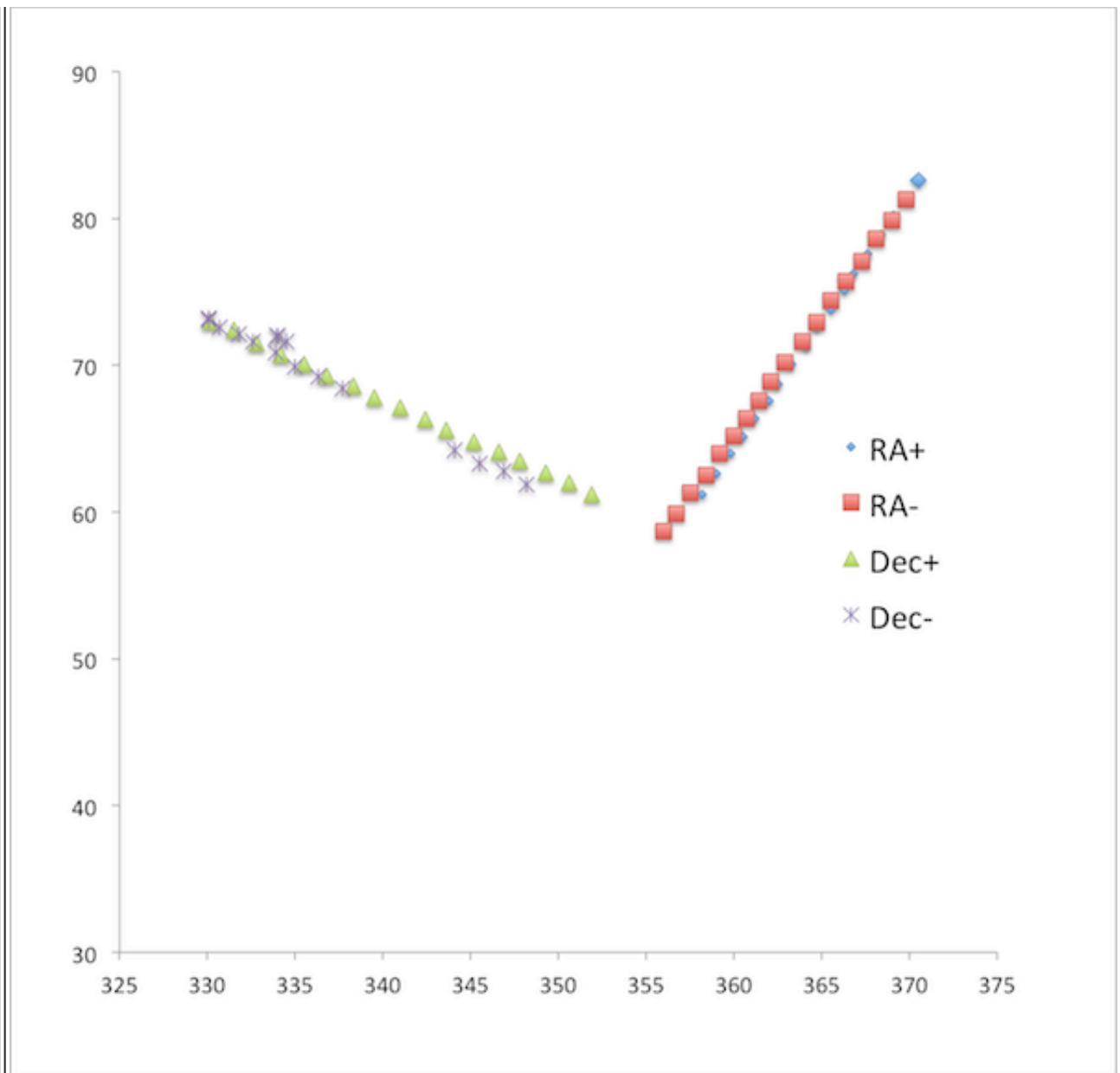
Calibration is failing - why?

PHD's calibration process works by repeating a loop of taking an exposure, finding the star, and moving the scope a bit, each time figuring out how far the star moved from the original "lock" position (where the crosshairs are). It repeats this until the star has moved "enough" (defined as 5% of the height of the screen). Calibration fails when the star doesn't move enough. So, we need to ask why?

Box 2 will help you understand the calibration portion of PHD's log file. If you plot the data using a spreadsheet (see Box 1), you can quickly see if there is something amiss. If you're not plotting, it really helps to have had your guide camera squared to RA and Dec so that one lines up with the x-axis and the other lines up with the y-axis. Ideally, RA- will "unwind" RA+ and end up in pretty much the same place where it all started. Dec+ will move perpendicular to the RA motion (e.g., if RA was mainly along the x-axis, Dec+ is along the y-axis). Dec- will likely end up not where you started (the result of backlash in the Dec gear), but should be along the same line that Dec+ formed. What might you see that doesn't look like this?

Box 2: Interpreting PHD's calibration data

The top of your log file, you'll find the calibration data. You'll see the position of the crosshairs ("lock" followed by two numbers) and where the star is when the calibration process begins. After that, you'll see a number of lines showing how the star is moving when RA+ (west) is applied followed by an equal number of lines showing how the star is moving when RA- (east) is applied. For each calibration step, you'll see the position the star was at. Here, "x" is the horizontal position, "y" is the vertical position, and "dx" and "dy" show how far it moved in x and y from the lock position (delta-x and delta-y).



This is the first spot to look not only for calibration errors, but also for guiding errors. If you were to plot these numbers (see Box 1), it might look like what's shown here. Here's where to spot errors. First, is it actually showing motion of the star? Second, does RA- follow along the same line as RA+? Does the Dec- follow along the same line as the Dec+? Both should "unwind" the positive direction. Is there an angle formed between the + and - versions? Finally, do RA and Dec form something close to a right angle? (Note, you'll need to make sure your plot box is square and the range on each axis is the same to really see this.)

If you'd rather not plot the data, you can just look at the numbers to see things like whether, after the RA- segment, you end up near the start position. If you're not plotting, it's a lot easier if you had your guide camera square so that RA and Dec line up with x and y (or y and x). If RA+ moves mainly in x, does RA- move the opposite way in x? Does Dec move in y and not x? It should...

The star doesn't move much at all

PHD is sending guide commands but the star doesn't move much. One real possibility here is that the guide commands aren't actually getting to the mount. Check that you've selected the right option in the "Mount" menu. If you've selected "on camera" but don't have a cable going from your camera to the mount, you're not setup right. "On camera" means you're using the ST-4 port on the camera and that's what PHD is telling to move. At this point, use the "Manual Guide" tool to send guide commands to the mount. These will be small, but you should be able to hear your mount's motors change as you do this (a stethoscope or a rubber tube may help).

Are you using the ST-4 port and nothing gets through? Check that your mount's controller is setup to actually listen to the guide port. Some mounts (e.g., the Losmandy Gemini) need to be in "Photo" mode to listen to this port at all. PHD is sending the guide commands but the mount is ignoring them.

Are you using the ST-4 port and only South gets through? This seemingly odd situation comes up more often than you might think. It's a cable problem. SBIG guiders expect a "crossover" RJ cable whereas others expect a "straight" cable. If you hold your RJ cable so that the two ends face the same direction and look at the colors of the small wires inside, do they go in the same order (straight) or reversed so that if you tried to plug them into each other, the colors would line up (crossover)? Unless you're using an SBIG camera, you most likely want a straight cable. (Note, the Takahashi adapter to go from their DIN to an RJ plug acts as a crossover cable and expects to be plugged into an SBIG style camera.) Note, two crossovers joined form a straight cable.

The star moves, but not nicely back and forth. Dec isn't perpendicular either

PHD is sending commands to speed up and slow down your RA motor but the star doesn't come back to the same spot. If you plotted it, the RA lines form a "V". There can really be only one answer to this problem and it'll go along with having some of that same motion show up when Dec is calibrating. PHD is going to assume that RA+ and RA- do opposite things. Yet, the calibration is showing that while they move in opposite directions to some degree, there is another component to the motion that is happening regardless of whether RA+, RA-, or even Dec+/- are engaged. That star drifting because you are not well polar aligned. Being off the pole is what causes Dec drift and if you're spot on with your alignment, you don't even need Dec guiding. A small misalignment is fine (and some do it intentionally to keep the gears loaded), but if you're seeing a "V" during under a minute of calibration, you've got way too much drift (drift that PHD thinks is the effect it's having on the star by turning on the motors!). You need to work on that alignment.

At times, users will insist that their alignment is spot-on and that they've done a three-star alignment in their GOTO system to make sure it is. Three-star models are great in that they use enough data points to figure out not only what error exists in your "scope down" position (one star needed for this), but also how far you're off the pole (and what kind of non-orthogonality you have your mount). These data points are used by the controller to get your GOTOs to be spot-on despite your polar misalignment. But, once there, the mount just has the RA motor move at 1x and move along the RA axis. Yet, to accurately track, you'd need both RA and Dec to move as, by being off the pole, you've taken a step closer to being an alt-az mount instead of an equatorial one. Search the web for drift alignment tutorials or iterative GOTO alignment tutorials. Once comfortable with them, they won't take long and your guiding (and shots) will be a lot better.

Calibration works on other nights, but not tonight and my signals are getting through

Remember, PHD is looking to have the star move by 5% of the screen size. Did you change guide scopes

to something of a shorter focal length? If so, it's going to take longer to get the star to move that much. Likewise, are you imaging nearer the celestial pole? If so, it will take longer guide pulses to get the mount to move. Odds are that under these circumstances, increasing the "calibration step size" in the advanced panel will clear things up. This will lengthen the duration of each pulse during calibration to get more motion out of each step.

One last note here is to check your guide rate in your mount's controller. When you're guiding by hand, a 0.5x rate may be nice (which amounts to the mount tracking at 0.5x or 1.5x). You're not helping PHD any by this and you're just increasing the calibration time and correction time by using anything other than full-speed tracking (1x).

Diagnostic tools

If the cookbook approach above doesn't solve your issues or if you want to know more about what's going on, it's time to turn to some tools of the trade that will help you understand what's going on. The most useful bit of information you can have is the log file PHD will generate if you ask it to (Advanced panel or Tools menu). Box 1 goes over the basics of how to read the log file. Let's use it here to start some diagnoses.

What am I up against? Generating a Periodic Error Curve

A key thing to determine is just what kinds of errors PHD is having to correct for. To see this, we need to generate a Periodic Error (PE) curve. Get things going and get PHD calibrated, ideally using a star on the meridian. If it's off the meridian, note the Declination angle of the star you're using as this will let you convert the error into absolute arcseconds. Once all setup, stop guiding and head into the Advanced panel and check "Disable guide outputs". What this will do is tell PHD to do everything it would normally do, but to skip the part where it actually tries to fix the error. While here, make sure logging is enabled.

Now, start "guiding" on the star as you normally would. You'll find the box moves as the star moves and that it will drift away from the lock position. Hopefully, after a bit, it drifts back (if not, your polar alignment needs work). Let this go for at least 10 minutes - ideally a half hour or so. Then, stop guiding and shut things down and copy the log file to the machine you'll be analyzing things on.

There are several excellent log file analyzers out there and you can feel free to use them. They can automate this process nicely. If you're using a spreadsheet, though, you can still get great information by simply plotting the RADistance column in a line graph. This will show you the error in RA over time. To get a bit fancier, do an X-Y plot with the X being the Time column and the Y being the RADistance column. To get fancier still, convert the RADistance column into arcseconds using the formula:

$$\text{Arcsec per pixel} = \frac{206.265 * \text{PixelSize}}{\text{FocalLength} * \cos(\text{StarDeclination})}$$

$\text{Arcsec of RADist} = (\text{RADist} * 206.265 * \text{PixelSize}) / (\text{FocalLength} * \cos(\text{StarDEC})) = \text{RADist} * \text{ArsSecPerPixel}$

If your star is on the meridian, you can skip the $\cos(\text{StarDeclination})$ bit as that amplifies the error to correct for how far you are off the meridian. While you're at it here, make another plot for the DECDuration column.

Now, have a look at these. Ideally, your DECDuration one will be centered on 0 and bounce around just a tiny bit. Polar misalignment will be indicated by a steady drift. If you see jumps in there, remember it's not PHD's fault (as PHD isn't sending any guide commands). Something caused the star to move a whole bunch right then. Did it jump in RA as well? Think about whether the mount could be rocking in the

gearsâ€¦

Turning back to the RA curve, the ideal curve would be a smooth sine wave, gradually undulating up and down. Is it just going up and down or is there a constant drift to the sine wave pattern? If so, again, your polar alignment is off. Outside of that, are there big spikes in the curve or areas with very rapid changes? If so, your worm gears are not smooth. Since guiding works after the fact (after the error has been made), rapid errors are tough to correct for as even in one sample, a sizable problem may have built up. Start thinking about cleaning and re-greasing those gears. How big is the error overall? Are we talking numbers closer to 10 arcseconds or closer to 100 arcseconds? If the latter, start thinking about whether trying to image at 0.5"/pixel is really reasonable on this mount.

At this point, go back to (or generate) a log file with guiding still enabled and do the same plot. This will show you how much error remains and comparing the two will show you how much of the error has PHD eliminated.

You can take PE curve analysis a lot further once you get into analysis packages like PEAS. These packages will also do FFT (Fast Fourier Transform) analyses on the curve to determine what frequency components are inside your curve. This kind of analysis can help you determine where the error is coming from. Not only will your worm gear be a source of error, but any other shafts and gears along the way will introduce their own error (the worm is just typically the largest). For example, on my Losmandy G11 mount is known to have an error with a period of 76 seconds that stems from issues in the worm block. As we can see in this analysis by PEAS, my particular mount has this, but not in copious amounts. So, I can know where I should start looking (and where I can ignore) if I want to tune things more and give PHD less it has to correct.

Using the log file

Box 1 above showed you how to start looking at the log file (you did remember to turn on logging, right?). If guiding went amok in the night, use the timestamps from your main images to figure out when and then look in the log file. Do you see anything around that time? Did the star mass drop a bunch? Did PHD lose the star? Was it sending guide pulses, but they were the max amount allowed (according to your Advanced settings)?

Using the graph

PHD can plot in real-time the current RA/Dec or dx/dy error to let you see how things are going. Use this to see if there is constant drift or if it spikes at times. It will also report the RMS error (in pixels) and an opaque "Osc-index" term. That term is the probability that the current RA guide error is in the same direction as the previous one (it counts the "different" and "same" side RA pulses). Were there no PE in your mount, the ideal value would be 0.5. All mounts have PE and so the ideal probability is less than 0.5. As you move up (or down) the PE curve, you'll keep making guide corrections in the same direction and it may be quite some time before you flip to the other direction. Very smooth mounts will have low ideal Osc-index parameters. Mounts with rougher PE curves will have higher ideal ones. There is no clear ideal value here, but values in the 0.25-0.4 range are typically good. It will at least let you monitor the effects of your changes.

So, what parameters should I adjust?

If you've gotten this far and are still having issues, it's time to think about adjusting parameters. OK, fine,

even before this point, you might want to adjust some parameters. Which ones and what do they do?

Parameters everyone should think about

The defaults are there for a reason and they work well for most, but there are some parameters that all users should think about a bit.

- **Calibration step size:** This parameter controls how long a pulse PHD sends during calibration. The exact value here does not matter. You just want something that will make calibration take a reasonable amount of time. Here, I define "reasonable" as more than about 7 steps and fewer than 40. If it is taking a long time to calibrate, increase this parameter. If it's taking 2 steps, or something very small, decrease it. If you don't mind it taking 50 steps, so be it. It's only when it takes a very small number of steps that it might affect guiding accuracy. But, if you're guiding with an off-axis rig at 3000 mm of focal length, the stock setting will make the star shoot off the chip so fast you'll want to drop it.
- **Min motion:** This parameter controls how many pixels of motion PHD must see before a guide command is sent. If you're imaging with a finderscope you'll want to send things with a small fraction of a pixel worth of error. If you're on that 3 meter rig, you will have to tolerate a lot more and probably won't want to send a guide command unless it's at least a half pixel worth of error. Figuring out the sampling on your main scope and on your guide scope using the equation above will help you dial this in.

OK, what's after those?

After these, the next ones to consider are the Dec guide mode / algorithm and the RA aggressiveness and hysteresis.

- **Dec guiding:** If you're perfectly on the pole, you won't need to guide in Dec. If you are off, you'll likely need it. If you're sure of the direction, you might as well tell PHD this. It will only send Dec guide commands in that direction and will veto any in the other. Assuming you don't know the direction and it's set to "Auto", you have two algorithms to try. "Resist switch" will try to guess the drift direction and only send guide commands in that direction. If enough evidence builds up that it's wrong, it'll change its assumed drift direction. "Lowpass filter" won't do this guessing, but smooths the Dec guide commands out over time, sending a running average guide rate rather than the current error.
- **RA guiding:** In RA, we need to correct in both directions routinely (unlike Dec). If you want to smooth out the guide commands more, you can increase the hysteresis (amount of the last guide command factored in) and/or decrease the aggressiveness (amount of the current error factored in).

Conclusions

Well, there you have it. That's quite a bit of troubleshooting for something that's supposed to be "Push Here Dummy". Very little of it, though, is in PHD's or any other guiding program's control. Balance, flex, etc. can all wreak havoc on your guiding accuracy. If you don't get those under control, you'll be fighting guiding at every turn. If your guide commands aren't getting to the mount, you'll be fighting things (and losing every time). If your polar alignment isn't decent, you're asking guiding to constantly pull out substantial errors. If you can get your mount physically in good shape, your guiding package, be it PHD or something else, is going to have a much easier time getting those stars round. Hopefully, this has helped you understand both a bit about how PHD works and about how to get it working when all seems

lost.

Craig