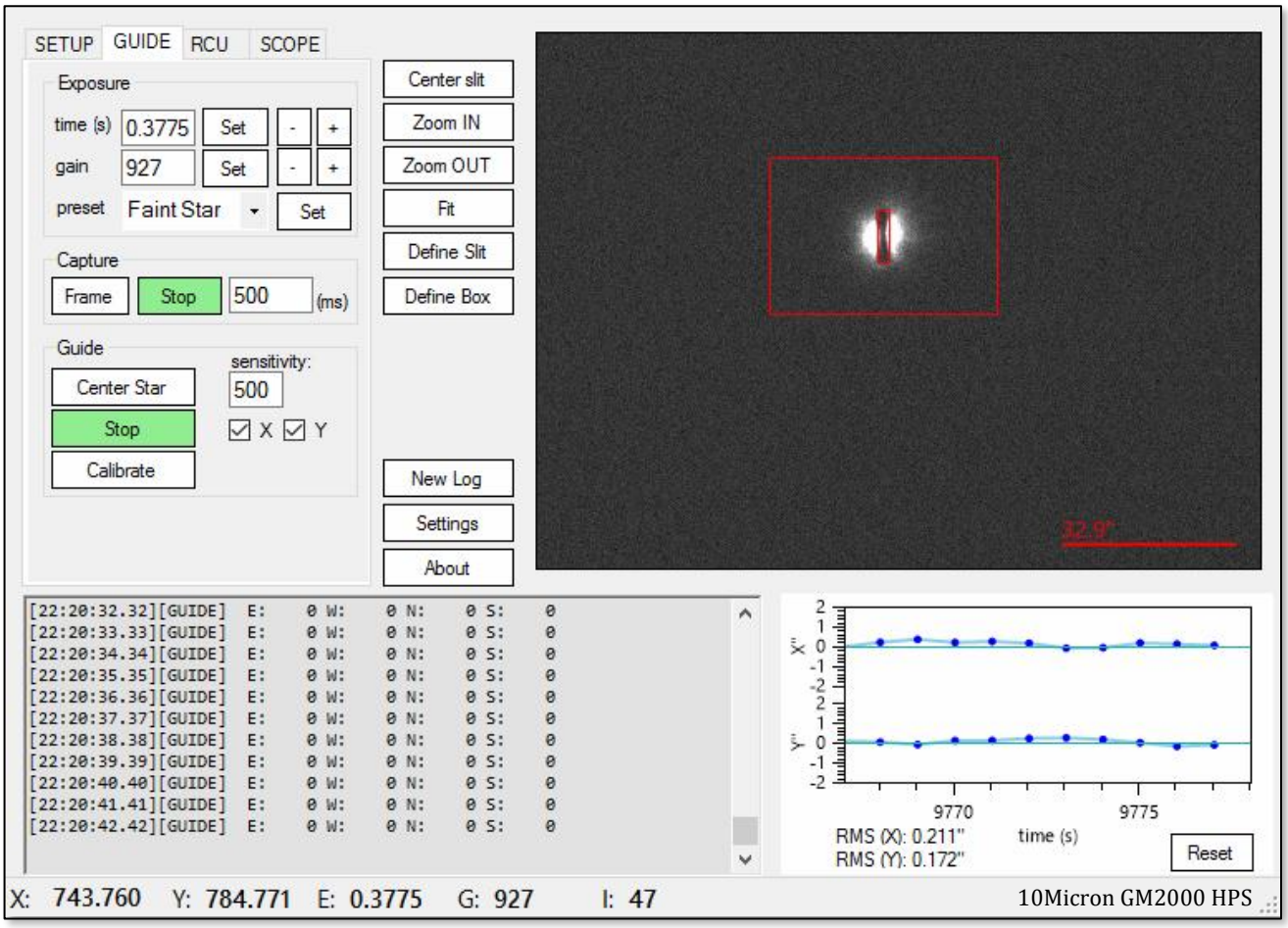
SpecTrack

Autoguiding Software for Stellar Spectroscopy



Manual/Tutorial 1.0 for Software Version 1.0

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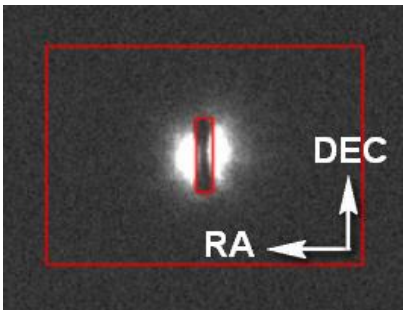
1. SpecTrack Features

SpecTrack is a software primarily for direct tracking on stars (autoguiding) on a spectrograph's slit. In order to obtain a stellar spectrum, most of the starlight must pass through the slit. To hold a star precisely on a slit, which itself may only be 25µm wide, presupposes many things: on the one hand, the mount should have a small periodic error; The advantage here is of mounts which are equipped with encoders and have residual errors in the range of 1 to 2 arcseconds. In addition, the polar alignment must be as accurate as possible, so that the star is positioned at the same point in the slit.



The normal case is that the spectrograph's slit is equatorially aligned: the width of the slit, which determines the resolution of the spectrograph, should be aligned in the RA direction. This means that the slit height is aligned in the DEC direction. Although SpecTrack can handle arbitrarily oriented slits, equatorial alignment is recommended in regard of smooth guiding.

If the star deviates from the slit in RA/DEC, SpecTrack corrects the position by controlling the drive with the chosen autoguiding speed.

SpecTrack differs from guiding software known from astrophotography: Normally, the position of the maximum of the star intensity is detected, and the star is always held on the sensor at the same point during image recording. SpecTrack can guide on stellar profiles too, however, and goes one step further. SpecTrack can not only track stars, but also stars that "disappear" in a spectrograph's slit. SpecTrack can be used with any slit spectrograph for tracking stars during astrophotography and stellar spectroscopy.

2. Technical Requirements

Operating system: Microsoft Windows 7 or Windows 10, 32-bit oder 64-bit.

Guiding: TheImagingSource[1] video cameras, monochrome or color
Celestron Skyris video cameras[2][3] (all video cameras w/o lens)

Data connection: USB 2.0, USB 3.0, Ethernet LAN (POE cameras supported)

Mount: ASCOM 6 – platform, ASCOM driver
(Driver possibly available from the manufacturer of the mount)

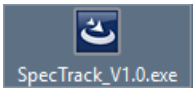
Note: This software has been developed primarily with and for 10Micron mounts, which are equipped with 10Micron absolute encoders and have a very high pointing and tracking accuracy. Other, less precise mounts may not achieve the same accuracy as described in the tutorial.

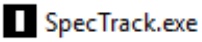
[1] https://www.theimagingsource.com/products/industrial-cameras/
[2] http://www.baader-planetarium.de/skyris/
[3] http://www.celestron.com/browse-shop/astronomy/astroimaging-cameras/series/skyris

3. Installation of SpecTrack Guiding Software

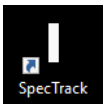
1. Before you use the video camera for the first time with SpecTrack, make sure that your video camera is plugged in and provides a video stream.

2. Install platform ASCOM 6, and the ASCOM driver of your mount. 

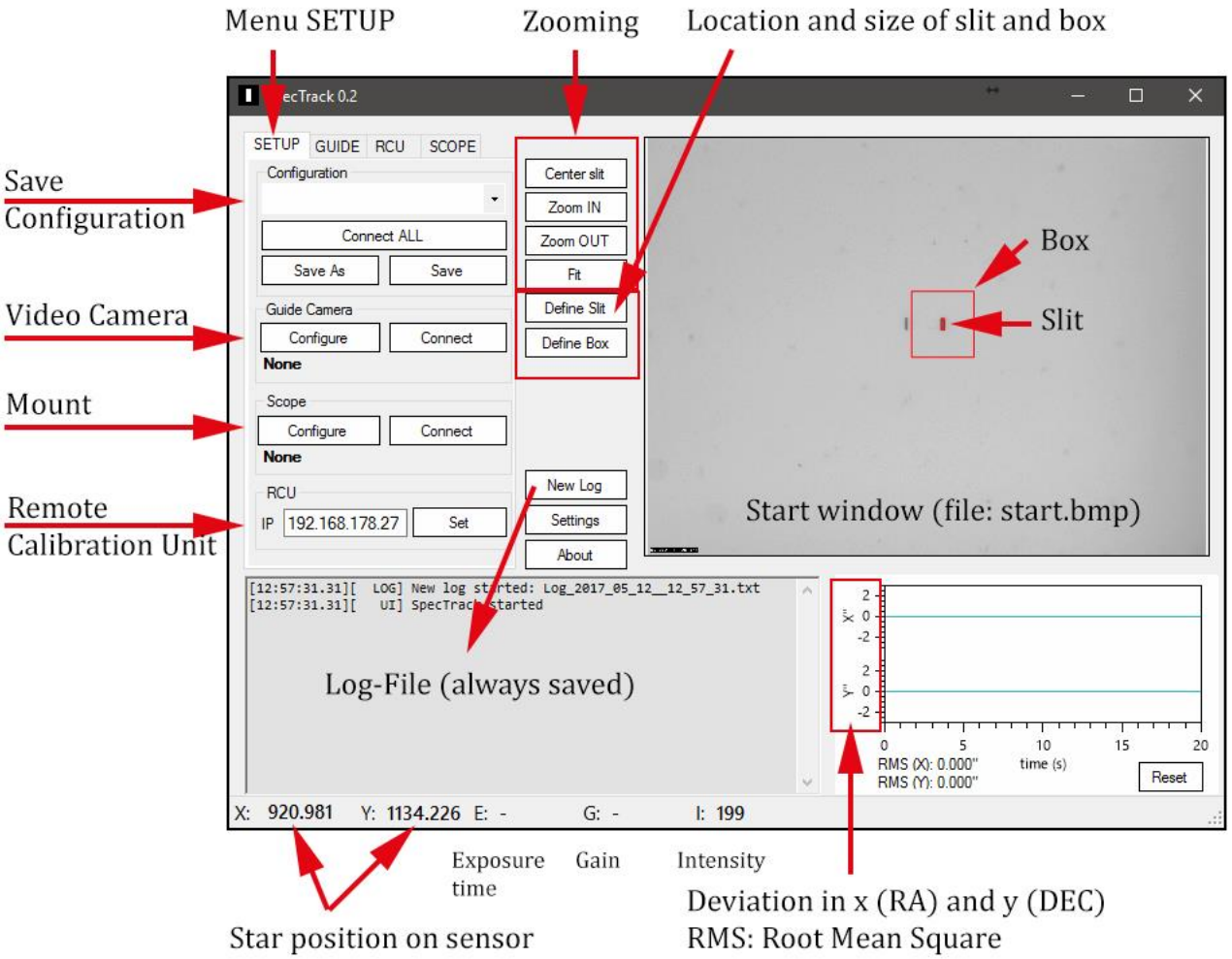
3. Start the installation file and install SpecTrack in the directory of your choice. 

4. SpecTrack.exe is the executable program file 

4. SETUP: First Start, Setup and Test

Start SpecTrack 

The SpecTrack window has a fixed size and cannot be scaled. The start window is a file in BMP format just for viewing. The box and the slit are later determined by the real image of the spectrograph. The box is the actual tracking window.

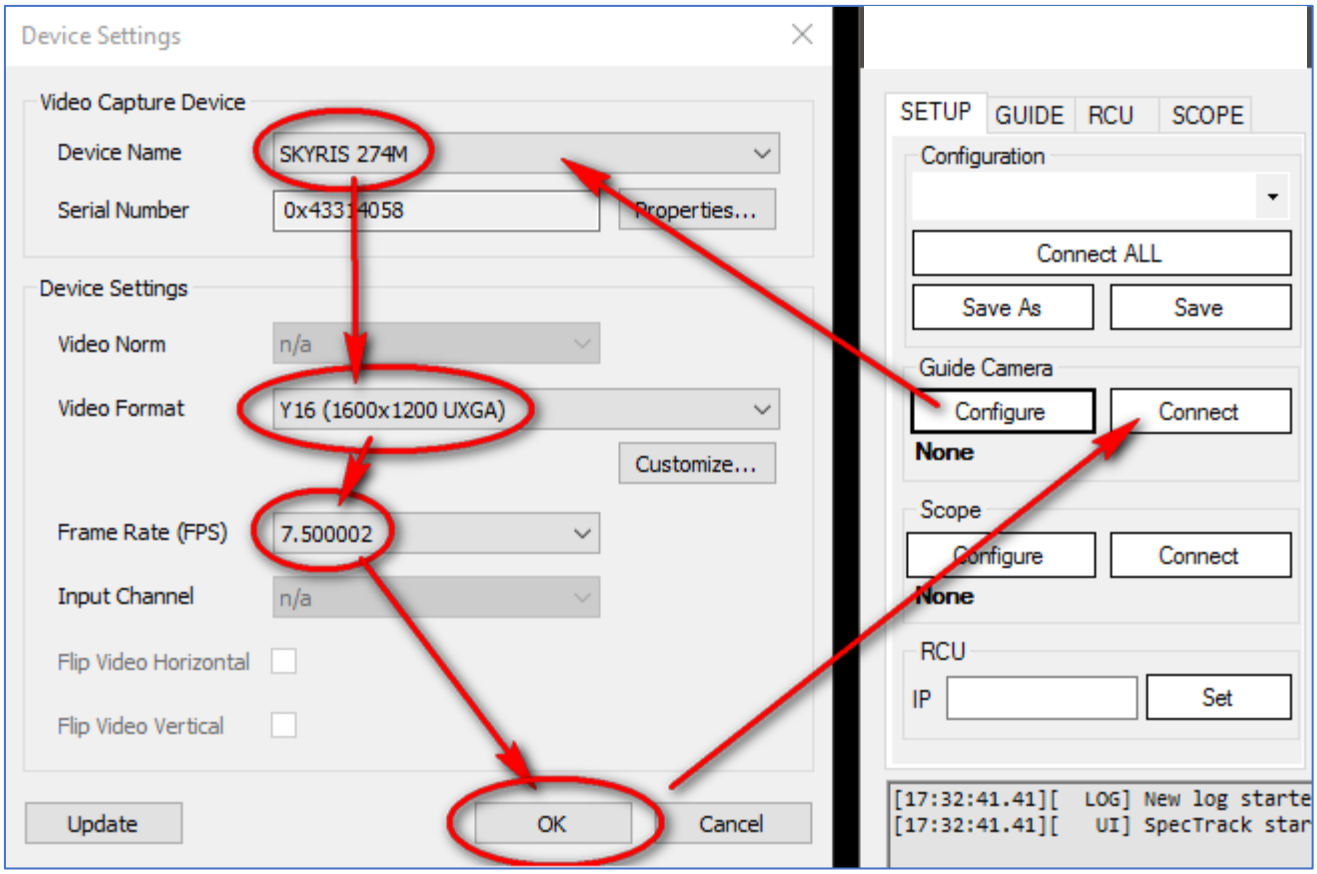


4.1 Guide Camera -> Configure

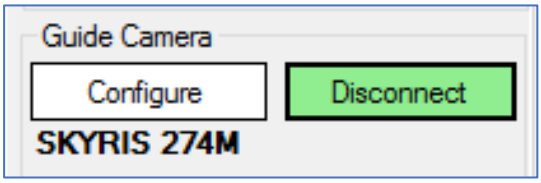
Operate your video camera in the desired video mode. "Y16" is a monochrome 16-bit format, "Y800" is an 8-bit monochrome and RGB24 an 8-bit color format. The best mode is Y16, followed by Y800. But not every TIS camera provides all formats. Under "Video Format" you can find the accessible video formats.

In principle, monochrome sensors are preferable to color sensors because of their lower noise. Select a sensor as large as possible, so that the target object is in the field of view after slewing the telescope. Precisely pointing mounts simplify finding faint targets.

The ”Frame Rate“ (FPS, frames per second) for guiding can be chosen low to relieve the PC, especially when remotely controled via Internet.

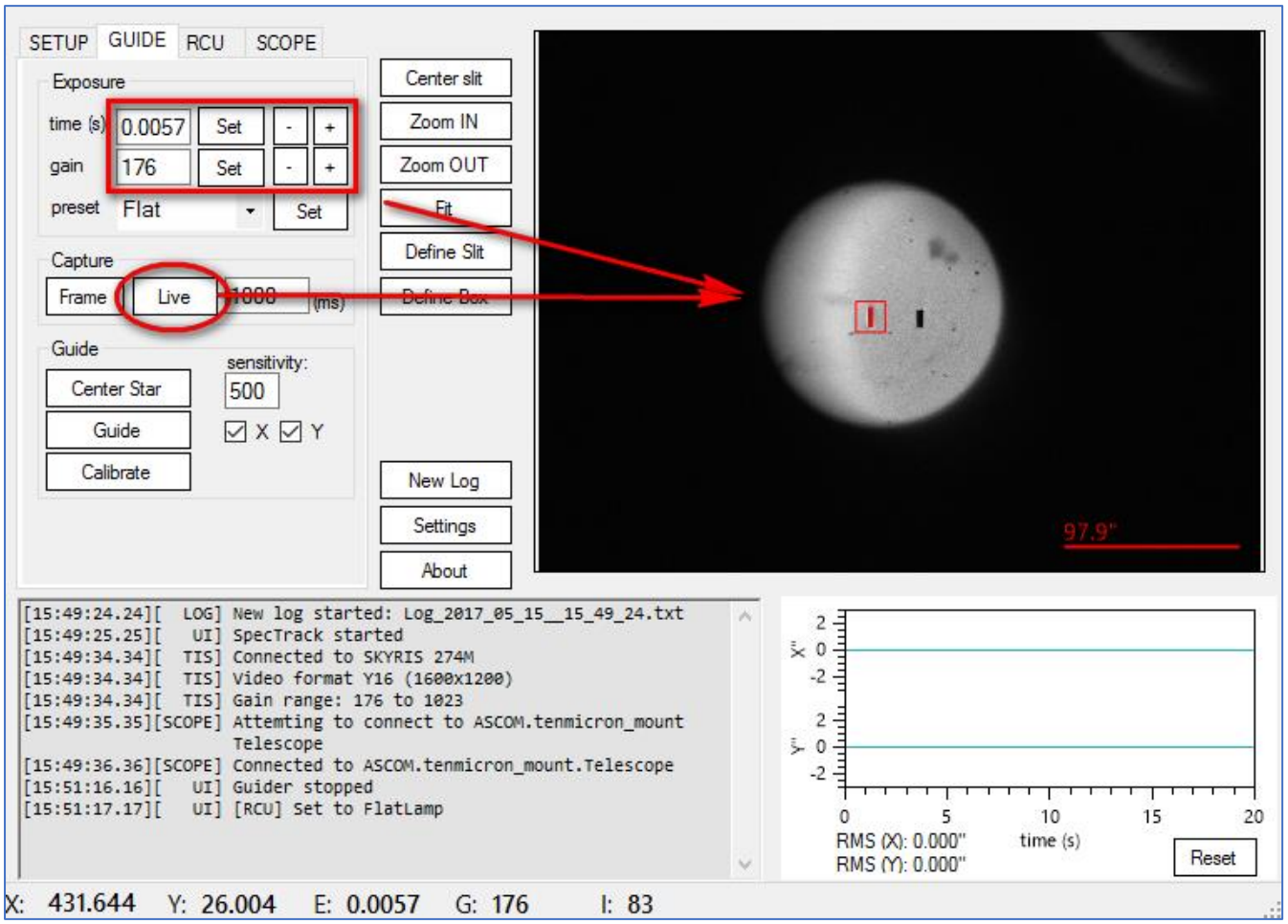


Now the „Guide Camera“ (for example: Skyris 274M) is connected.



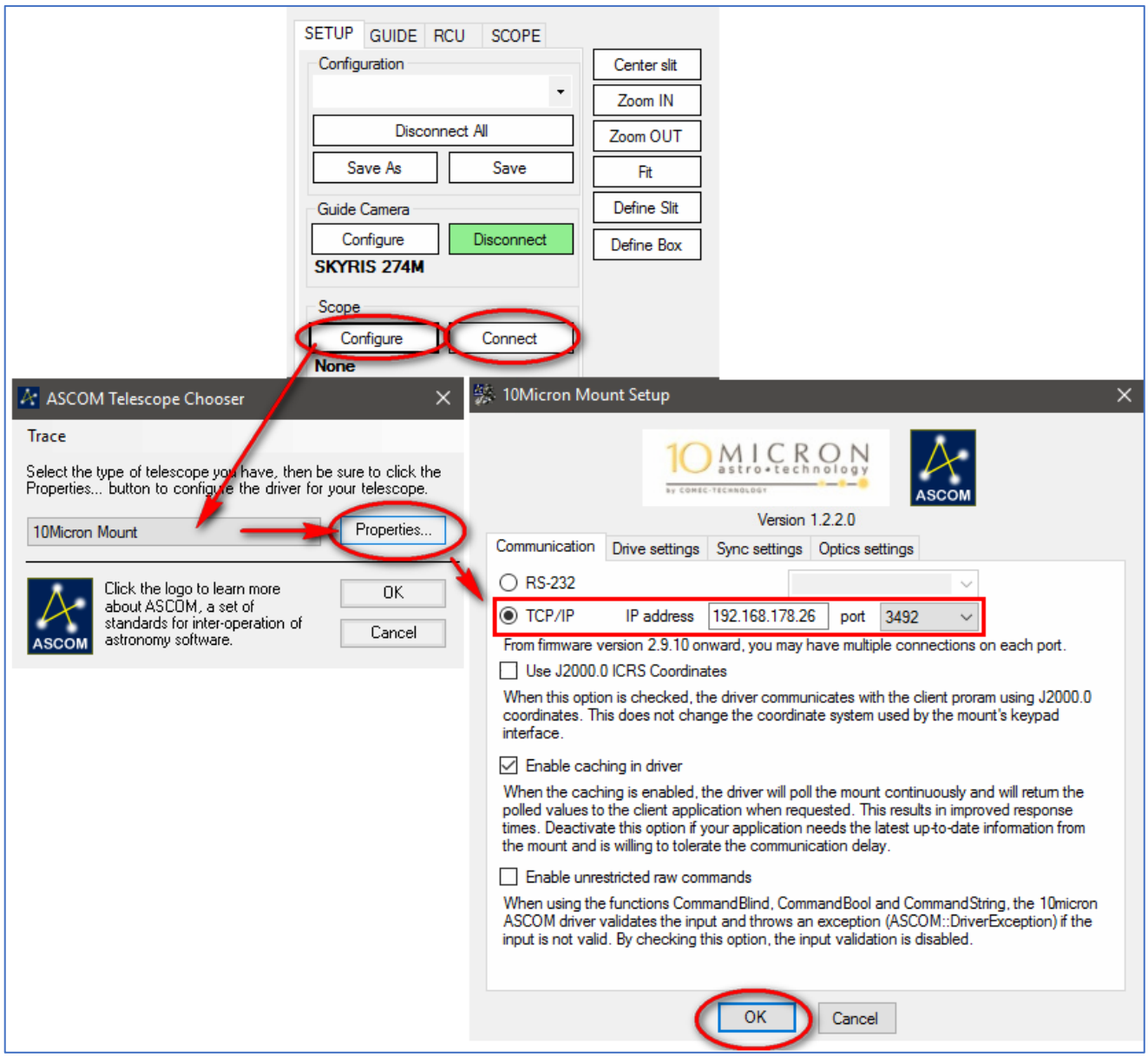
Press button GUIDE -> “Capture“ -> “Live“ and check the video image. Point the spectrograph at a bright light source, or turn on the RCU if it is already registered in the system.

During guiding the Live View does not need to be switched on as the displayed image will be automatically updated after each guiding cycle.

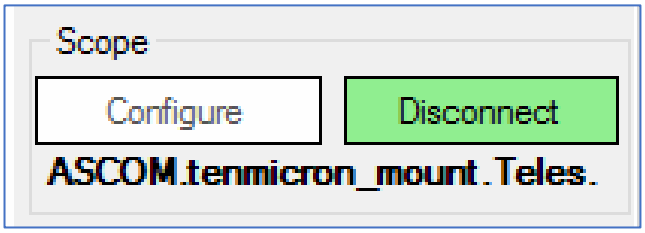


4.2 Scope -> Configure

In this menu the ASCOM driver of the mount is selected and configured. Guiding can take place optionally via the autoguider input or via a network address, if the mount is capable of.



After pressing the “Connect“ button, SpecTrack connects with the telescope mount drive “Scope“.



4.3 RCU

SpecTrack is able to control the *Remote Calibration Unit*[4] (RCU) for the BACHES Echelle Spectrograph. This is, however, not absolutely necessary to work with SpecTrack.

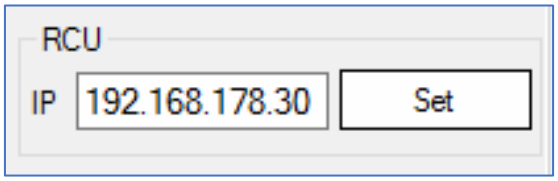
Anyone working with BACHES and RCU will appreciate that you do not need a separate web interface to switch the reference lamps on and off in the RCU.

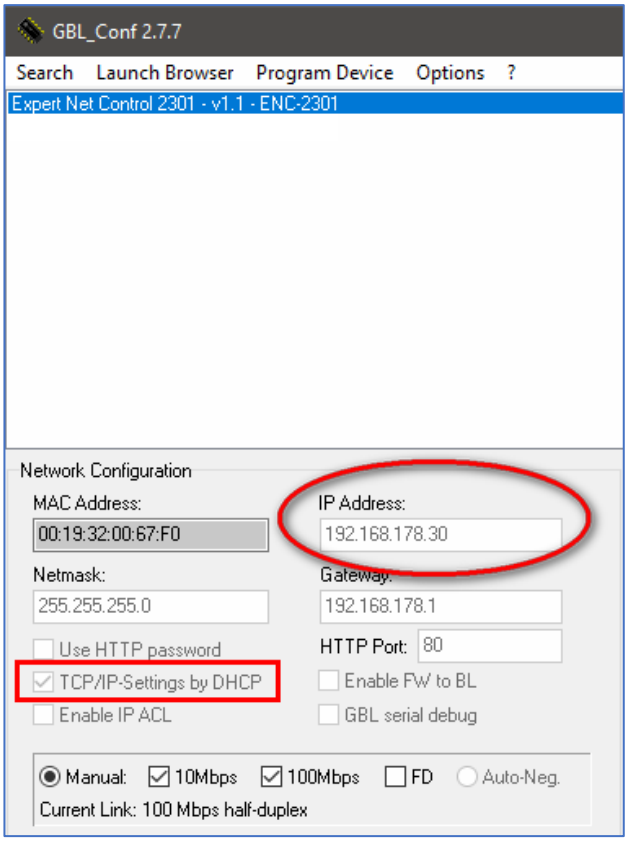
The RCU must be connected to the network and assigned its own fixed IP address. If your RCU does not already have an IP address in your network or if you do not know it, proceed as follows:

1. Start the program *GBL_Conf.exe* included with the RCU.

2. Allow your router and *GBL_Conf.exe* to assign a permanent IP address by DHCP.

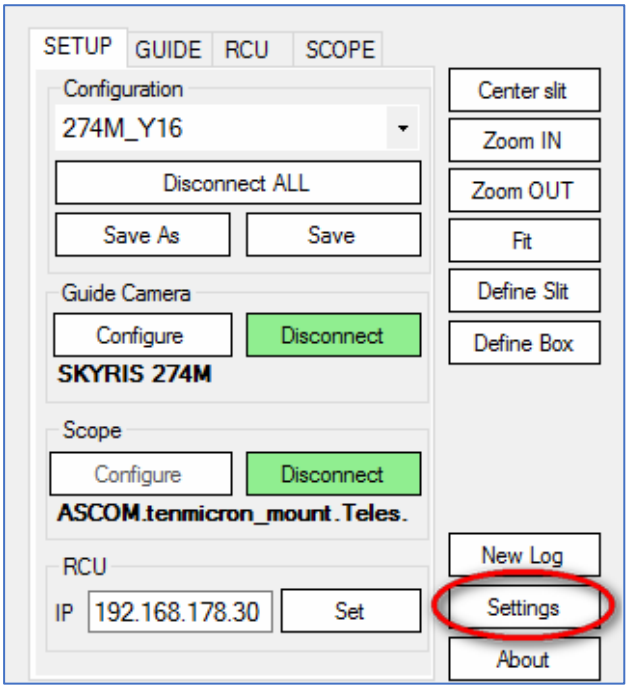
3. Enter this IP address in SpecTrack and press Button “Set“

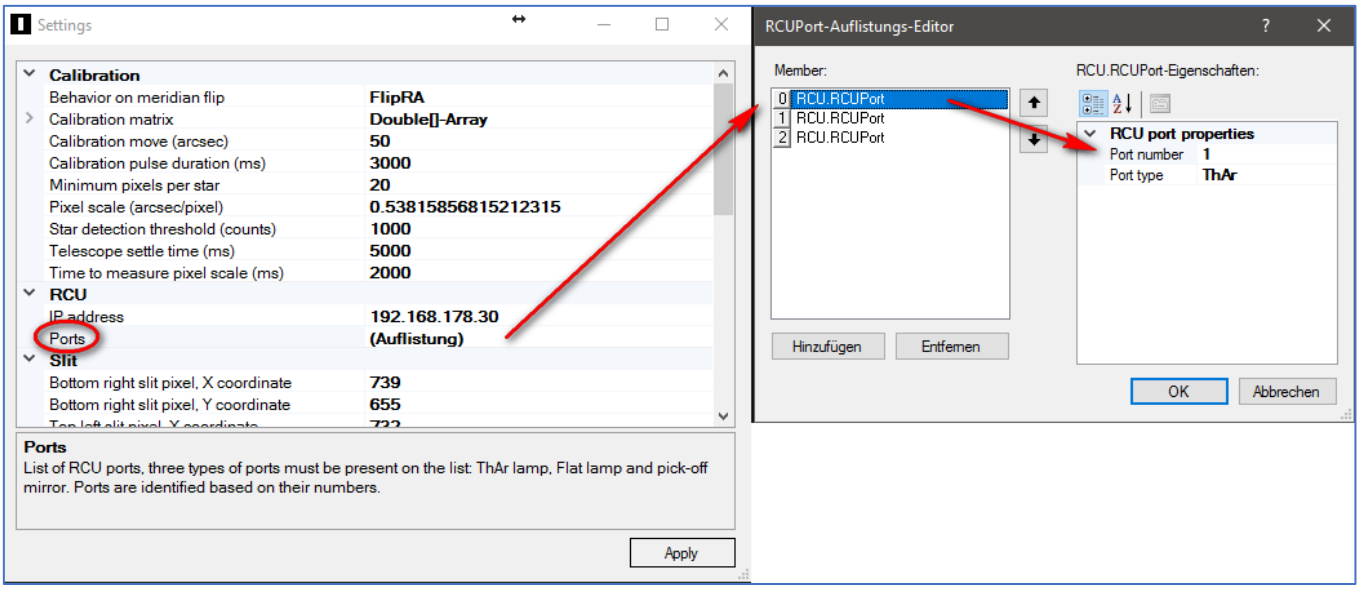


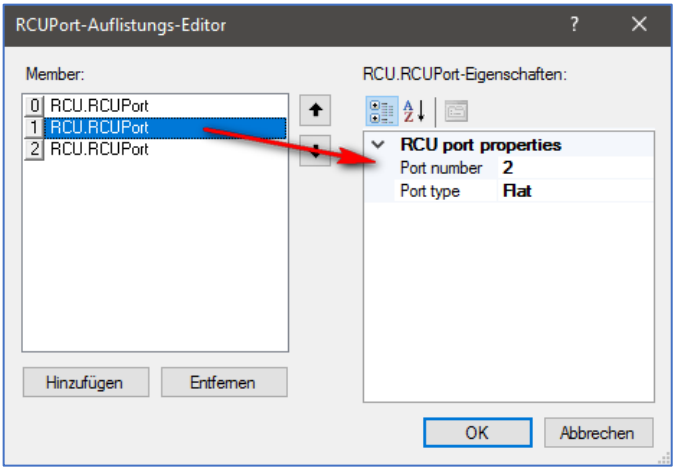


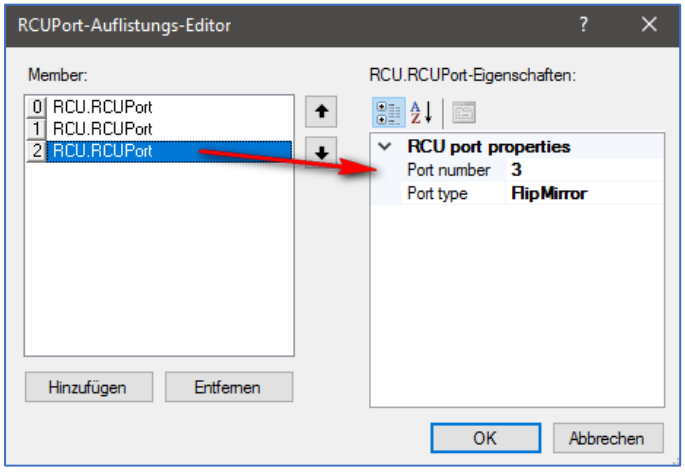
[4] http://www.baader-planetarium.de/baches/download/rcu_manual_e.pdf

4. Press buttons "Settings" -> "RCU" -> "Ports" and define the ports for the RCU if they have not yet been entered.

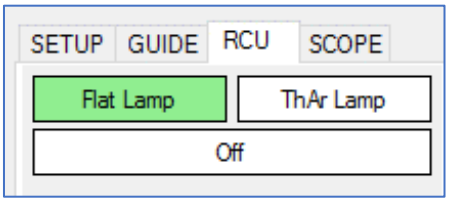








5. Flat Lamp oder ThAr Lamp, same procedure.

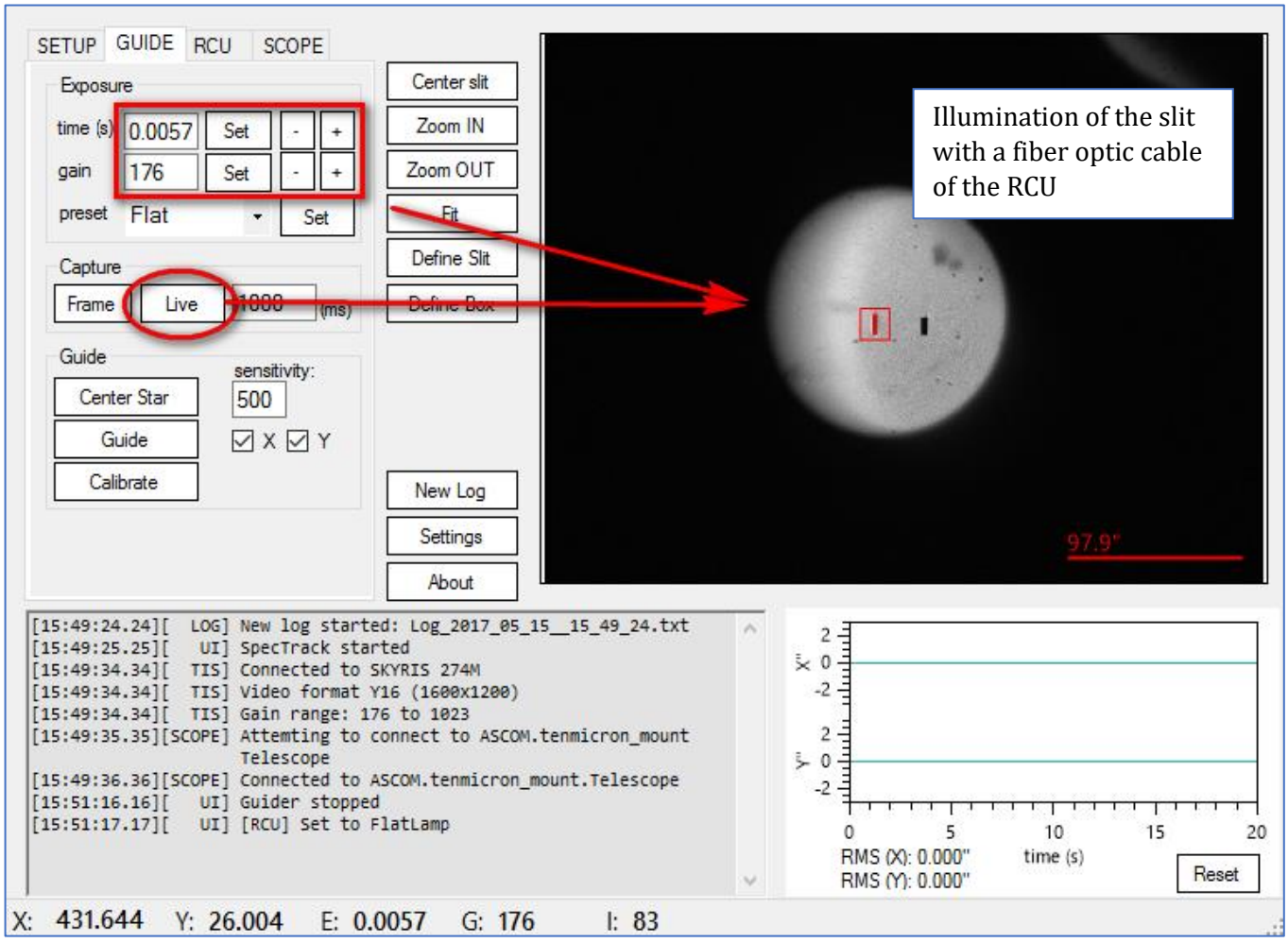


6. The field lights up green and you hear the flip-over of the coupling mirror in BACHES. If the guider camera is already in operation, the live image of the slit can now be viewed.

7. Menu GUIDE -> Press “Live“.

8. Set “exposure time” and “gain”, or press "Preset Flat" you have defined exposure time and gain before.

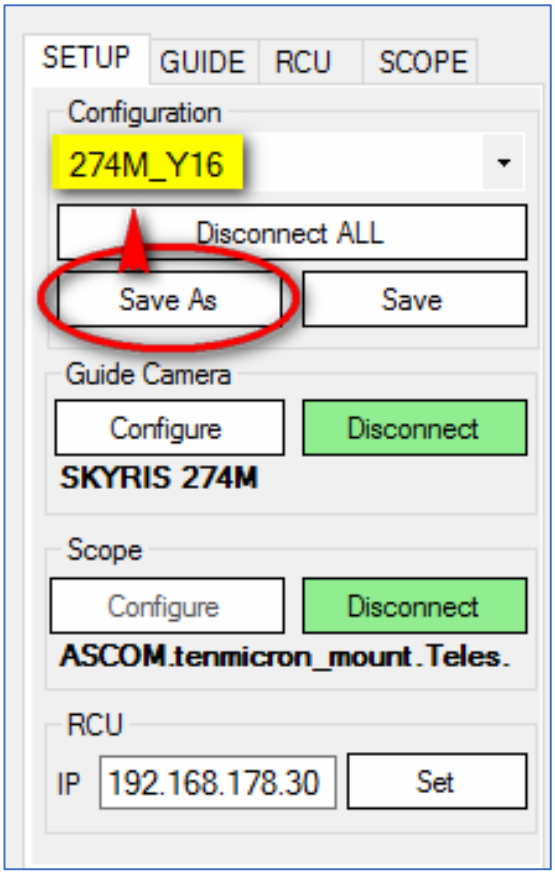
9. Set “Flat Lamp“ to “off“. This also stops the “Live” mode of the guide camera.



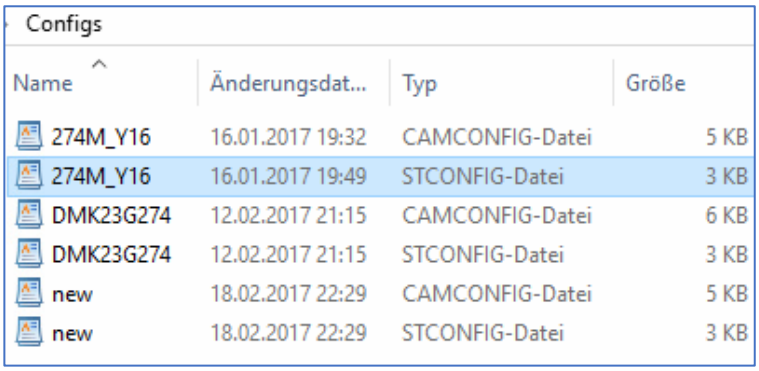
4.4 Saving the Configuration

After "Guide Camera", telescope "scope" and possibly "RCU" are registered and configured, this configuration can be saved and recalled at the beginning of a new session.

„Configuration“ -> “Save as“ (name). Choose a characteristic name. You can find all camera configurations stored in this way and you could even edit them if necessary. Different camera models can also be stored.



Configuration files are stored in the directory */ProgramData/Baader Planetarium/SpecTrack/Configs*.

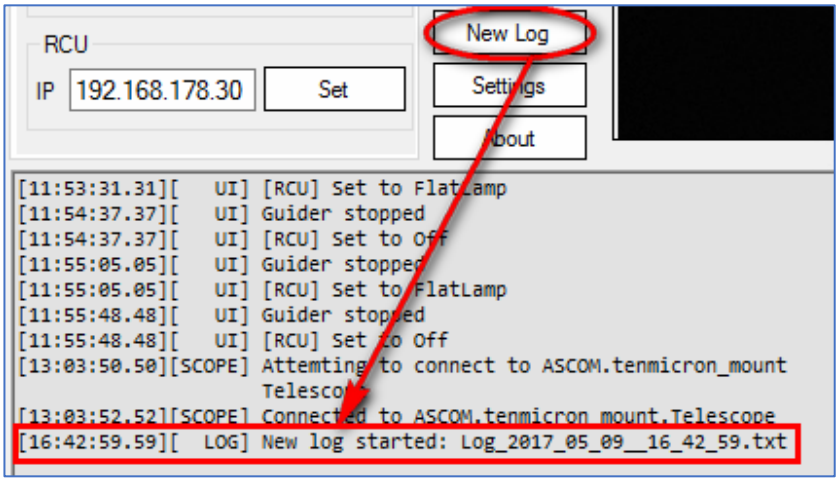


4.5 The Log File

You will notice that SpecTrack stores all events and messages in a log file that is stored in the subdirectory Log.

Each time you click "New Log", a new log file is started, all events are logged and automatically stored in the directory log.

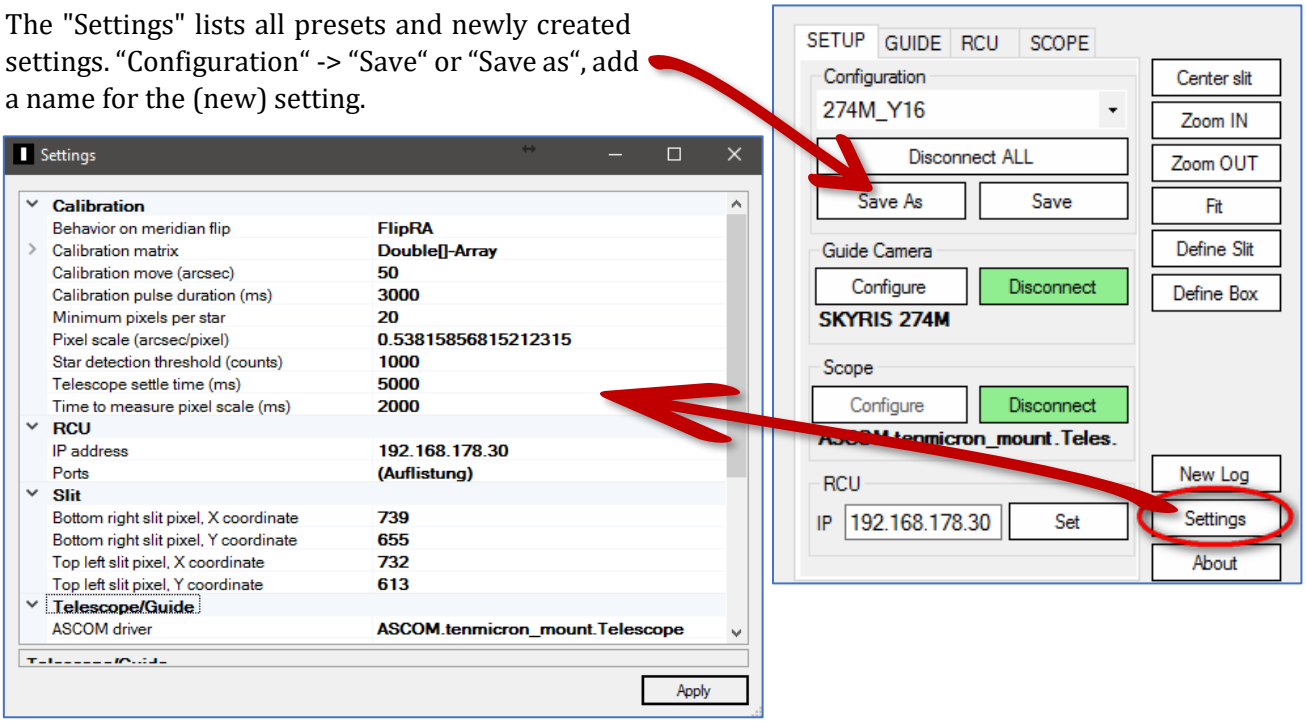
The log file is used to detect and solve problems or to improve the guiding behavior.



Log files are stored in the directory */ProgramData/Baader Planetarium/SpecTrack/Logs.*

4.6 Settings

The "Settings" lists all presets and newly created settings. “Configuration“ -> “Save“ or “Save as“, add a name for the (new) setting.



The settings in this tutorial were determined in the following hardware environment:

Mount: 10Micron GM2000HPS, ASCOM driver: 10Micron
Optics: Celestron 14 EdgeHD @f/7.7 (w/Reducer)
Guide Camera: Celestron Skyris 274M (compatible to TheImagingSource) with attached SlitViewer at guiding port.
BACHES Echelle Spectrograph
Remote Calibration Unit (RCU): Reference lamp ThAr for wavelength calibration, and Halogen flatfield lamp

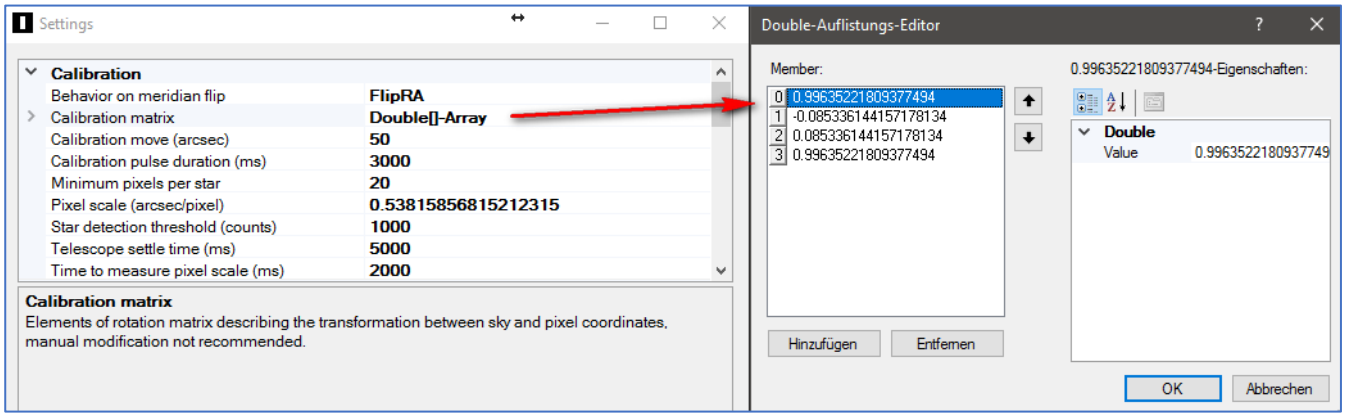
4.6.1 Calibration

Settings for the calibration run to determine drive parameters. Clicking on a parameter in the “Settings” menu gives you a brief explanation of its function. These are usually self-explanatory, so that we explain selected parameters only.

Note: If you have problems with a calibration run, you can change individual parameters in the “Settings” menu. As back-up for settings, we recommend screenshots of the settings window.

Calibration matrix
If the sensor of the video camera is aligned to RA/DEC, the entries are close to 1/-0/+0/1 after a calibration run. Changing the signs causes the axes to be interchanged and is not recommended. If the sensor is not aligned to RA/DEC, the matrix has different coefficients. Nevertheless, guiding should work.

After a pier Flip a new calibration run can be carried out, but is not required.



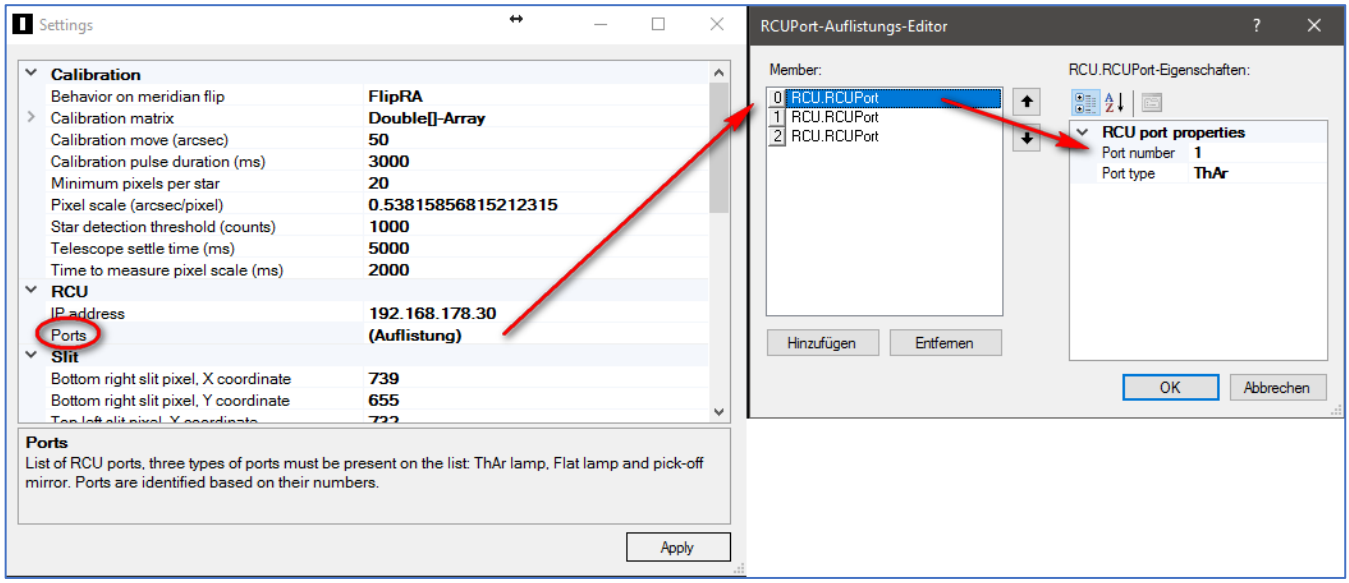
Star detection threshold (counts)
This value determines the intensity at which a pixel is to be considered as part of a star, which is green circled after detection. This value must be determined experimentally, but there is a presetting which usually works:

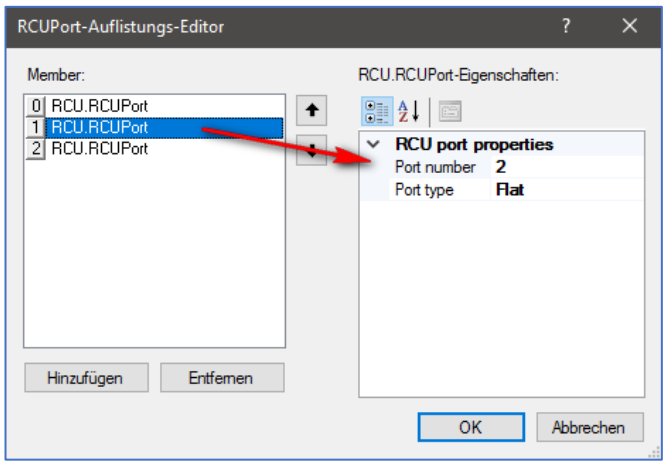
Threshold approx. 1000 for a 16-bit camera (Codec Y16, 0….65635ADU, e.g. Skyris 274M)
Threshold approx. 100 for a 8-bit Camera (Codecs Y800, RGB24, 0…256ADU) or a 16-bit Camera in 8-Bit mode.

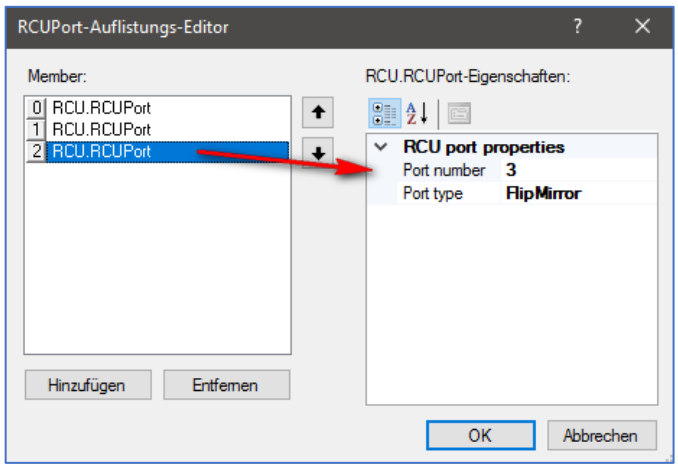
Pixel Scale: Scale determined in a calibration run, measured in arcsec/pixel. The pixel scale is used only when the Guide -> Center star command is executed and for proper RMS and scale display. It is not crucial for guiding itself.

4.6.2 RCU

The *Remote Calibration Unit* for the BACHES Echelle spectrograph can be directly controlled by entering the IP address in SpecTrack. If the port list is empty, define the three ports for the RCU:

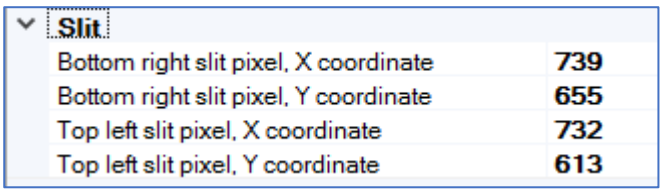






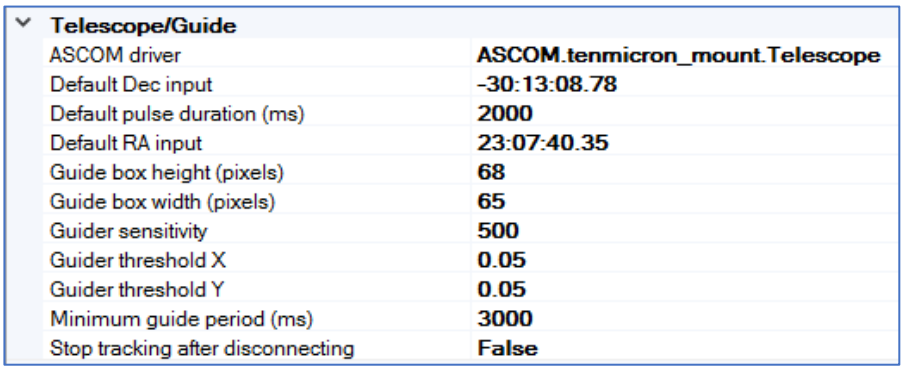
4.6.3 Slit

The coordinates of the spectrograph's slit are automatically recorded. The values have been defined by "Define Slit", using the mouse to draw a rectangle around the slit. You may edit the values to make a fine adjustment. Usually you will not need to do it.



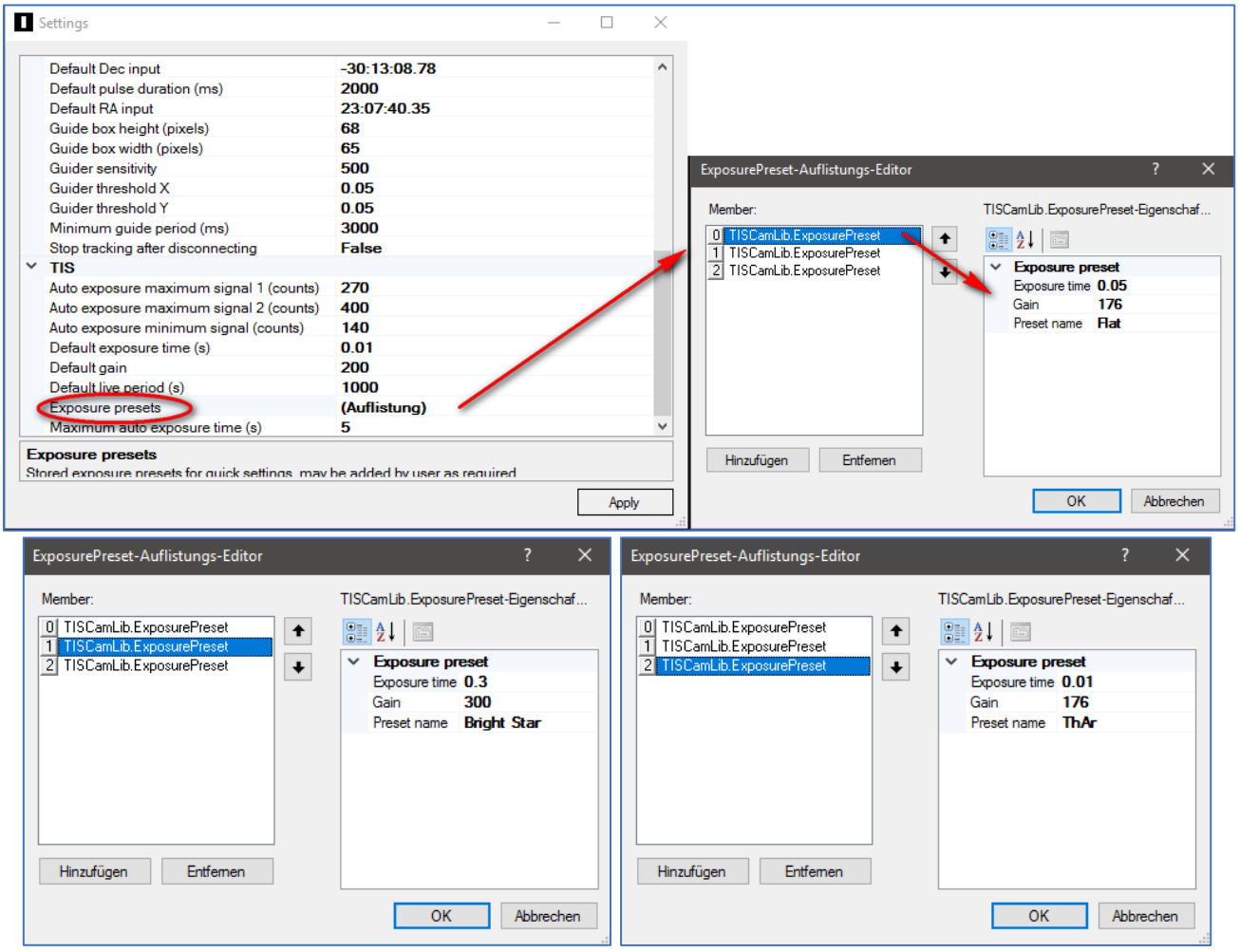
4.6.4 Telescope/Guide

Minimum guide period: Large guiding RMS errors are usually due to poor seeing when a long focal length telescope attached to a mount with small periodic error is used. Use a longer guide period.
Guide box height/width: Size of the guide box.
Guider sensitivity: A relative value to determine the aggressiveness of guiding (0 …. 2000+)
Guider threshold X/Y: Maximum guiding error (pixel)



4.6.5 TIS

TIS: Currently, only TheImagingSource compatible cameras are supported.

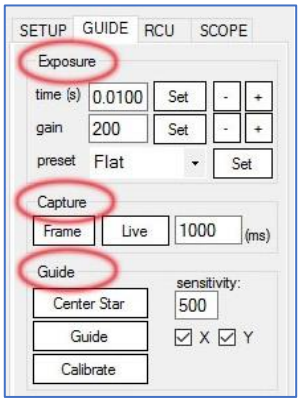


5. GUIDE

Make settings for the guide camera and calibrate the drive.

Exposure

Exposure time and gain. The gain can only be varied within the limits of the camera manufacturer's specifications. The permitted values are recognized automatically.



Capture

You can choose between a single shot ("Frame") and a video ("Live"). If you choose "Frame", you can adjust the exposure time in milliseconds (ms). Why do you need single shot images instead of having a video? Suppose you are operating your telescope remotely over the Internet, and you need to control both the camera and the guide camera over a slow DSL line. If you want to see what the video camera streaming besides taking spectra, this can lead to delays. Allow the camera to automatically guide and press the "Frame" button only to see if the guide mode is still active.

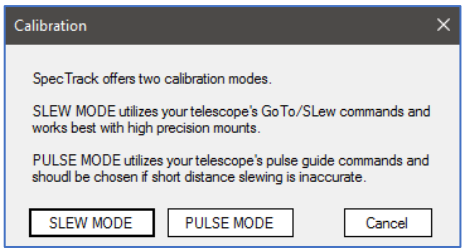
Guide

Sensitivity: Set a relative value for the guiding aggressiveness. Empirical values are between 10 (little correction) and about 2000 (permanent tracking). You can still choose whether you want to guide in both axes or in one axis alone.

Note: If you find that the RMS error in RA is mainly caused by seeing and not by the mount, you should try to reduce the "Sensitivity". Or try to get through without guiding in RA (X). Guiding in DEC (Y) may still be necessary if a poor polar alignment leads to deviations in DEC. Mounts with encoders using a pointing model do not need much drive corrections.

Calibrate: The calibration scale and the orientation of the guider sensor with respect to RA/DEC are determined by a calibration run. There are two ways to accomplish do this:

SLEW MODE or PULSE MODE

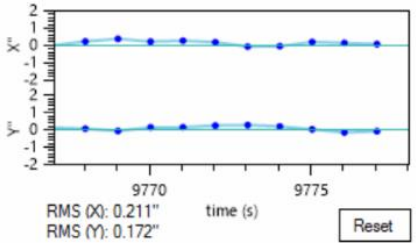


SLEW MODE: It is assumed that the telescope knows exactly the current coordinates. The telescope, using the SLEW command of the drive controller, slews to target coordinates higher and lower RA and DEC, respectively, thereby determining the imaging scale and the new "calibration matrix". Please be patient: "Slew mode" may take a few minutes - please pay attention to the log window, which indicates when the calibration run is finished.

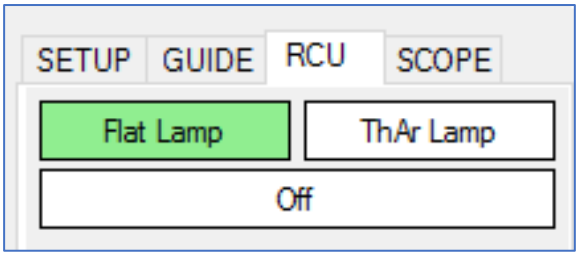
PULSE MODE: Without knowing the current position, the drive will run slightly slower and faster in RA and DEC to perform the calibration. "Pulse mode" is faster than "Slew mode". The values can be read in the "Settings".

Center Star centers the guide star. Fine positioning within the Guide box is best done by manual drive control of the mount.

Guide: If everything is set up, guiding can start. You may use the mouse wheel to stretch or shorten the time scale.



6. RCU

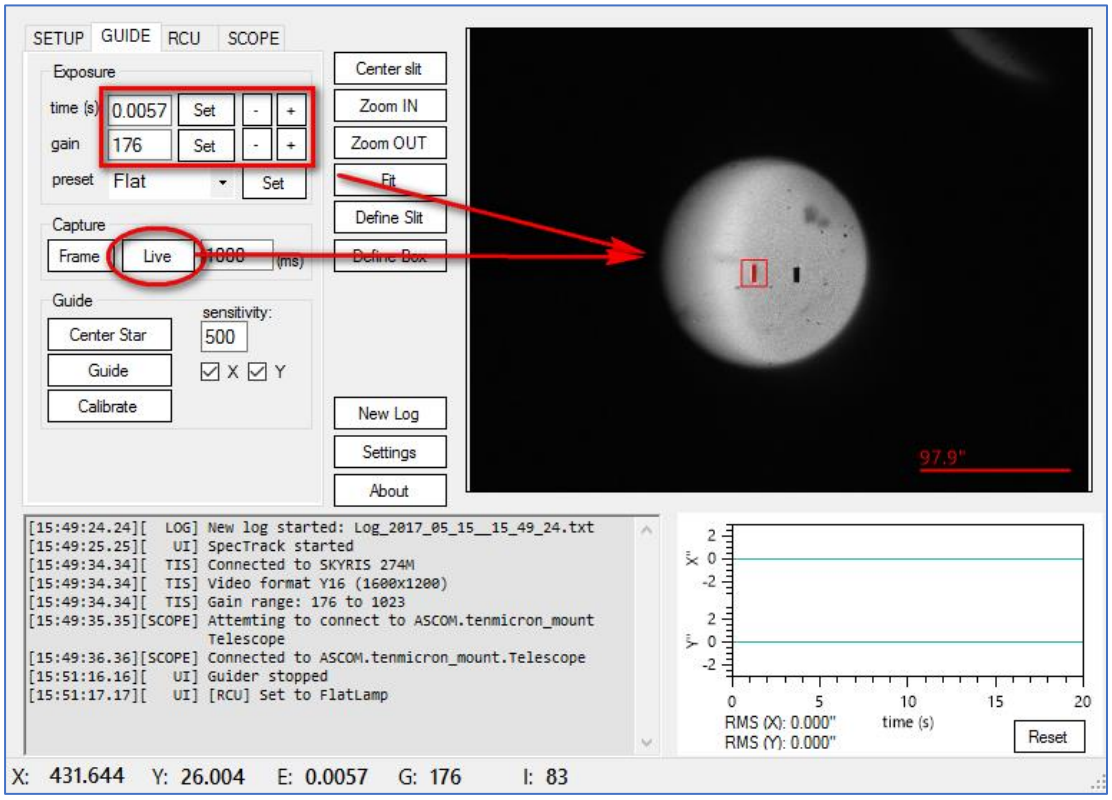


1. Chose “Flat Lamp“ or “ThAr Lamp“. The procedure is the same.

2. GUIDE-Menu -> Press „Live“.

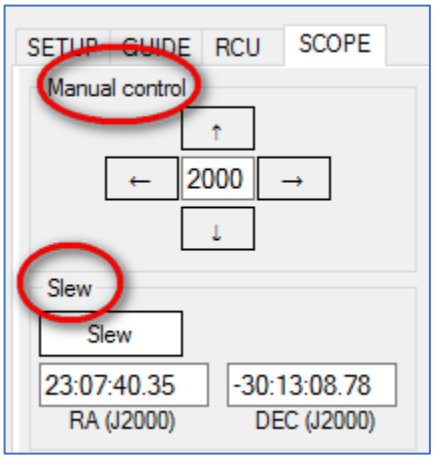
3. Set the “exposure time” and “gain”, or press the preset “FLAT” you may have previously defined.

4. Exit by pressing “Off“. This also stops the guide camera.



7. SCOPE

The SCOPE menu allows direct control of the mount.



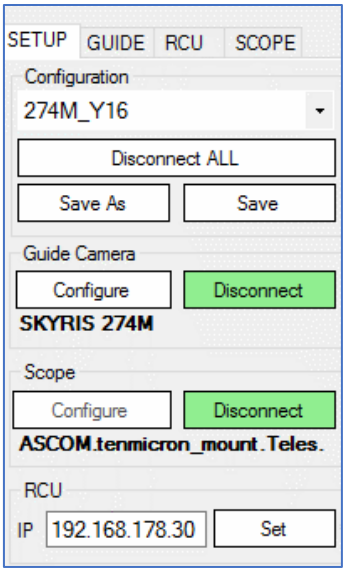
Manual Control
"2000" is the default value in milliseconds that the telescope is moved in the direction indicated by an arrow. We recommend aligning the sensor as exactly as possible parallel to RA/DEC.

Slew
The telescope moves to the target coordinates RA/DEC with the slew speed of the mount.

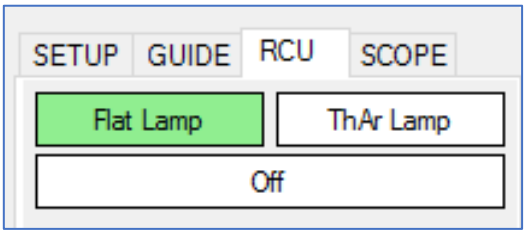
8. Autoguiding with SpecTrack: The Workflow

The presented optimized workflow for guiding spectral images results from the author's own experience.

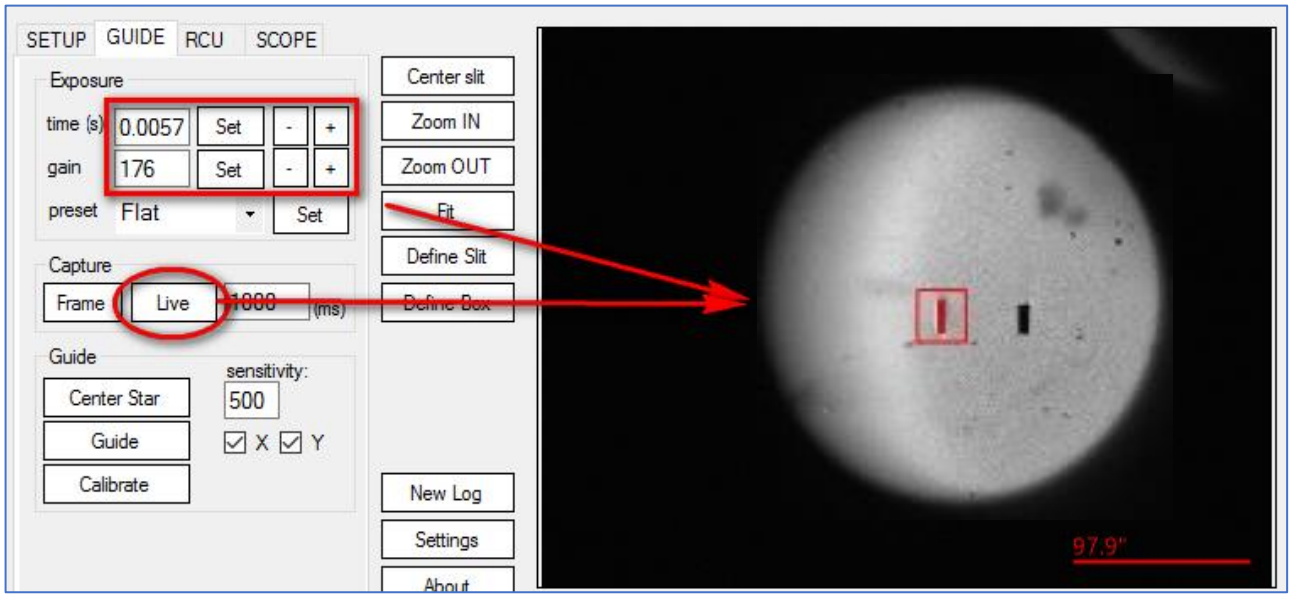
1. **SETUP:** First, connect to the following devices. Instead of single connects you can also load a previously saved Configuration.
   a. Guide camera
   b. Mount
   c. RCU (if available)



2. Illuminate the slit by turning on the RCU, or point the telescope at a bright light source.



3. **GUIDE:** After adjusting exposure time and gain, press "Live". You can see the slit(s) of your spectrograph. In the picture below the 25µm by 130µm slit of BACHES is the active one.



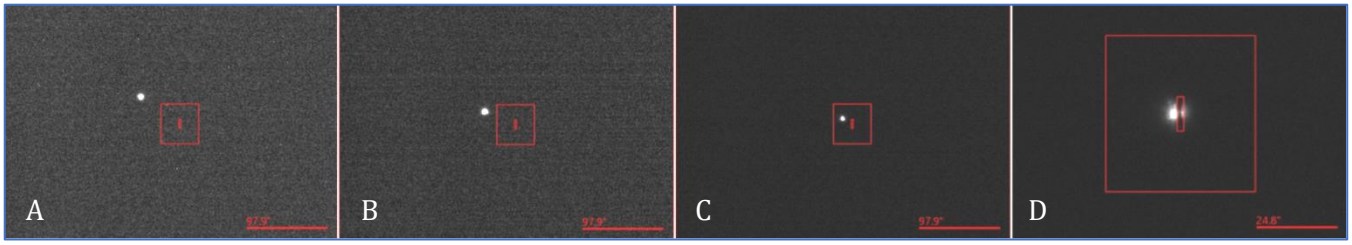
   a. Define Slit: Draw a narrow frame around the slit.
   b. Define Box: Pull a larger box out of the slit center. This is the so called “Guide Box”, whose center coincides with the slit frame.

4. Turn off the illumination of the slit. If you press "Off" in the RCU menu, the video mode is also switched off.

5. Slew to the target star by using the telescope drive control. Now it depends on the pointing accuracy of the mount. Ideally, this is so high that the target star is already visible in the field of the guide camera (A). The image scale is shown bottom right in the field of view.

6. Use the fine movement control of your telescope to move the star into the guide box (B, C). No other object should be in the guide box.

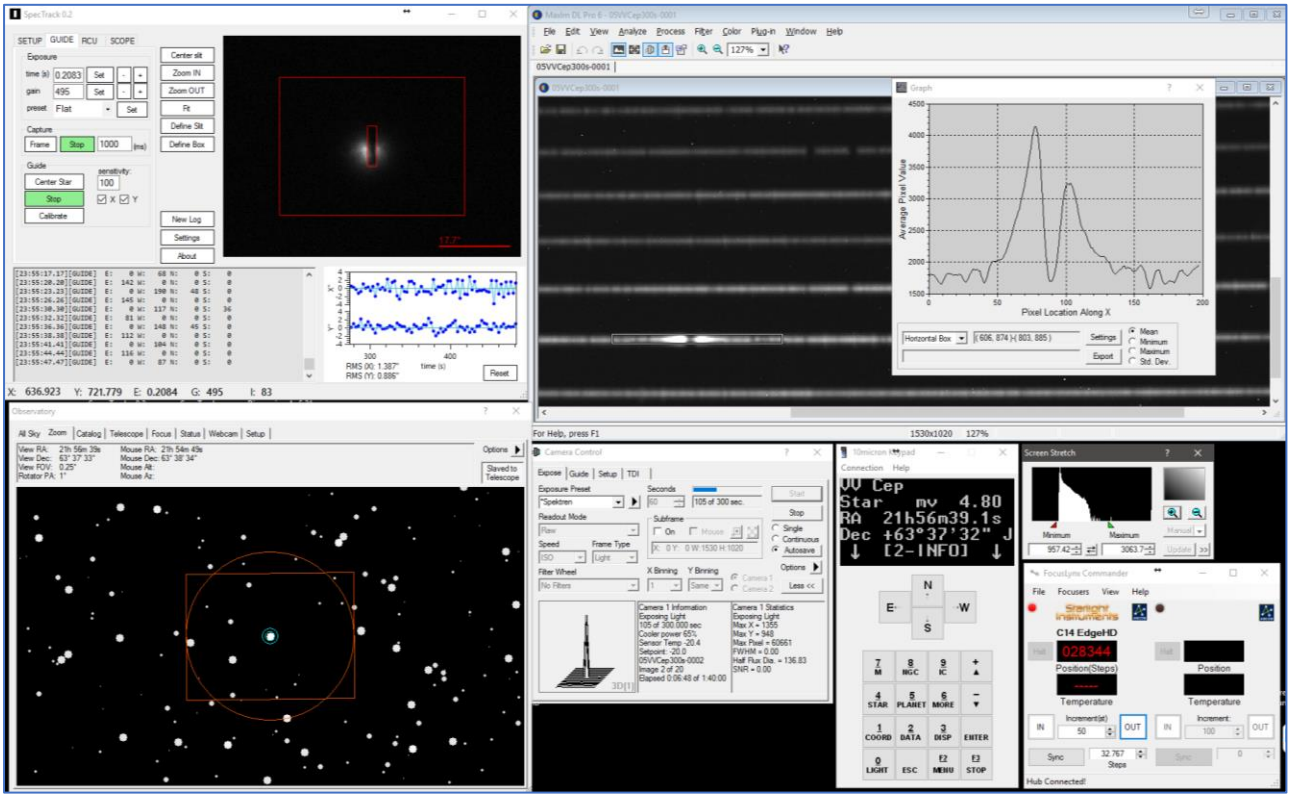
7. From now on, you can use the command "Guide" to automatically move the star towards the center of the red slit box and follow the star (D). Guiding will work as soon as the star is within the guide box. However, if the box is large it may be quicker to move the star closer to the slit using the telescope manual control arrows.



9. Examples

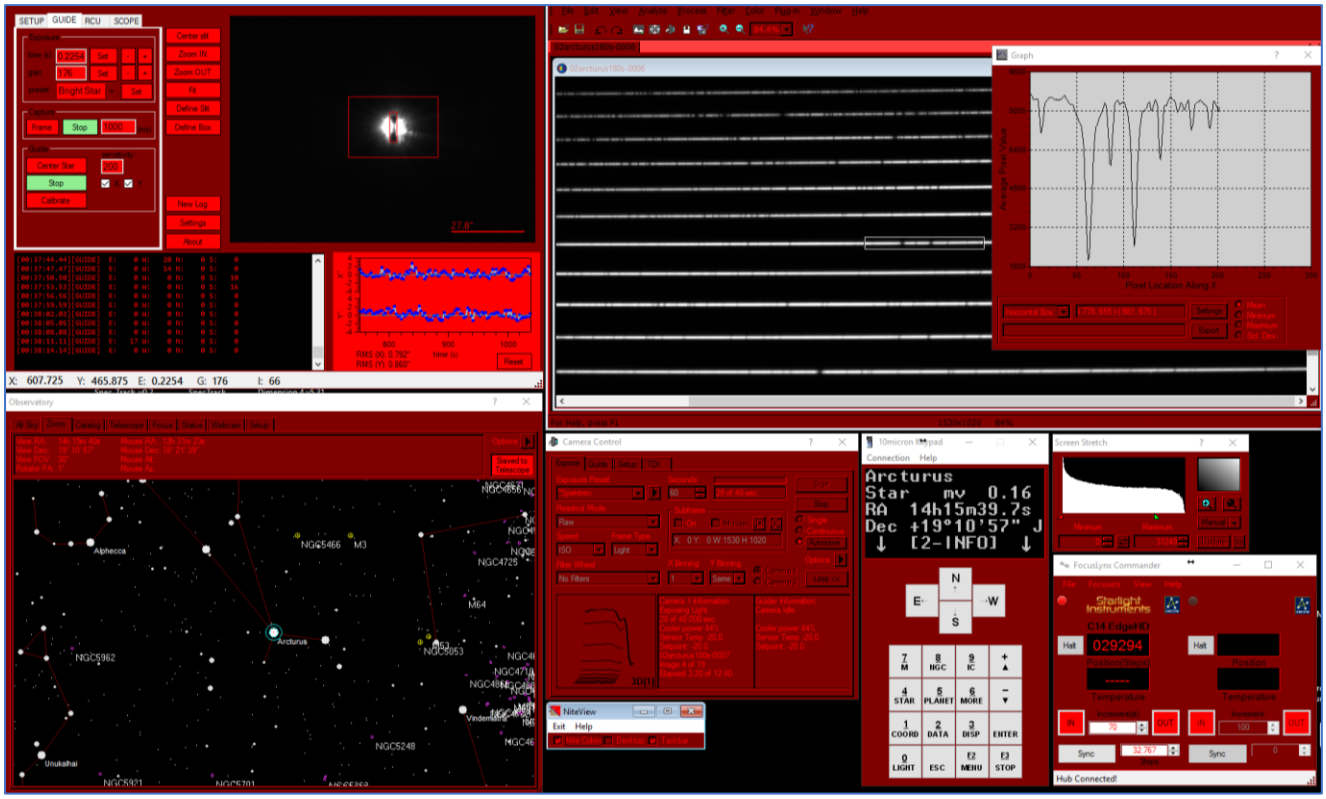
Influence of Seeing

The RMS value of the errors in RA and DEC depends, on the one hand, on the accuracy of the drive. A mount vulnerable to wind with a large periodic error results in higher values. The quality of the spectra is not affected, longer integration times are required. In case of poor seeing, you should consider a longer integration time of your guide camera and reduce the aggressiveness ("sensitivity"). In principle the same problems as in the case of guiding on stars in astrophotography.



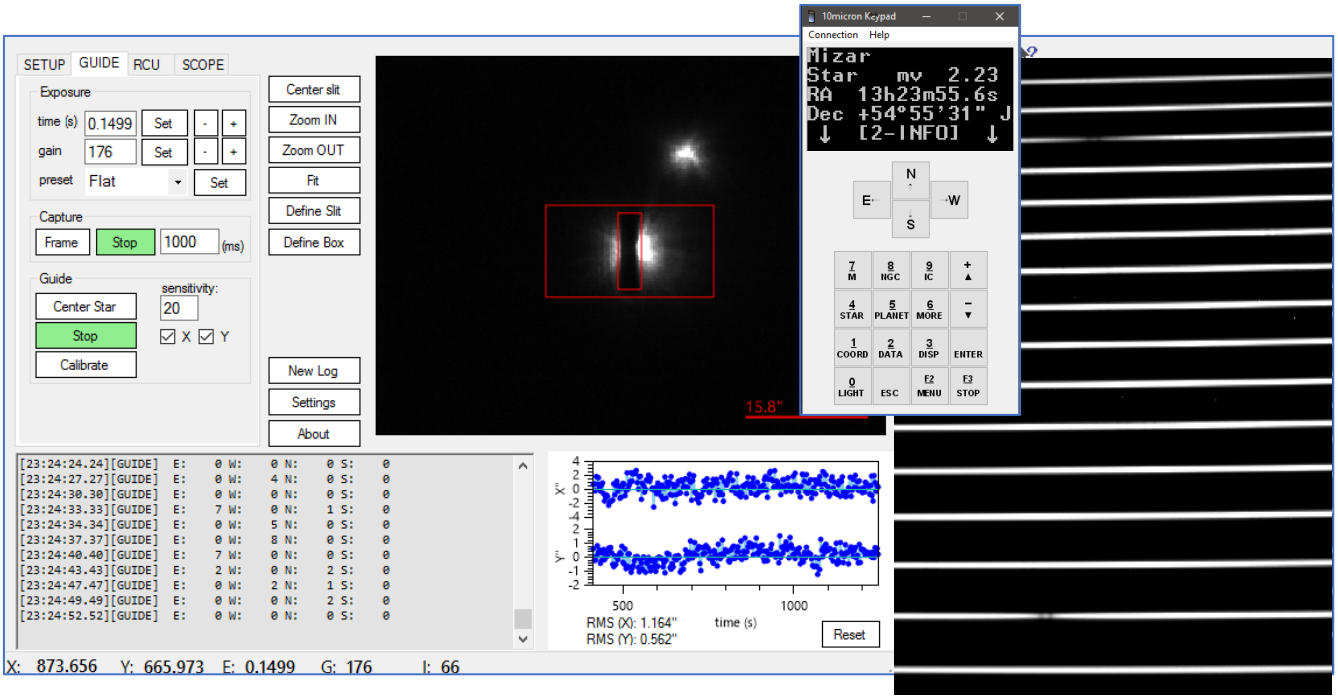
Tipp: NiteView (http://niteview.software.informer.com/)

NiteView is a small, nice program to reduce the glare of your screen.



Binary Stars

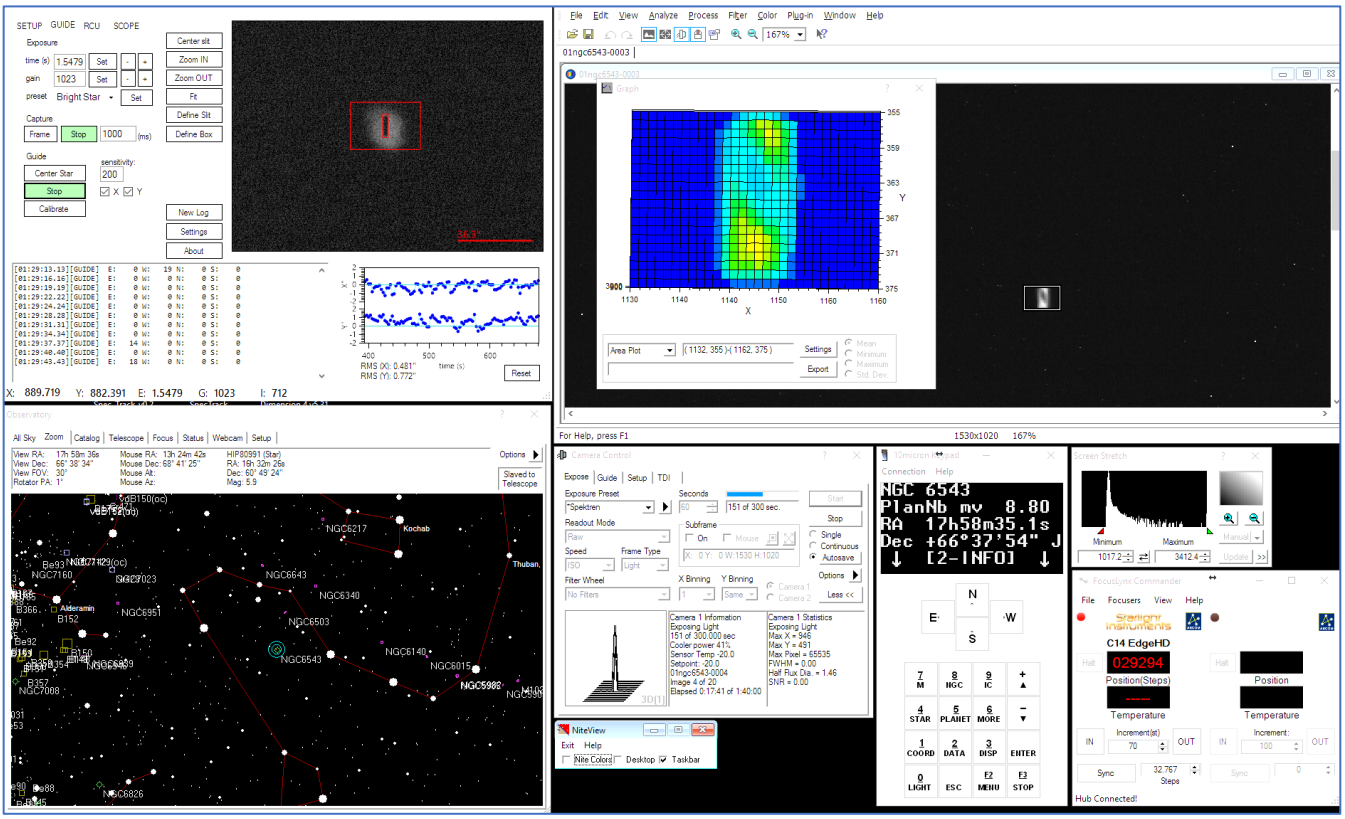
Guiding takes place in the guide box only. If there are additional stars in the field of the guide camera, the guide box must be reduced to such an extent that only the target star, in this example ζ UMa (Mizar A) is included. Note the poor seeing conditions at that particular evening!



Planetary Nebulae

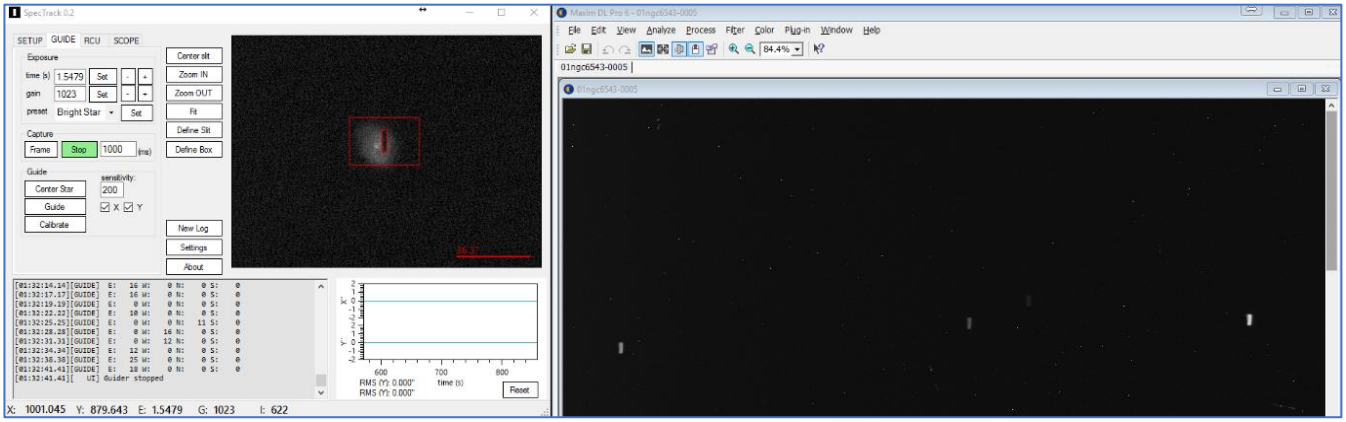
1. Autoguiding on the central area of NGC 6543 containing the 15^m central star

The integration time of the guider camera was set to 1.5s. Since the drive error of the mount 10Micron GM2000HPS is small, the tracking interval can be extended to 10s to 20s without the "central area" leaving the slit box. This improves the limiting magnitude and you can even recognize the internal nebula structures on the video screen.



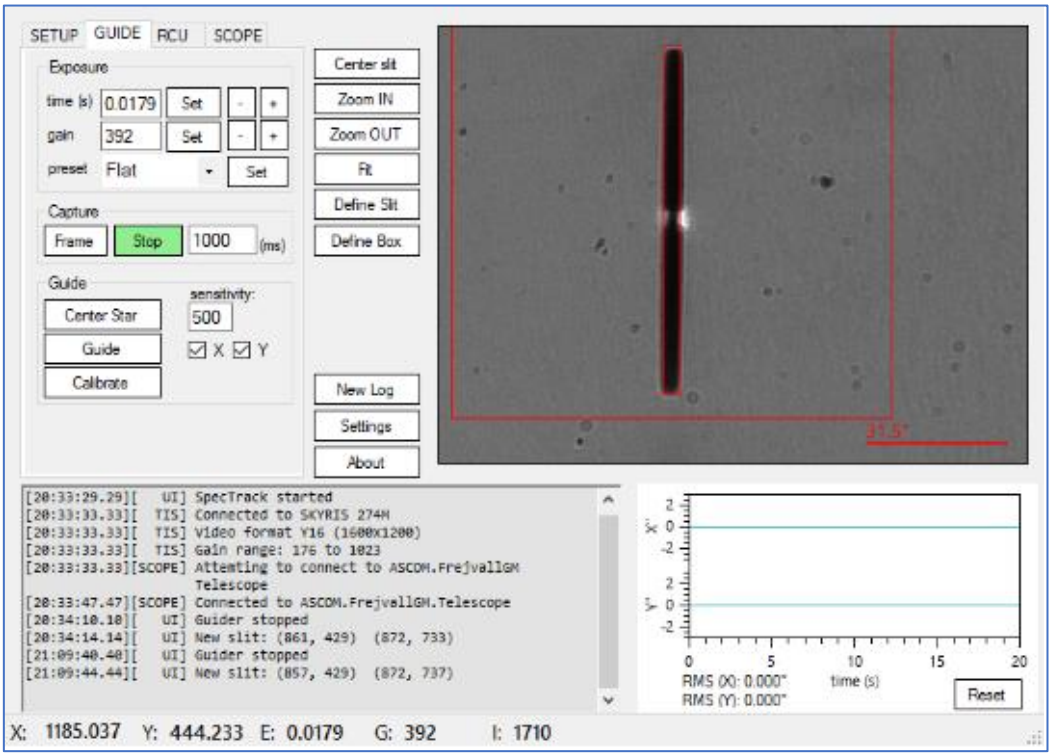
2. Outer nebula area of NGC 6543

SpecTrack is also useful if you do not need autoguiding at all! In case of very low drive errors of your mount, spectra of faint nebulae can be taken easily. Select a long integration time to recognize the nebula on the guide screen and correct the position occasionally by using the telescope control.

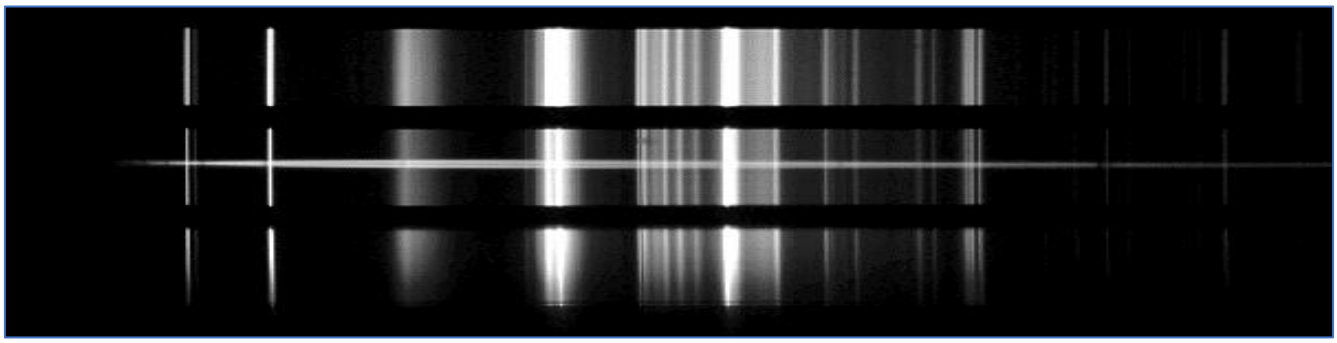


10. SpecTrack Autoguiding of the DADOS Slit-Spectrograph

Since "slit box" and "guide box" can be defined by using the mouse, SpecTrack can be used with any slit spectrograph. SpecTrack has been developed and tested in its full functionality for use at BACHES echelle spectrograph attached to a C14 EdgeHD on a precise 10Micron GM2000HPS mount. It was successfully tested also with the DADOS spectrograph. Since the RCU is not available as a controllable calibration light source for DADOS, this is the only restriction with respect to the full functionality of SpecTrack.



Spectrum of the class A star Regulus with a superimposed reference spectrum of an energy saving lamp.



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