

CCDTRACK

Tracking Software for the ST-4

Copyright Notice

This manual and the software described in it were developed and are copyrighted by Santa Barbara Instrument Group (SBIG). Neither the manual nor the software may be copied in whole or in part except as follows:

- 1) You may make backup copies of the software for your own use provided that they bear SBIG's copyright notice.

CCDTRACK Manual
Version 1.0
Printed September 1990
Converted to PDF November 1998

Table of Contents

INTRODUCTION	2
RUNNING THE PROGRAM.....	3
TRACKING CAPABILITIES.....	5
THE TRACKING MENU.....	8

CCDTRACK - Tracking Software for the ST-4

INTRODUCTION

The CCDTRACK program is one in a series of programs from Santa Barbara Instrument Group to enhance the operation of the Model ST-4 Star Tracker and Imaging Camera. The CCDTRACK program allows you to use your IBM PC or compatible computer in conjunction with the ST-4 to do Autoguiding with several improvements over the ST-4's built in capabilities. With CCDTRACK you can designate the object (star, asteroid, comet, etc.) within the field of view, and are not limited to tracking the brightest object in the field of view. Additionally, the software can scan the object periodically along a line for use with spectrometers or other instruments. Finally, the software gives the user complete control over the tracking gains and hysteresis and reports tracking performance with both instantaneous and RMS tracking errors reported.



Getting Started

This section describes what you need to do to get the CCDTRACK software up and running on your PC including installing the software. If you've spent any time with the CCD program included with the ST-4 you'll feel right at home and can briefly scan this and the following section. The CCDTRACK program duplicates the function of the CCD program with the addition of the new **Track** command. If you haven't run the CCD program, then read through this section and then spend some time with the CCD program and its manual to further familiarize yourself with the specifics of the **Focus**, **Grab**, **Image I/O**, **Display** and **PC** commands. Only after you have a good feel for these commands should you try to use the CCDTRACK program.

Making a Backup Copy

The first thing you should do is make a backup copy of your CCDTRACK diskette and put the original away in a safe place. The program is not copy protected so you can use the DOS "DISKCOPY" command or your favorite utility. This doesn't mean the software isn't copyrighted

though, which it is. Please don't give copies of the software away. Making a backup copy is especially important if you intend to run the CCDTRACK program from a floppy diskette.

Installing on a Hard Disk

If you have a hard disk on your system and wish to install the software on it we suggest you install it in the directory containing your CCD program. In this way the two programs can share access to the graphics driver programs (CGA.BGI, EGAVGA.BGI, etc.), and you will only need to copy the two files "CCDTRACK.EXE" and "CCDTRACK.CFG". If however you wish to, you may install the CCDTRACK program in its own directory, but in this case you will also need to copy the graphics driver programs as well.

RUNNING THE PROGRAM

Running the CCDTRACK program is just a simple matter of making the directory containing the CCDTRACK program be the current working directory using the DOS "CD" command if necessary, and running the program by typing "CCDTRACK" followed by hitting the "Enter" key. If you're running from a floppy diskette and are swapping diskettes to get access to system files or data files, you will need to insure that the program diskette is installed in the disk drive when you quit the program. The program remembers the user's settings in the CCDTRACK.CFG file which gets updated when you quit the program.

Elements of the User Interface

The CCDTRACK program interacts with the user through a friendly and efficient user interface containing pull-down menus and dialog boxes, and operates in two distinct modes: Text mode and Graphics mode. The Text mode is activated when the program is first run and contains the pull-down menus, dialog boxes, and other items requiring an interactive role with the user. The Graphics mode is used for displaying images and analyzing them with cross-hairs, etc. This section describes the elements which together make up the user interface.

Menu Bar and Menu Commands

At the top of the screen (in text mode) is the menu bar showing the different menu titles or commands (**Grab**, **Focus**, **Image I/O**, etc.). At any time only one menu in the menu bar is highlighted, and the highlighting can be moved from menu to menu using the left and right arrow keys. Once a menu title is highlighted, hitting the "Enter" key causes one of two things to happen: Either a pull-down menu is revealed with several sub-commands (as is the case with the **Image I/O** command) or a dialog box is shown (as is the case with the **Grab** command). Either of these can be exited or canceled by hitting the "Esc" key. How each of these items interacts with the user is described in individual sections below.

Note:

Commands can also be invoked from the menu bar by hitting the first letter of the intended command. For example, hitting the "I" key invokes the **Image I/O** command, revealing its pull-down menu.

Pull-Down Menus

Pull-down menus show several commands arranged vertically, with one command highlighted. The highlighting can be moved from command to command using the Up and Down Arrow keys (or the Tab and Shift-Tab key combinations). Once a command is highlighted it can be invoked by hitting the "Enter" key. Invoking commands can cause a dialog to be displayed or can cause some immediate action, depending on the individual command.

Note:

Commands in menus can also be invoked directly once the pull-down menu is visible (without moving the highlighting) by hitting the key corresponding to the highlighted capital letter shown in the command.

Dialogs

Dialogs are outlined boxes drawn in the center region of the screen for interacting with the user and typically contain several parameters which can be changed by moving to the desired line and changing the setting. You move the flashing cursor up and down through the dialog parameters using the Up and Down Arrow keys (or the Tab and Shift-Tab key combinations).

Note:

In the dialogs, the descriptive text to the left of each parameter contains a single highlighted character. This character indicates that you can move the flashing cursor directly to that parameter by pressing the "Alt" key in conjunction with the highlighted character

The method used to change a parameter's setting depends on the type of the parameter, of which there are two: ones where you select a single choice from a list of choices and ones where you type in some number or text. For the first type, you select the desired setting by using the Left and Right Arrow keys. In the second case you simply type in the desired setting. You can use the "Backspace" key to edit the text or use the "Del" key to completely erase all the text entered in the parameter. When you are done setting the parameters in the dialog, you can proceed on to execute the command by hitting the "Enter" key or abort the command by hitting the "Esc" key.

Status Box

Towards the bottom of the Text mode display is the Status box which is used by the program to convey passive information to the user such as the introductory information presented when the program is first run. You will want to check the status box periodically for this information.

Data Buffer Information Box

Just below the Status box is the Data Buffer information box which indicates whether any image data is currently held in memory, whether that information has been saved on disk or not, and whether the image data has been zoomed (and thus could be unzoomed).

Graphics Display Mode

The program switches to Graphics mode when images need to be displayed or analyzed, such as after executing the **Display** command. You can switch back to Text mode from Graphics mode by hitting the "Esc" key.

Where To?

At this point you should do one of two things. If you have used the CCD program that came with your ST-4 and are now comfortable with the various commands, then you can proceed to the next section. If however you are not familiar with the operation of the CCD program you should now spend some time working with that program and its manual. Only then should you proceed with the next sections.

TRACKING CAPABILITIES

This section describes the operational capabilities of the CCDTRACK program in regards to using the PC for tracking. These capabilities are accessed through the new **Track** command which should not be confused with the Track mode of the **Focus** command. The CCDTRACK program uses the PC as an autoguider while the CCD program only allows the user to manually correct much as he/she would using the hand controller, but with the assistance of the graphics display of the **Focus** command.

How the PC Does Tracking (The Fixed Tracking Mode)

In the Fixed tracking mode, where the object of interest is autoguided and held at a fixed position on the CCD, a full frame image is captured and downloaded and then the user selects the object of interest in the CCD's field of view using a 32 x 32 pixel box. The program then cycles repeatedly, taking exposures, downloading the small subset of pixels contained within the box, calculating the centroid, then calculating the tracking error and correcting the telescope's position. This cyclic process is described in detail below.

The length of the exposure is controlled by the user (via a parameter in a dialog, which is described further below). Shorter exposures allow the PC to correct more often, but may not work for dim objects or when there is a lot of scintillation (poor seeing). Increasing the exposure time will give better tracking performance and in the latter case tend to average the effects of the the star's jittery position. You will not want to increase the exposure to the point where pixels in the star saturate because the non-linearity associated with such a condition can adversely affect the tracking performance. Additionally the *Anti-blooming gate*, *Gain*, and *Camera baseline level* items in the **Camera Setup** command can be applied for the exposures as desired. Enabling the Anti-blooming gate when there are bright objects within the field of view will help prevent streaking of those objects, and raising the Gain and Camera baseline levels for dim objects can give the PC more signal to work with, improving tracking performance for those objects. Finally, a Dark frame can be captured into the ST-4 using the **Grab** command, and subtracted from each exposure, reducing the effects of hot pixels, again increasing the tracking performance with dim objects.

Note:

If the telescope drive has a rapid error, increasing the exposure beyond the point where the star drifts more than 1 or 2 pixels in an exposure will degrade the tracking.

Once the exposure has been taken (and dark frame subtracted if desired), the pixels within the 32 x 32 box designated by the user are downloaded to the PC. The program scans those pixels and determines a background level which is between the sky background level and the brightest pixel value. Using the background level as a discrimination level, the centroid is calculated. Pixels below the background level are not included in the centroid calculation, reducing the centroid's sensitivity to the sky background level.

Using the centroid calculated above, the instantaneous tracking error is calculated in terms of fractions of pixels where:

$$\text{Error} = \text{Actual Position} - \text{Desired Position}$$

How the telescope is instructed to move due to this error depends on the setting of several user items. First, you can select the polarity of the correction in the X and Y directions. A "Forward" polarity means the telescope should be driven in the negative direction for a positive tracking error (meaning the star is to the right or below its desired position). A "Reverse" polarity means the telescope should be driven in the positive direction for a positive tracking error. The required settings will depend upon the orientation of the CCD head in the eyepiece holder, and the particular optical system (see Figures 1 and 2 below).

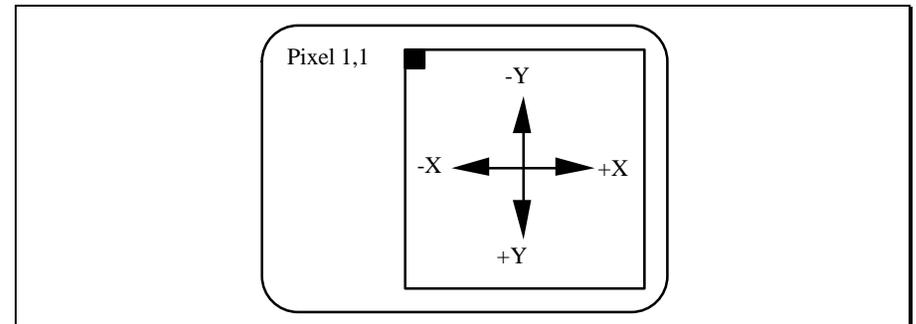


Figure 1 Pixel 1,1 and XY Axes in Graphics Mode

Important Note:

You must orient the CCD so that the declination and Right Ascension axes of the field of view are along the CCD's Y and X axes respectively. The angular orientation is not so critical, and can be off by as much as 10° to 20° without adversely affecting the tracking performance.

You can determine the proper polarity settings by using the **Move** command described later. If the star moves to the right or down when the right (+X) or up (+Y) relays are activated then the "Forward" setting is required. Otherwise the reverse setting is required (remember the images are shown with pixel 1,1 in the upper left corner, causing +Y to be down, not up as you might think). Additionally, if the CCDTRACK software causes the star to move away from the crosshair rather than towards it when in the tracking mode, then you more than likely have one or both of the polarities set incorrectly.

Assuming the polarities are correct, the program also needs to determine how long to "punch the button" to move the star back to its desired position, knowing how far it is away from that position (i.e. the tracking error). It does this by using four correction speed parameters set by the user (+X, -X, +Y, and -Y). The correction speeds are in terms of pixels of movement per second of correction, and again can be determined using the **Grab** command while imaging a relatively bright star. You note the star's position (using the Crosshairs of the **Display** command) prior to and after holding each of the correction switches in turn for a period of time (2 to 10 seconds). The correction speed in each direction, in pixels per second, is then the amount the star moved in that direction divided by the time duration of each of the corrections. If you measure the correction speeds incorrectly one of two things can happen. A correction speed parameter which is set lower than the telescope's actual correction speed will cause the tracking to overshoot and oscillate about the desired position since it will correct for a longer period of time than necessary. If the setting is too low by more than a factor of 2 the star will end up further away (on the opposite side) and will eventually go out of the 32 x 32 pixel box. On the other hand, if the correction speed parameter is set higher than the telescope's actual correction speed the tracking will take more cycles to reposition the star at its desired position since the correction will be shorter than is actually required. In extreme cases, where the correction isn't great enough to cancel the drift, the star will eventually be lost.

The software also allows for compensation of drive hysteresis which represents itself as a temporary lack of motion when the correction signal or drive direction is reversed. For example, some telescopes when slewing positive in declination, will have a dead period when then driven negative in declination, and vice versa. The software allows you to specify what these dead periods or hysteresis parameters are in terms of seconds of correction. When you are first learning how to uses the CCDTRACK software you should leave these parameters set to zero. This will work even with drives having hysteresis. The tracking will just take an extra cycle or two to correct. When you have a good feel for the operation of the software you can measure your drive's hysteresis in the 4 directions. For example, to measure the +X hysteresis using the Focus mode, you would drive the telescope in -X until the star was moving regularly, then measure the amount of time it takes for the star to start moving in the opposite direction when using the +X correction.

Note:

The CCDTRACK program can work with very faint stars, stars invisible to the eye, using 3 to 5 second exposures. Set the ST-4's gain to 4 (using the **Camera Setup** command) and save a dark frame in the ST-4. Very faint stars can be discriminated from "hot pixels" since they move in response to the drive buttons.

Tracking Along a Line (The Scanning Tracking Mode)

The Scanning tracking mode works much the same as the Fixed tracking mode described above, but instead of the desired X position being a fixed point on the CCD, it is a point along a line of pixels. The software follows the induced motion of the object by downloading a 32 x 32 pixel box centered on the object's last position and moving that box as the object moves. The desired X position is scanned linearly between two pixel values (the X endpoints, specified by two user parameters) over a period of time (also a user specified parameter). In this way, the star is made to traverse along a line repeatedly with a controllable period. This can be extremely handy for scanning the star along the slit of a spectrometer for example. All you would need to do is orient the CCD head such that the slit is horizontal (oriented along the X axis), and specify the X pixel coordinates of the end points of the slit, the Y coordinate of the slit, and the desired scanning period.

Note:

An interesting application of the Scanning Tracking mode is to use it to move a star currently in the field of view to a set position. This is handy for centering a nebula or galaxy in the field of view for example. Determine the desired X and Y coordinates of some star, and then use those coordinates as the Scanning Tracking mode's X and Y tracking coordinates. Finally, use the Tracking command, designate the star, and then watch the CCDTRACK software move it to its desired location.

THE TRACKING MENU



The Tracking menu contains five items or commands which are described individually in the paragraphs below.

The Exposure Setup Command

Invoking the **Exposure Setup** command reveals a dialog where you can specify the exposure time and whether or not to use a dark frame. If you enable use of the dark frame, you must use the **Grab** command (with the *Take dark frame* parameter set to Yes) to capture the dark frame into the ST-4's internal memory prior to using the Tracking menu's **Go** command to start the tracking process.

The Pixel Setup Command

The **Pixel Setup** command is used to specify the tracking mode and various parameters relating to pixel coordinates and contains the following parameters:

Tracking Mode:

This item should be set as desired to use the Fixed or Scanning tracking modes described above.

Box Size:

This item controls whether all pixels within the 32 x 27 box are used in calculating the objects centroid (*Large* setting) or whether a 9 x 9 box of pixels centered under the brightest pixel in the 32 x 27 box is used (*Small* setting). For dim stars or close binary stars, the *Small* setting is recommended, but you should experiment with both.

Left:

This parameter only applies to the Scanning tracking mode and is the X pixel coordinate of the leftmost extreme of the desired line of pixels over which the object is scanned.

Right:

This parameter only applies to the Scanning tracking mode and is the X pixel coordinate of the rightmost extreme of the desired line of pixels over which the object is scanned.

Y center:

This parameter only applies to the Scanning tracking mode and is the Y pixel coordinate of the desired line of pixels over which the object is scanned.

Scan period:

This parameter only applies to the Scanning tracking mode and is the time in seconds over which the object should traverse the desired line of pixels.

The Relay Setup Command

The **Relay Setup** command contains parameters associated with the relays which control the telescope drive. These are described below:

Relay Polarities

These parameters control the direction the telescope will move in response to an error. If pressing the +X or +Y button on the ST-4 causes object to move to the right or down these will need to be set to Forward. If pressing the +X or +Y button causes the object to move left or up these will need to be set to Reverse. Finally, if you do not want the program to correct in one of the axes, set that axis' parameter to Inactive.

Having either of these items set incorrectly (Forward vs Reverse) it is easy to detect when you start the tracking because the star will be driven away from the zero-error point rather than towards it in that axis. Also, the settings of these items will depend on the orientation of the CCD in the eyepiece and the optical system (whether a right angle eyepiece mount is used, etc.). You must orient the CCD such that the X and Y axes of the CCD are oriented in Right Ascension and declination respectively, and may use the picture of the CCD head below as a guide. We suggest settling on one particular orientation of the CCD and optical path.

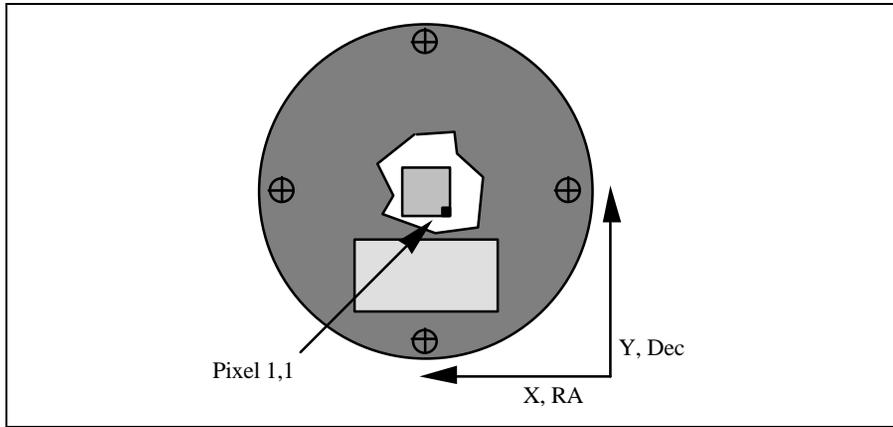


Figure 2 Required CCD Head Orientation (Rear View)

Hysteresis

These four parameters are the hysteresis or amount of turn around (in seconds) in each direction. Start with them set to 0.0 when you are first learning how to use the program. When you are familiar with the tracking performance, these can be measured by noting the amount of time the hand controller (or ST-4 switches) must be depressed to cause the drive to reverse directions and start moving. For example the +X parameter is the amount of time you must press the +X button after the drive has been slewing in -X before the star starts to move in the +X direction. Typically drives will have little or no hysteresis in Right Ascension, but will have some hysteresis in declination.

Note:

When the ST-4 is in Find and Focus mode, holding any of the four relay buttons down will activate the appropriate relay for the duration the button is down. When the ST-4 is interrupted, displaying "HELLO", each button press will result in a only 0.2 second activation of the relay.

The Correction Speed Command

The **Correction Speed** command contains parameters which are described individually below. The four speed parameters are the the speed an object moves in the four directions in pixels per

second. These can be measured using the **Grab** command in conjunction with the **Move** command from in the Tracking menu. For example the +X correction speed is the number of pixels a star moved to the right (in the +X direction) divided by the amount of time you instructed the telescope to move (Grab an image, measure the (X,Y) position of a reference star, use the **Move** command to move the telescope, then Grab another image and measure the amount the star has moved from the first image. The speed is then the X distance moved divided by the amount of time used in the **Move** command).

X+:

This is the speed of the object as it moves to the right in the displayed image. This speed will depend on the object's declination and will reduce as declination is increased towards the poles. At a declination of $\pm 60^\circ$, the speed will be half its value on the celestial equator.

X-:

This is the speed of the object as it moves to the left in the displayed image. This speed will depend on the object's declination and will reduce as declination is increased towards the poles. At a declination of $\pm 60^\circ$, the speed will be half its value on the celestial equator.

Y+:

This is the speed of the object as it moves to the bottom in the displayed image.

Y-:

This is the speed of the object as it moves to the top in the displayed image.

Max Move:

This is the maximum number of pixels the CCDTRACK software should try to move the star in response to a tracking error in any one pass through the tracking loop. This is important for the Scanning tracking mode because if the star moves too much in one pass it will move out of the 32 x 27 pixel box and get lost. A setting of 8 is recommended, but if you loose the star while the Scanning software is initially trying to move the star up to the tracking line then you may wish to lower this item.

For the most precise determination of correction speeds you will want to make sure you exclude the effects of hysteresis by giving the drives plenty of time to reverse directions prior to measuring the correction speed.

Note:

When using the **Move** command to measure the correction speeds, activating the X+ relay will not necessarily make the star move to the right in the image. The direction it moves in response to activating any of the relays will depend on the optical system, orientation of the head, wiring of your hand controller, etc. Never the less, the X+ speed must be the speed the star moves to the right regardless of which relay (X+ or X-) caused that movement. Which direction it moves will however determine the setting of the X+ *Polarity* item in the **Relay Setup** command.

The Move Command

The **Move** command allows you to activate any one of the four relays (X+, X-, Y+ or Y-) in the ST-4 for a period of time. This can be used to measure the proper settings for the *Relay Polarity* items in the **Relay Setup** command and the *Correction Speed* items in the **Correction Speed** command as described below:

Relay Polarities

If activating the X+ or Y+ relay causes the star to move to the right in a captured image in response to the X+ relay or down in response to the Y+ relay then the *Forward* setting is required. If however it causes the star to move to the left in response to the X+ relay or up in response to the Y+ relay then the *Reverse* setting is required.

Correction Speeds

Use the **Grab** and **Display** commands to capture an image and measure the (X,Y) position of a reference star. Then use the **Move** command and then capture and display a second image. Measure the amount the star has moved (in pixels) and divide that by the time used in the **Move** command (in seconds) to get the Correction speed in pixels/second.

The Go Command

Once all the parameters in the **Exposure Setup**, **Pixel Setup**, **Relay Setup** and **Correction Speed** commands have been set, invoking the **Go** command starts the tracking. How that progresses is based upon the selected tracking mode, and is described in the paragraphs below.

Fixed Mode

The Fixed tracking mode starts with the software taking an exposure, and downloading the entire frame. The image is displayed (with auto contrast), and a 32 x 32 pixel box is shown superimposed over the image. Using the four arrow keys, you should position the box over the desired object to track. The arrow keys will move the box 1 pixel at a time, where as the "Shifted" or "Num Locked" version of the arrow keys (4, 8, 6, and 2) will move the box 10 pixels at a time.

Note:

You may find it convenient to keep your left hand on the shift key and use your right hand to work the keypad. By holding or releasing the Shift key you can affect the speed at which the box moves across the image. Additionally, the I, J, K, and M keys on the keyboard can be used to simulate the four arrow keys.

Once the designated object is in the box (it doesn't have to be centered), hitting the "Enter" key causes the software to calculate the object's X and Y centroids, and make those coordinates be the desired position or zero-error position of the object. The software then starts the tracking loop mentioned above where an exposure is taken, the error calculated, and corrections made.

Note:

If during the course of tracking, the star is lost, the software will make no corrections in that cycle. If the star is lost for four consecutive cycles, the computer will beep.

While tracking, the image of the object is shown with a crosshair superimposed at the zero-error point. An image zoom of 4 x 1 can be toggled on and off using the "Z" key, and tracking can be terminated by hitting the "Esc" key. While the zoomed image is easier to see, the process of zooming the image does take time, and will lengthen the cycle time. This may be appreciable for short exposures depending on the speed of your PC.

Also shown to the left of the image is a table (X and Y) of tracking parameters as described below:

Des: Desired Position

These are the desired X and Y coordinates of the object as determined by its centroid in the first (full frame) image.

Pos: Actual Position

These are the object's current X and Y coordinates based upon the last exposure.

Err: Instantaneous Error

These are the object's X and Y distances from the desired or zero-error position in pixels, which is also called the instantaneous error.

Avg: Average Error

These are the object's average error in pixels in X and Y for the last 16 cycles. Any persistent error such as that caused by a misadjustment in the speed of the Right Ascension drive will show up here.

Rms: RMS Error

These are the object's RMS (root mean squared) error in pixels in X and Y for the last 16 cycles.

Cor: Correction

These are the corrections made in seconds in X and Y based upon the instantaneous error.

Brt: Brightness

The parameter shown in the left column (X) was the initial brightness of the object from the first image., and the parameter shown in the right column is the object's current brightness. The brightness is the total energy (sum of pixel values) that the software is using to track the object, and if the brightness ever falls below 33% of its initial value the object is presumed lost.

Note:

If the object becomes too dim or is lost, the **Pos**, **Err** and **Cor** parameters above will be shown as "-".

Scanning Mode

The Scanning tracking mode starts like the Fixed tracking mode, with the software taking an exposure, and downloading the entire frame. The image is displayed (with auto contrast), and a 32 x 32 pixel box is shown superimposed over the image. Using the keypad, you should position the box over the desired object to track.

Once the designated object is in the box (it doesn't have to be centered), hitting the "Enter" key causes the software to switch out of graphics mode back to text mode, display a "For Your Info" box with a table of displayed parameters (discussed individually below) and then start the tracking loop where an exposure is taken, the error calculated, and corrections made.

Throughout the tracking cycle, a four character message will appear in the upper right corner of the info box indicating which part of the cycle the software is in (EXPO for exposure, DOWN for downloading, DISP for displaying the results, and CORR for making corrections). If during the course of tracking, the star is lost, the software will make no corrections in that cycle. If the star is lost for four consecutive cycles, the computer will beep. Hitting the "Esc" key terminates the tracking.

Desired Position:

These are the desired X and Y coordinates of the object along the line. Since the object is scanning, the X coordinate will vary between the left and right ends of the line while the Y coordinate will remain fixed.

Actual Position

These are the object's current X and Y coordinates based upon the last exposure. Since the object does not have to start on the desired tracking line, it may take several iterations for the software to bring the object to it desired position.

Error:

These are the object's X and Y distances from the desired or zero-error position in pixels, which is also called the instantaneous error.

RMS Error:

These are the object's RMS (root mean squared) error in pixels in X and Y for the last 16 cycles.

Correction:

These are the corrections made in seconds in X and Y based upon the instantaneous error.

Note:

If the object becomes too dim or is lost the **Actual Position, Error** and **Correction** parameters above will be shown as "-".

Note:

A pixel in the CCD is 13.3 microns (0.52 mil) wide in X and 16 microns (0.63 mil) tall in Y. An RMS tracking error of around 0.5 pixel will result in a smear or increased stellar diameter of only 5 mils (barely detectable) in a 10X enlargement of the resulting photograph.