Why Self-Guiding is Essential

by Alan Holmes, Ph.D.

An amateur new to CCD astronomy is confronted with trying to select a camera from a large number of possible choices, with a bewildering selection of features to choose from, and at a range of prices that seem steep. Some of the features may seem to be frills, and not necessary to get good results. Self-guiding is one such feature which may not seem necessary since CCDs can image deep sky objects in just seconds. Self-guiding, though, is not a frill - it is absolutely essential to obtaining excellent images of faint objects, as this section will illustrate.

When a CCD is used to image deep sky objects, such as a nebula or galaxy, the amount of light collected by each pixel is proportional to the length of exposure, the area of an individual pixel, and the inverse square of the F/number of the optical system. For example, let us define a figure of merit as being just this:

Merit = exposure * pixel area (in microns squared) / (F# * F#)

I will also make the following statement, which I can easily prove with a variety of images.

"An ST-6 at F/6.3 in 60 seconds can get a pretty good image of most popular objects."

Let's see what this means: an ST-6 uses a CCD with a pixel size of 23 x 27 microns, so the figure of merit for a "pretty good image" is:

Merit = 60 * 23 * 27 / (6.3 * 6.3) = 940

Of course this approach is a simplification - a very accurate figure of merit would take into account the dark current and readout noise of the CCD camera. I will ignore these factors for this discussion.

For our ST-7, the figure of merit would be only 123 since the pixels are so much smaller. This implies you need to take an exposure about 7 times longer to get a comparable signal level as the 60 second ST-6 image. And, since the pixels are only a third as large, trailing due to guide error would be objectionable after only 20 seconds. The problem starts to become apparent - small pixels mean long exposures to get good images, along with increased sensitivity to guiding. This was the reasoning that led SBIG to put self-guiding in our popular ST-7 and ST-8 camera: we wanted to make the longer exposures required easier. Do not be mislead by advertising - even good PEC correction will only allow you to expose for about a minute before trailing is noticed in most cases. A minute is not long enough!

Once one has decided to implement some sort of automatic guiding to enable longer exposures to be captured, one has a variety of choices. Four approaches are guiding with an autoguider using a radial off-axis guider, guiding with an autoguider using a separate guide scope, Track and Accumulate, an SBIG patented technique where multiple images are added together with shifts to produce a longer equivalent exposure, and self-guiding. Let us look at the advantages of each.

Radial off-axis guiders have a severe problem in that a small prism or mirror is used to pick off a tiny portion of the light to direct to the eyepiece. Guide stars tend to be dim, and one is forced to rotate the assembly to find a guide star. When one rotates the assembly, the star motion directions (in response to guiding inputs) also rotate, and one is forced to recalibrate the autoguider quite often. Also, the dim stars force some autoguiders to require very long exposures, negating their ability to compensate for periodic errors and drive hops. In short, radial guiders are clumsy to use.

Another alternative, a separate guide scope, works quite well for refractors and Newtonians, but poorly for SCT systems. The problem here is differential deflection - slight tilts or wobbles of the primary mirror can shift a star position significantly on the imaging CCD. The mirror tends to shift since the gravity loads change as the telescope counteracts the earth's rotation. (Don't laugh, but some SCT primary mirrors are mounted on springs)! Our experience with differential deflection is that one can only go about 5 minutes before it becomes a problem. Also, by the time one has bought an autoguider, and a separate guide scope with mounting rings, one has spent more money than an ST-7 costs relative to its cheaper competitors. And you still have to manually find guide stars.

Track and Accumulate is a good technique at fast F ratios or with large pixels. The key to Track and Accumulate working well is to be able to use an exposure long enough that the noise due to the photon flux in the sky background dominates the readout noise. This technique is particularly effective for the ST-6 with its large pixels, where 30 seconds at F/6.3 is long enough that the sky background dominates. It is less useful for cameras with smaller pixels. Note that SBIG's cameras with small pixels and no self-guiding, such as the ST-5C, use Track and Accumulate. These cameras were intended to be used either with a focal reducer or with the Celestron F/2 Fastar in order for Track and Accumulate to work well.

Self-guiding is the premier approach. The full aperture of the main telescope is used, allowing maximum sensitivity. Differential deflection does not occur, since the optical system is common to imaging and guiding CCDs. Long exposures can be commanded between readouts of the imaging CCD. And, a feature not to be downplayed, one has the ability to select the guide star using the computer, with total control over the guiding process. You can see the image the guider is working with, instead of wondering whether or not the guider is in focus. With self-guiding you can take much longer exposures, and you can do it with ease. You will obtain much better images, which is why you wanted the camera in the first place!

To summarize, we make the well known ST-4 autoguider, and yet we chose to make it unnecessary with the ST-7-7 and ST-8. Why did we render our own product unnecessary? We did it for several reasons - to save our camera users money, and time, to improve the tracking, and to simplify the tracking process to where it is no longer a burdensome chore of astrophotography. We have since discovered that self guiding is an enabling feature, enabling an adaptive optic system that can improve atmospheric seeing and eliminate wind and drive fluctuations, and enabling a spectrometer that can show what's on the entrance slit and guide itself. Astronomical applications demand the self-guiding capability! Do not underestimate the challenge of capturing well guided hour long images!

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Revised: September 23, 1998 12:16:34 PM.