

<http://eqalign.sourceforge.net>



Welcome to EQAlign 2.0

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To Katja Baumhauer and Matías Fraga, for their love and patience
Antonio Fraga

To Antonio Fraga, to Marta Garzo and my **family** for their comprehension.
Francisco José Calvo

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Release notes

EQAlign 2.0 adds several changes to previous versions.

- Totally new step-by-step oriented environment seeking for an easy-to-use interface. New toolbar with direct access icons, direct process button panel, etc.
- Added support for long exposure modified webcams (Steve Chambers's mod). Shutter control can be done through parallel or serial ports. Camera control allows subframe zooming, sum or average stacking frames, histogram stretching and real time gaussian blur filtering of captured frames.
- Added support for Atik (ATK-16IC, ATK-16 y ATK-16HR), QHY5 and Meade DSI cameras (QHY6 coming soon).
- EQAlign 2.0 computes sky position for more than 10.000 stars and deep space objects. It also accurately computes Sun, planets (series96) and moon (elp82) positions and solves orbital elements of comets and asteroids. Orbital elements can be updated or added from the Internet.
- Local sky is drawn on a planisphere in the projection screen, so you have a complete ephemeris for the observing night, with star magnitude, moon and planet phases and comet tail size and orientation.
- Added support for LX200 and ASCOM compatible mounts and a complete control system for Microgiga DA1 controller. RA and Dec axes can be controlled from EQAlign telescope control panels. Scope can be directed and synchronized from/to specific coordinates.
- A friendly full-featured Go To system provides database search with different criteria, object addition, photo association, tour planning and saving in the database. Personal catalogs can be created and updated.
- Aligning star selection is graphically done in the sky projection planisphere where "safe zone" is highlighted. So best star selection for your observing condition can be made in a more easy and intuitive way.
- EQAlign 2.0 implements two guiding algorithms: adaptive linear and adaptive PID controller (Proportional-Integral-Derivative). Guiding control can be done using serial port (LX200 standard or ASCOM protocols), or with Shoestring's GPINT-PT or GPUSB port interfaces (ST4 compatible) or with Pierro-Astro USB Autoguider.
- Added Periodic Error evaluation Utility. All measurements, including aligning and autoguiding ones, are analyzed in a dedicated screen including RA/Dec time derivatives graphics, frequency analysis, RA maximum/minimum peaks, fundamental periods (PE), angle trends (RA/Dec), Standard Deviation and RMS values (in pixels and arcseconds) and time drift units (minutes per arcsecond), allowing the user to evaluate aligning quality.
- On screen azimuthal axes projection computation allows star moving direction prediction when Altitude or Azimuth axes are adjusted, making correction easier. If autoguiding utility is used star is automatically centered making aligning process more easy and comfortable.
- Improved simulation system with configurable parameters: simulated alignment error (in Alt/Az pixels) and Periodic Error fundamental frequency and amplitude. The simulation system uses all these parameters and aligning star coordinates to compute RA/Dec drift values. This simulator provides realistic training in aligning, calibration, autoguiding and EP measurement processes, so you can do the real processes with previous user "experience".
- Added night vision mode.
- Added online self-updating. If Internet connection is available new versions are automatically detected, downloaded and installed. You can control each step manually or let EQAlign do it for you.

EQAlign 2.0 is a totally new project different from 1.0 version: The whole code has been re-written making it more modular and many advanced numerical analysis algorithms have been implemented, providing a faster and more efficient alignment error calculation.

Hoping you will be comfortable with all these changes, any user recommendations or ideas will be appreciated.

Acknowledgements

We want to thank Francesc Pruneda for his collaboration on Catalan translation of the EQAlign 2.0 environment (manual will be available in this language soon) and Thierry Serieys for his translation of the environment and manual to French.

We encourage other users to translate this manual to their own languages and so make this software friendly to more people. Thank you very much.

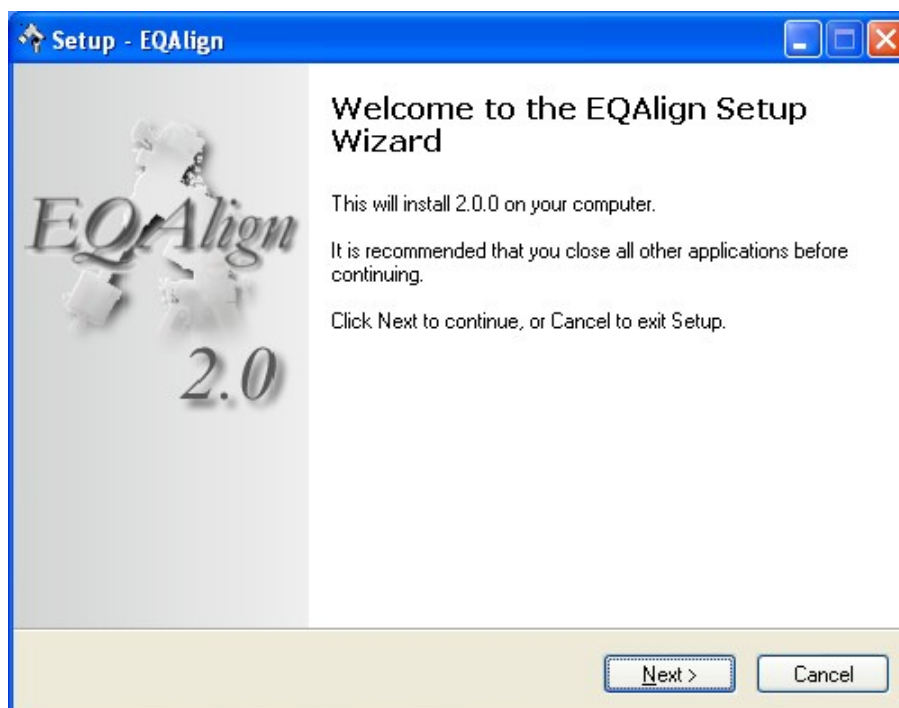
We will also like to acknowledge **Miguel Ángel Hernández Pérez** of **Alphacygni** (<http://alphacygni.com>) and **Henrik Hansen** of **astroQcam** (www.astroqcam.dk) for sponsoring this project supplying different resources to use in EQAlign development.

We also thank the Tenerife Astronomic Observatory Group (G.O.A.T.) and everyone who has collaborated or been interested in this project.

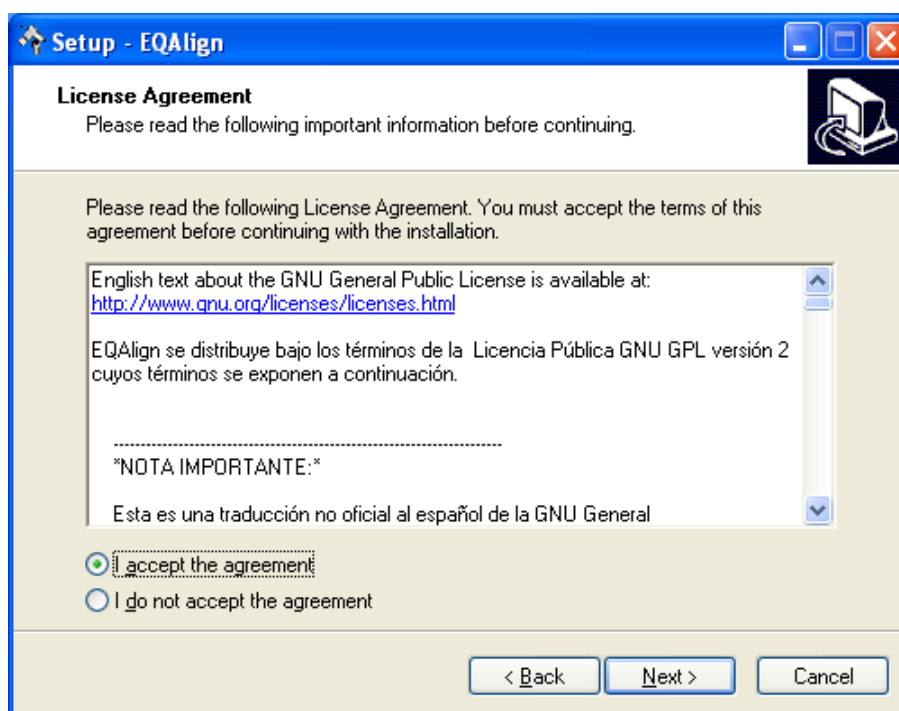
1. First steps

1.1. Installation

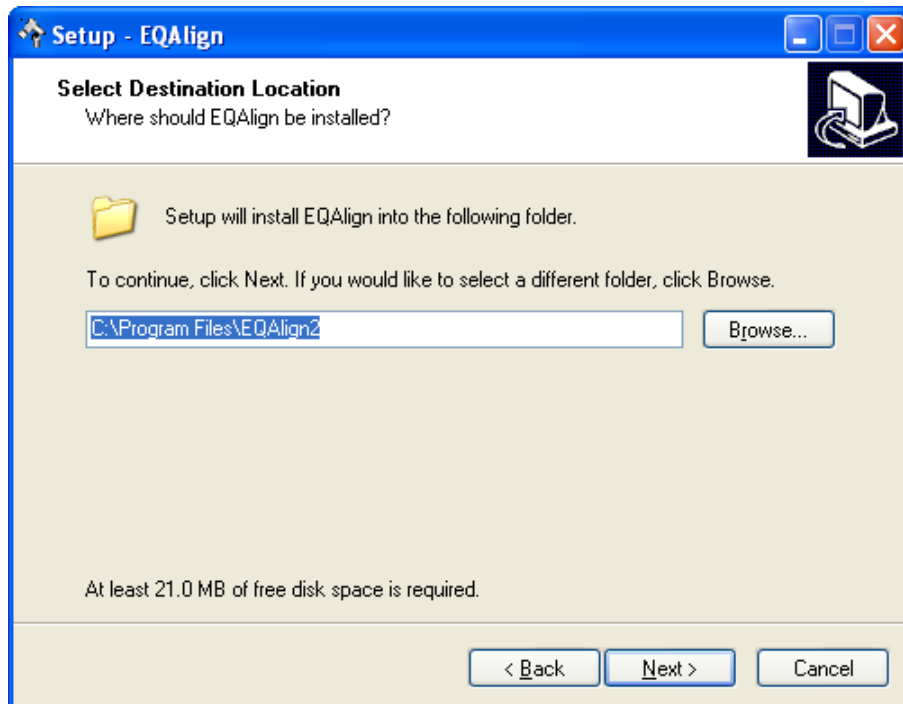
Installation is done in a simple six-step process:
First step is the welcome screen, just click "Next":



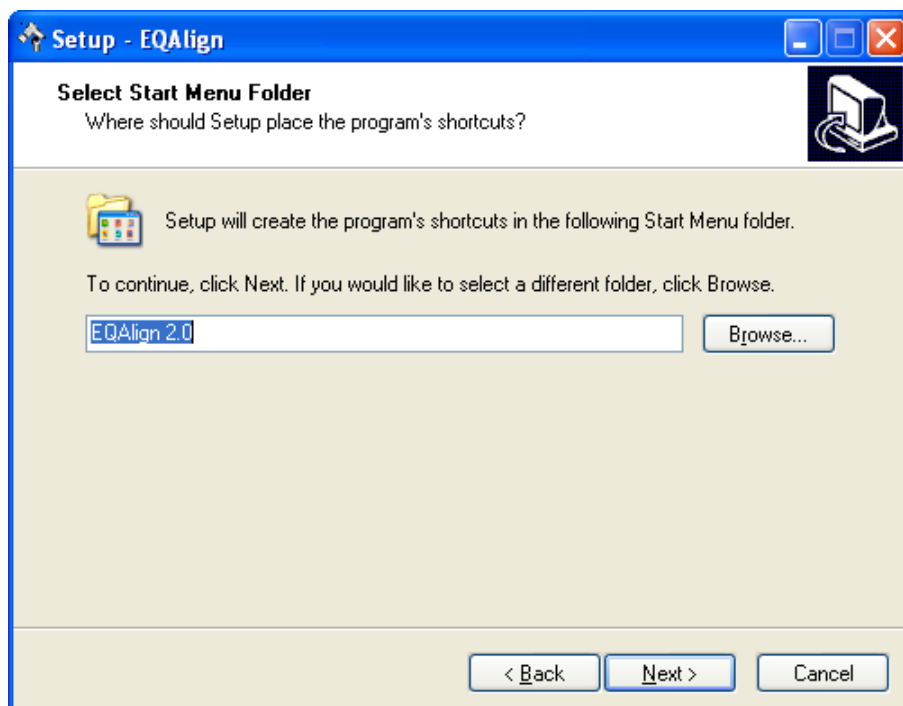
Second screen shows GNU/GLP license agreement. After reading the license select "Accept" and click "Next".



In the third screen you can change the installation folder for EQAlign files, then click "Next".

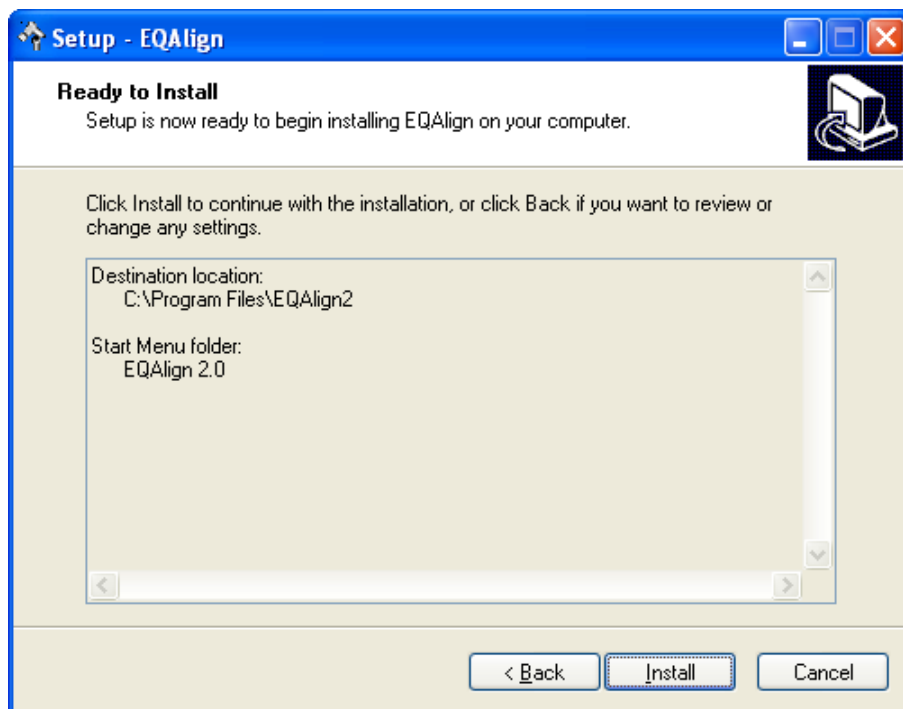


The following screen lets you select where to create EQAlign shortcut in the Start Menu, click "Next":

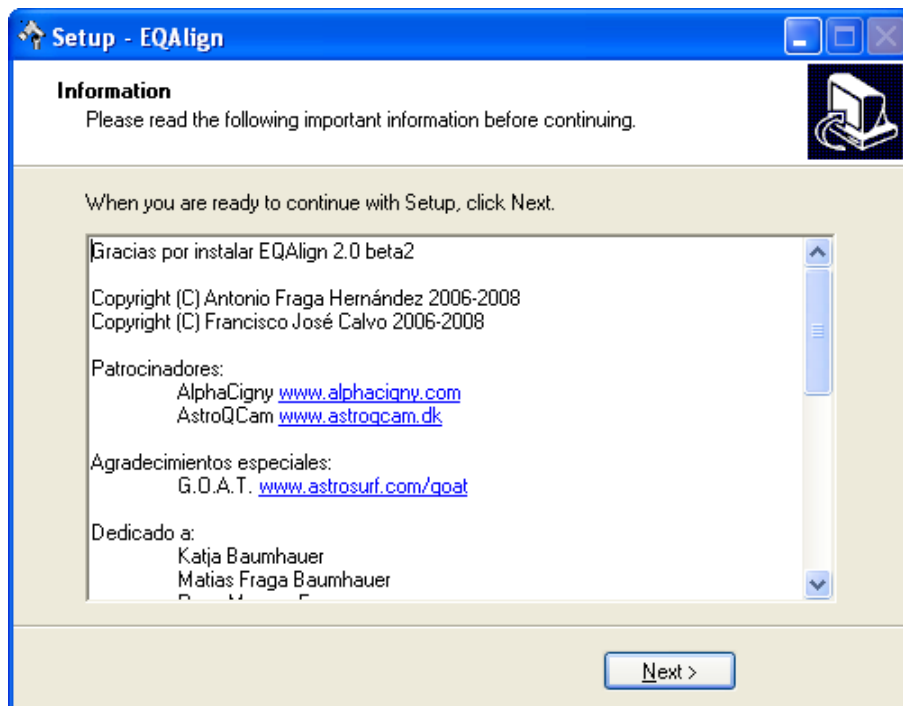


A menu folder will be created containing two links: "EQAlign 2.0" and "Uninstall EQAlign"

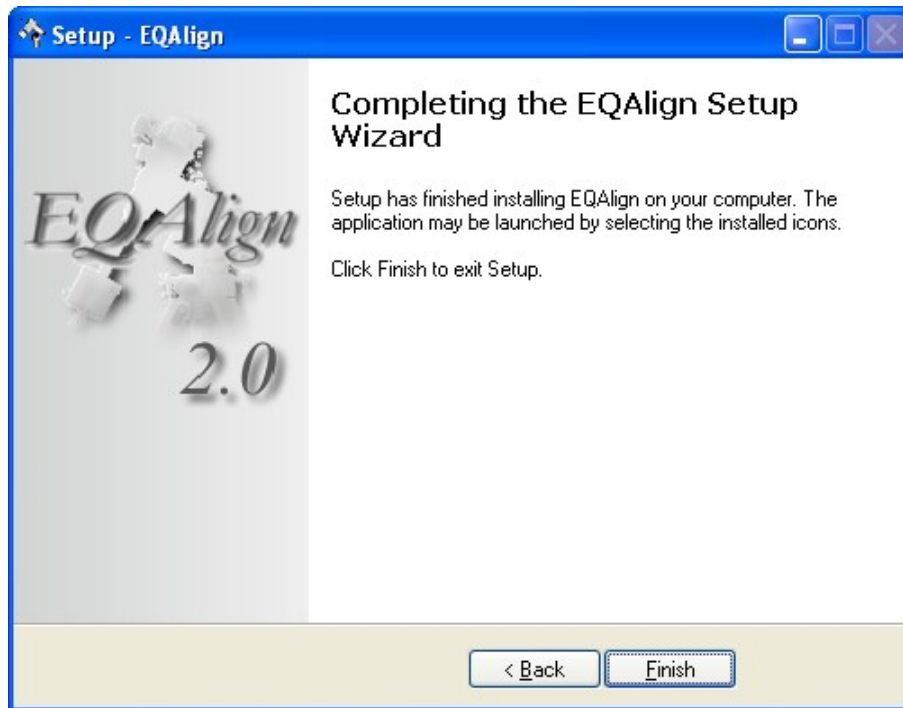
Next screen shows components to be installed, click "Install":



Installer will copy software files to the selected folder and show an information window when finish. Click "Next":



At this point installation is complete. Click “Finish”:



Now you can run EQAlign.

When you run EQAlign for the first time, the [basic configuration screen](#) will be shown.

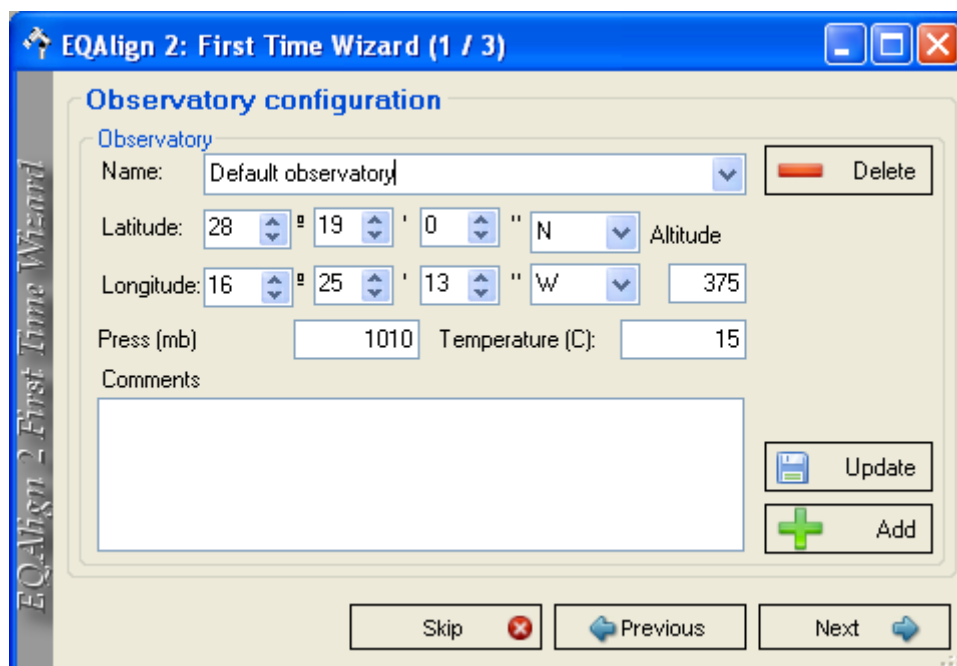
1.2. Basic configuration

Once you have installed EQAlign, when you run it for the first time, “First Time Wizard” will be shown. Here you can select the default language:



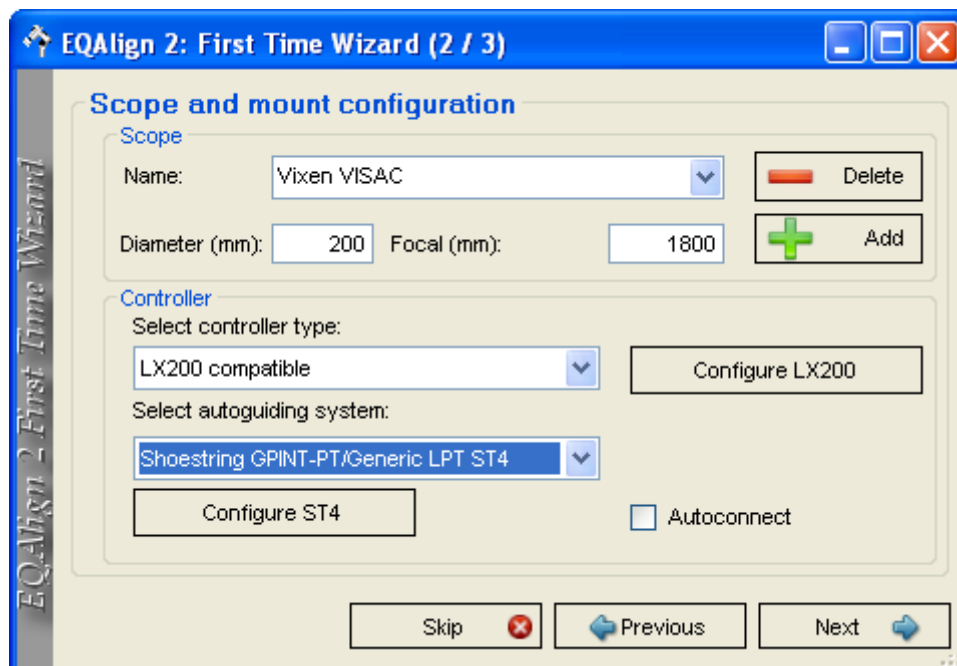
In the next wizard step you can specify geographic coordinates for all your usual observing sites.

EQAlign comes configured with the author's usual sites as default. You can delete the default sites (“Delete” button), add a new site (enter new site name and information and click “Add” button) or modify an existing site (change information and click “Update” button):

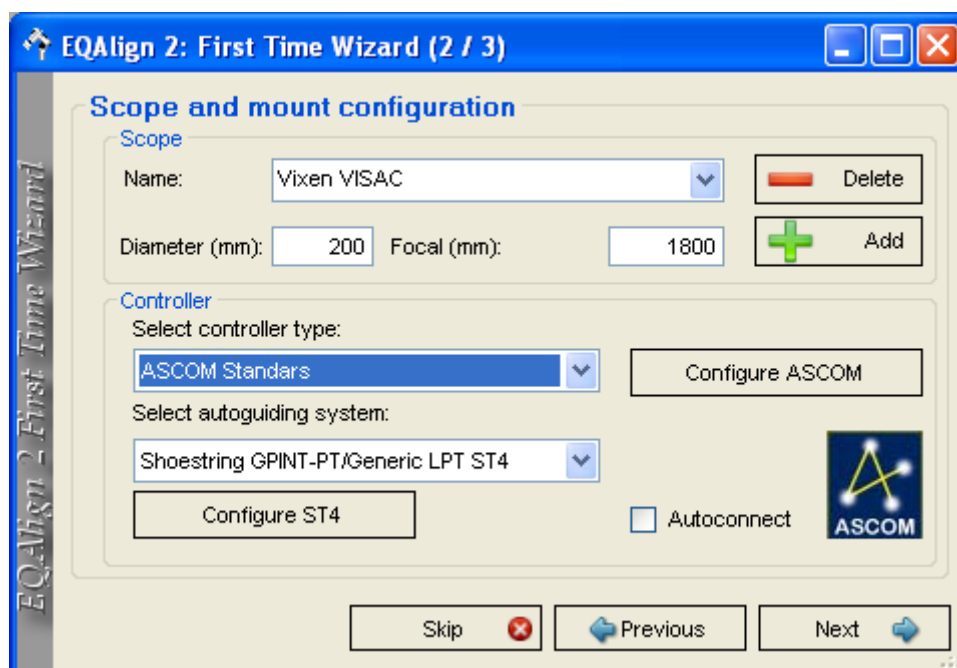


In the next step usual scope(s) can be specified. As in the previous step, you can delete/add as many scopes as you want. The “Focal” parameter (and “camer pixel size in microns” as will be seen later) are used to compute the equivalence between pixels and arcseconds. You can also

specify the default mount controller type (LX200, ASCOM, DA1 or manual if there is no mount driver control) and the default port the software will use to control the mount. Checking Autoconnect EQAlign will connect to the autoguiding system at startup.



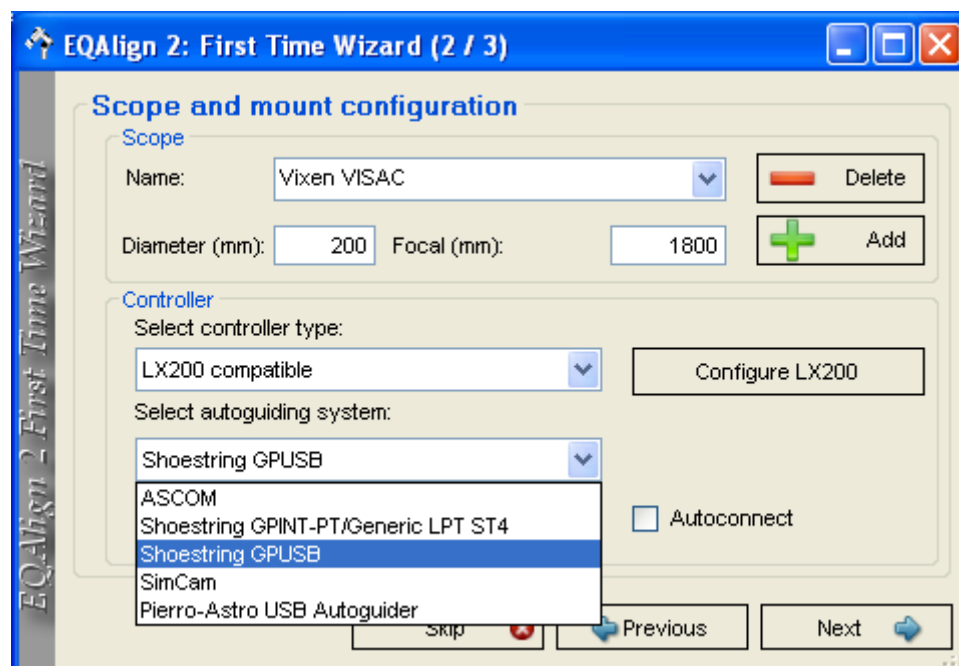
If you select ASCOM standard controller, "ASCOM config" button is shown. Clicking this button you access to the standard ASCOM driver selection dialog:



If you select DA1 controller, "DA1 config" button is shown. Clicking this button you access to the DA1 driver configuration dialog:



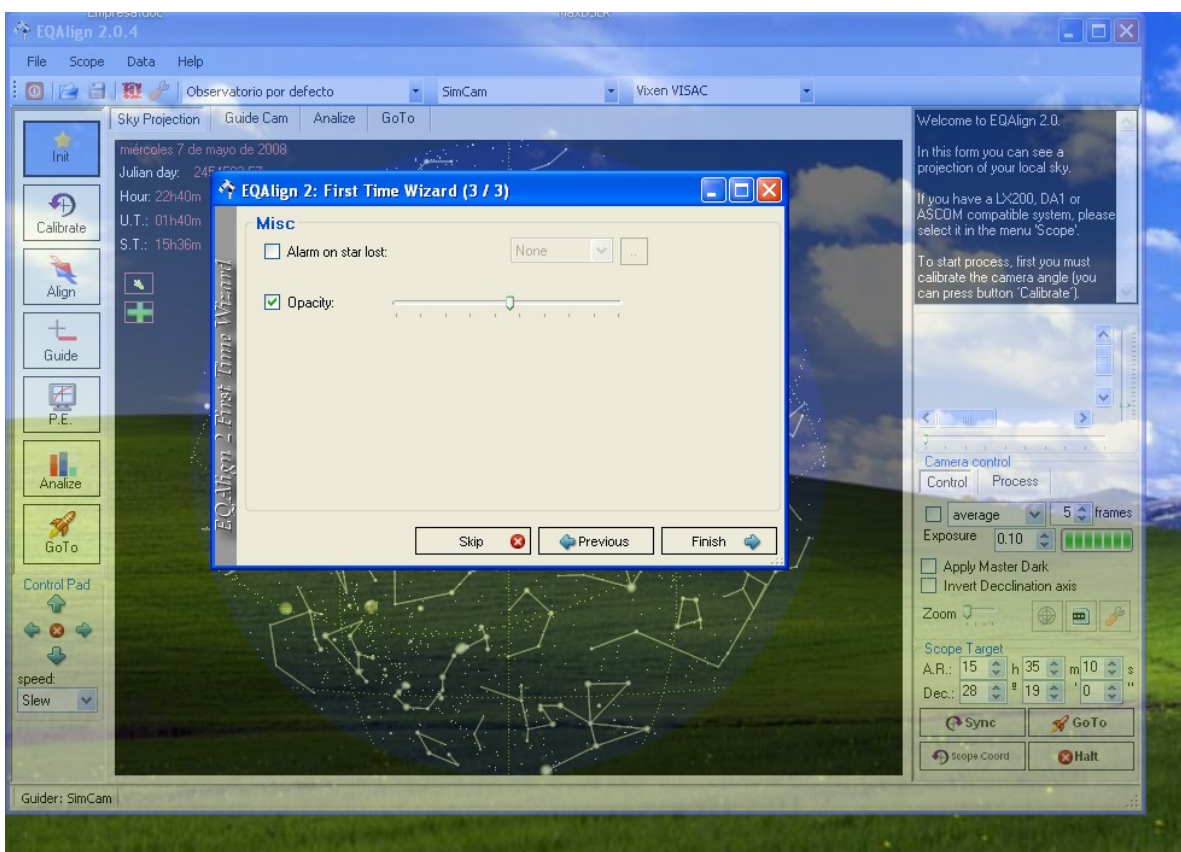
You can also specify the default autoguiding control system:



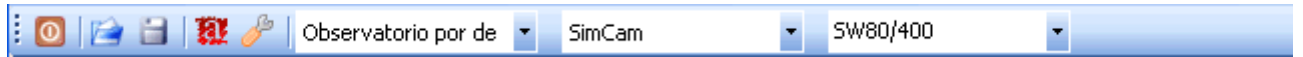
On the next Wizard screen "Alarm on star lost" allows selecting alarm sound in case a star is lost during measure process. You can select "None", "Sonar" or "Buzzer" (internal program sounds) or any wav file in your PC.




“Opacity” option allows setting opacity level for EQAlign main window. This option may be useful to watch other software running on the background (as the main camera capture program) while using EQAlign:



Once you have entered this information, EQAlign continues with normal startup. Basic configuration information can be seen on the toolbar in three pull-down lists, making one-click site, camera and scope selection possible.

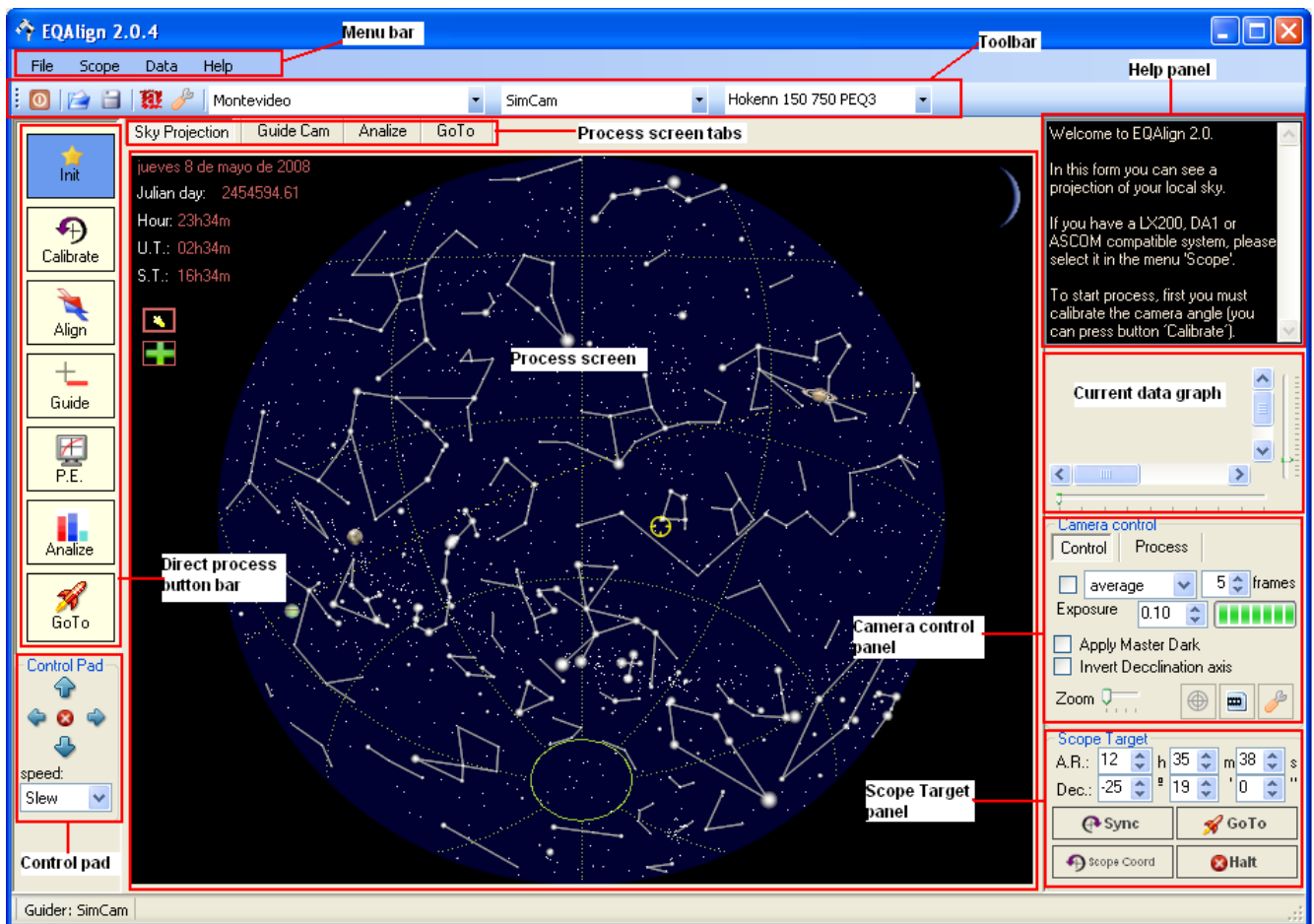


You can return to basic configuration anytime to add/modify new scopes or sites, change language or other options. Just select “File” > “Config assistant” in the menu or click on the toolbar icon .

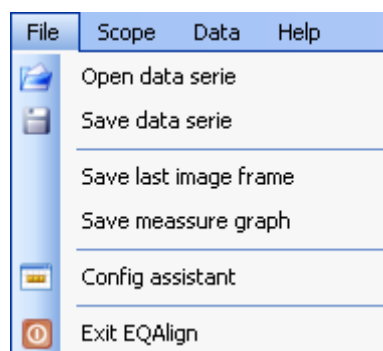
Congratulations, now you are ready to start using EQAlign!

2. Program elements description

This screenshot shows all the main elements.



2.1. File Menu



“Open data series” loads previous measurement data saved with “Save data series”.

“Save data series” saves an ASCII file containing information about the scope, camera, observing site, mount controller and autoguider (if used), measured star equatorial coordinates and hour angle, recording date and time and record duration in minutes. Saved measurement data are: elapsed time since recording start (in seconds), Right Ascension error, Declination error and autoguiding RA and Dec pulses when used. A graph is created from these data and it can be analyzed in the [“Analyze”](#) process window.

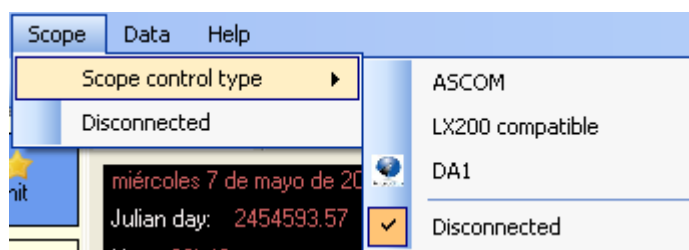
“Save last image frame” saves the last frame captured from the camera (with reticle if active) in jpg or bmp format.

“Save measurement graph” saves the graph generated from measurements in memory, in jpg or bmp format. These measurements may be the last measured ones or loaded from saved file (see [“Analyze measurements”](#)).

“Config assistant” starts the “First Time Wizard” for site/scope configuration as seen on [“Basic configuration”](#)

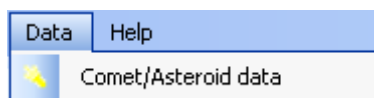
“Exit EQAlign” closes scope and autoguiding connections and exits the program.

2.2. Scope Menu



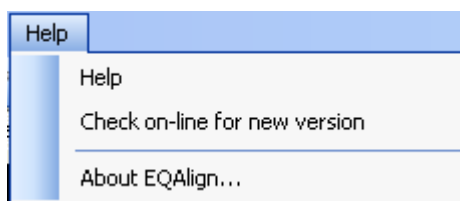
Most of the processes that had to be manually done with previous version (like stopping drive to measure camera angle) can now be automated if there is a LX200, DA1 or ASCOM protocols compatible controller. In this menu this controller can be connected, disconnected and configured (see [“Scope selection”](#))

2.3. Data Menu



In this menu you can configure the object catalog (stars and deep space objects) and update comets and asteroids data (see [“Comet and asteroids data update”](#))

2.4. Help Menu



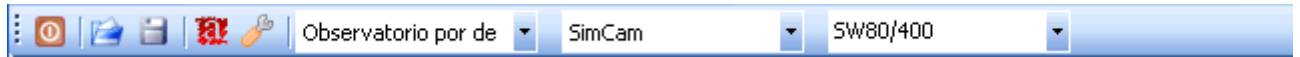
0

- Help:** On line help is not available yet.
- Check on-line for new version:** EQAlign will connect to the Internet and search for the last available version, check current version and inform if there are available updates.
- About EQAlign:** shows a dialog with information about EQAlign, authors, license and acknowledgments.

2.5. Direct process button bar

This bar on the left of the screen have buttons to activate each of the main processes screens.

2.6. Toolbar



The toolbar has shortcut icons to exit the program, open or save measurements, toggle night vision mode or call configuration wizard. It also has pull-down lists for site/camera/scope selection.

2.7. Camera Control

Using the Camera control panel (middle right side of screen) you can

- Sum or average stack frames (very useful if you don't have a long exposure camera),
- Modify histogram, gamma, contrast and image blur,
- Control long exposure time (for SC modified webcams, Atik, QHY5 or Meade DSI cameras),
- Show/hide reticle on camera image window,
- Take and apply MasterDark for dark current and hot pixel correction,
- Invert Declination axle direction,
- Toggle between Control and Process Camera panels (see ["Camera selection and control"](#))

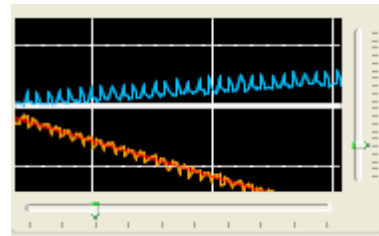
2.8. Telescope movement and pointing

At the bottom of the screen, Telescope Control Pad (left) and Scope target panel (right) allow controlling the scope through guiding pulses, point it to specified coordinates (GoTo) or synchronize the scope with selected coordinates (Sync) (see ["GoTo System"](#))

2.9. Current data graph

This panel on the right side of the screen display current measurement data in real time (orange for Dec and blue for RA).

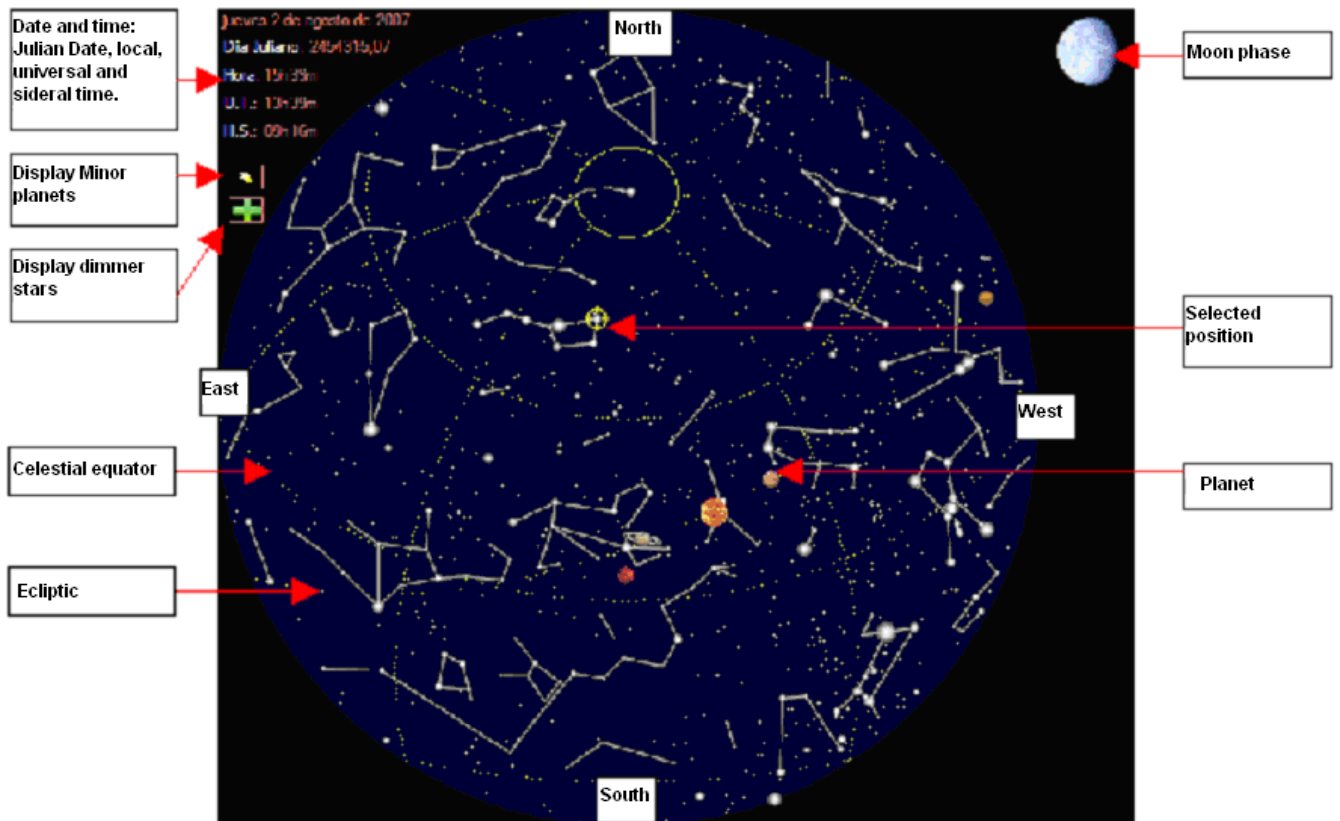
Horizontal and vertical scales can be adjusted using the sliding bars bellow and right of the graph.



2.10. Help panel

This panel in the upper right corner of the screen displays helping tips about the current screen operation.



3. Ephemeris and Projection



Ephemeris and Projection screen displays a map of current sky showing position of stars, moon, planets and minor planets.

This screen is used as support for other EQAlign functions making graphic coordinates selection possible. These coordinates may be used to define aligning star or as target GoTo or Sync coordinates.

Using the projection screen is easy:

- Cursor polar (RA & Dec) and local (Alt/Az) coordinates of the mouse point are shown,
- When passing over, object type, name, magnitude, rise, culmination and set time are shown,
- Coordinate setting is done left clicking on the selected position; this position is marked with a yellow circle sight.
- In/out zooming (centered on the selected position) is done using the mouse wheel.
- Minor planets visualization can be activated clicking on the "Minor planets" icon  in the left side of the screen. This operation can't be undone.
- Default projection shows only brighter stars but dimmer stars can be shown clicking on the "More stars" icon  in the left side of the screen. This operation can't be undone.

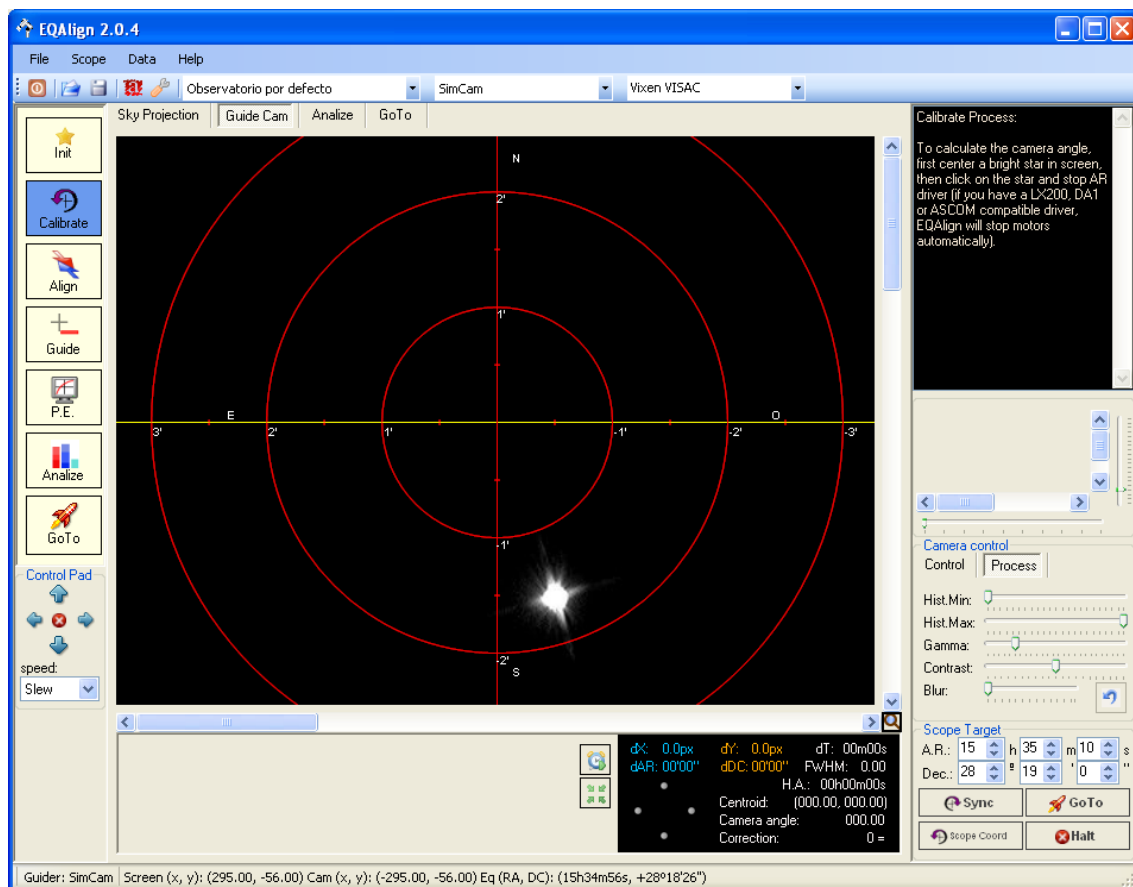
4. Simulation System

EQAlign 2.0 includes a simulation system designed to help you on aligning process training during daytime before a real observing night.

The simulation system use given alignment error, periodic error (adjusted to a sinusoidal of given amplitude and period) and selected star coordinates to simulate drift behavior of the star. To activate simulation mode, just select "SimCam" in the camera pull-down list.

Then you can use any process screen of EQAlign like if you had a real camera in a real scope pointing to a real star. You can measure camera roll angle, align the "mount", autoguide or measure periodic error.

We recommend using the simulator mode to train your skills on EQAlign use and features (comfortably indoors and during daytime) before doing the real thing in a real observing night.



5. Camera Selection and control

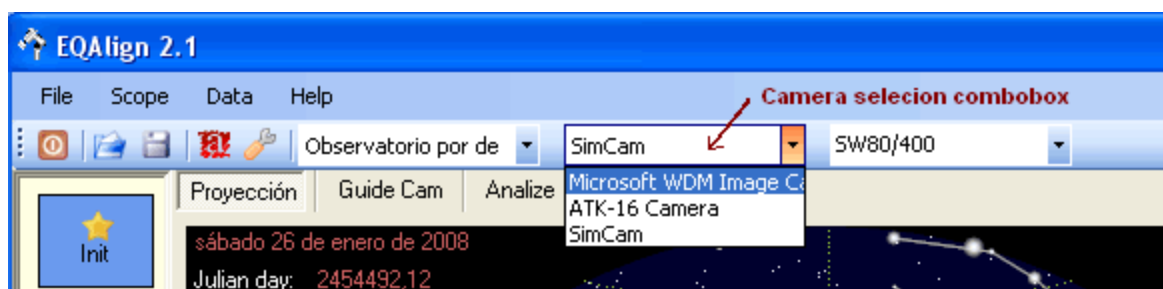
EQAlign is compatible with any camera using WDM standard (almost any webcam) and also supports long exposure cameras, including SC modified webcams and Atik series 1 and 2. It can also detect and capture frames from Atik16IC, Atik16, Atik16HR, QHY5 and Meade DSI (QHY6 coming soon). We are working on further camera support.

EQAlign detects cameras during startup and try to connect to them.

If connection is not possible, because the camera is connected to another application or because there is no camera connected, only the simulated camera will be available.

5.1. Camera Selection

To activate a camera, just select it from the camera pull-down list in the toolbar:



This list contains all detected cameras that were available (not connected to another application) at startup and the Simulation camera (SimCam).

5.2. Camera Control

Camera control panel (at the right side of the screen) has two modes: "Control" and "Process".


In **Process mode** it is designed to allow setting of several camera image parameters in order to capture clear images of dim stars, needed for accurate measurement.

Histogram: Black ("Hist.Min") and white ("Hist.Max") levels can be set with two sliding bars to make a histogram linear stretching.

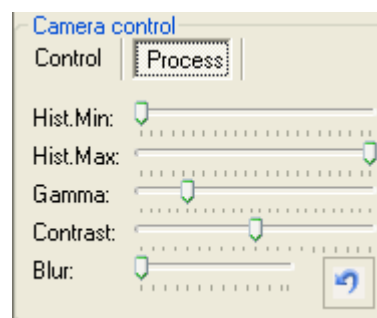
Gamma: Gamma value may be set with this bar for gamma histogram stretching.

Contrast: changes image contrast in real time.

Blur: This bar sets the level of blur filter applied to captured image. This is useful in some cases like high turbulence.

Reset to default : Resets image options (histogram, gamma, contrast and blur) to default values.

NOTE: All theses image modifications not only affect displayed image, but also captured image used to compute star centroid for measurements.



In **Control mode** you can control camera exposure and image calibration settings:

Stacking options: Up to 10 frames can be stacked by average or sum. This is useful when a long exposure camera is not available.

Exposure: if a long exposure camera is available, exposure time can be set here starting from 0.1 seconds. When a non-modified webcam is used, this value only affects sampling time.


Zoom: When a star is selected in the camera image window, zoom level can be set x1, x2, x3 or x4. Zoom activation is toggled on/off clicking on the magnifying glass icon in the lower right corner of the capture image window.

Apply Master Dark: this check box activates Dark Frame calibration of captured images. This operation compensates hot pixels that may be misidentified as stars.

Invert Declination axis: this box indicates to EQAlign if the Dec axis is inverted in the image due to an odd number of mirrors in the scope light path. It should be unchecked for Newtonian scopes at primary focus but checked if a diagonal prism is used.

There are also four process buttons:

Reticle show  **and hide** : toggles between show/hide reticle on camera image window.

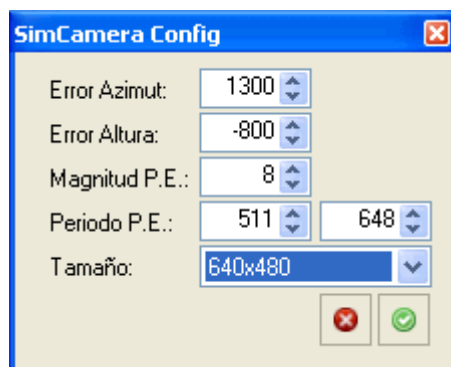
Take Master Dark : starts Dark Frames capture and Master Dark calculation process. When this button is pushed EQAlign asks you to cover the camera and captures 9 Dark Frames with the specified Exposure time. Then average stacks dark frames into a Master Dark and starts applying the Master Dark. Master Dark application may be deactivated anytime later unchecking the "Apply Master Dark" check box.

Camera config : calls the camera configuration dialog (see ["Camera configuration dialog"](#))

5.3. Camera configuration dialog

Each camera type has a different configuration dialog.

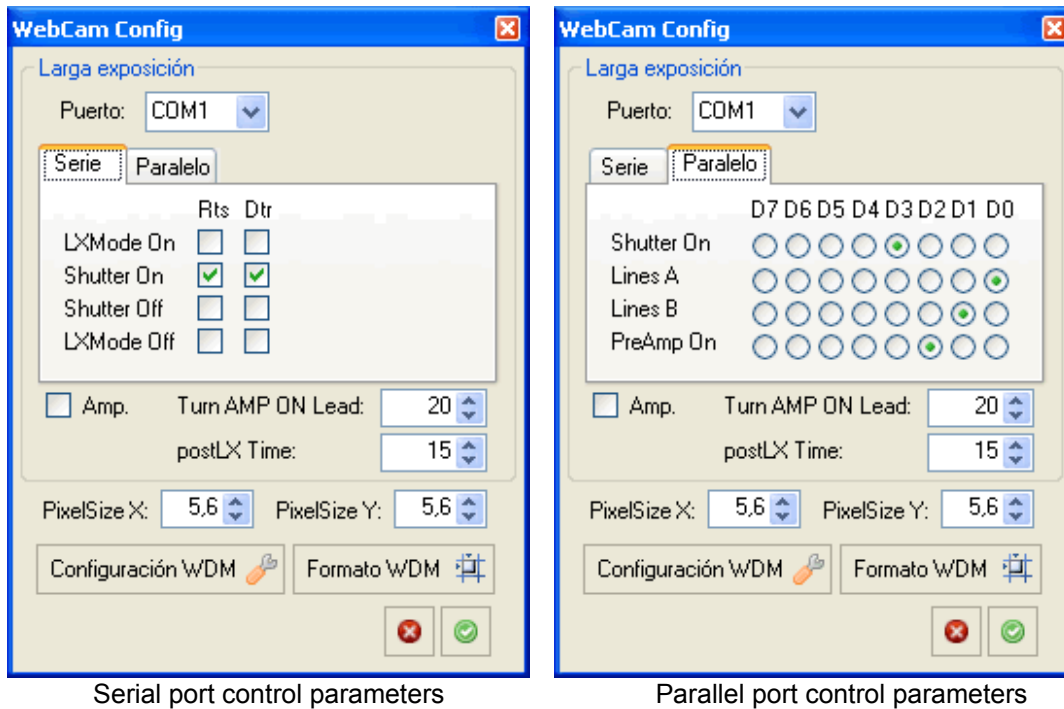
Configuration dialog for simulated camera:



Here you can set some simulation parameters: Azimuth and Altitude alignment error (in pixels), Periodic Error amplitude (in arcseconds) and period (in seconds). Image size can be selected between 640x400, 752x852 or 1392x1040.

Configuration dialog for webcams and long exposure modified webcams:

Here you can select long exposure control port (COMxx or LPxx). For the selected port, pin configuration may be modified. Default pin configuration has standard values, you will probably not need to change them, just select the correct control port for your webcam.



Amp checkbox: activates Amp-off mod use during exposure.

Turn AMP ON Lead: set lead-time with amp turned on before starting frame download at the end of a long exposure. Usually 20ms is OK.

PostLX Time: set time delay in milliseconds after “end exposure” signal is sent to the camera and before starting frame download. Too little values may cause frame loss and too big values may cause to download a later frame instead of the long exposure one. Values between 10ms and 20ms seem to work OK.

PixelSizeX and PixelSizeY: set X and Y pixel dimensions in microns. These parameters are combined with scope focal length to compute equivalence between pixels and arcseconds.

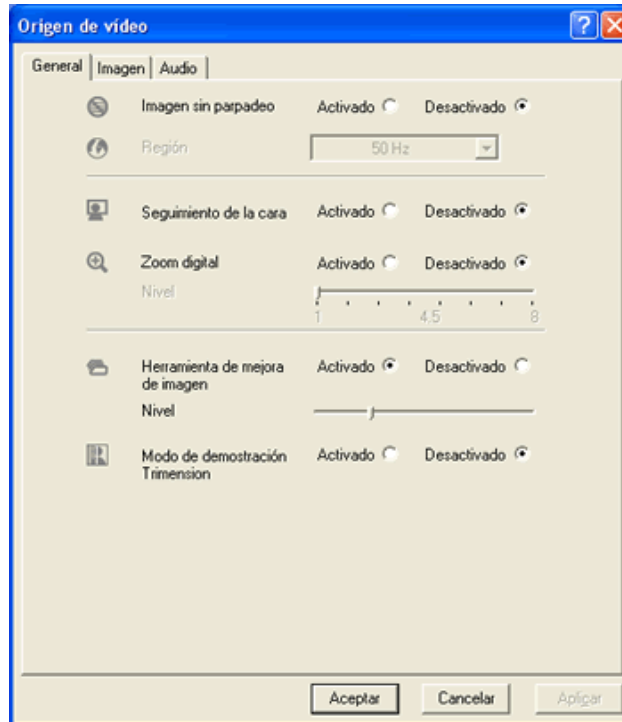
Any changed configuration parameter is saved in the application register and you will not need to change them unless configuration changes (port or webcam).

Video source configuration and **Video format** dialogs can be seen pushing “WDM config” and “WDM format” buttons.

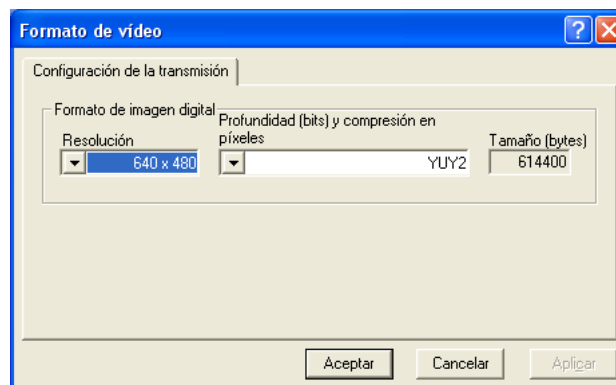
These are the usual dialogs for your camera and how they look like depends on your camera model.

Here are some examples:

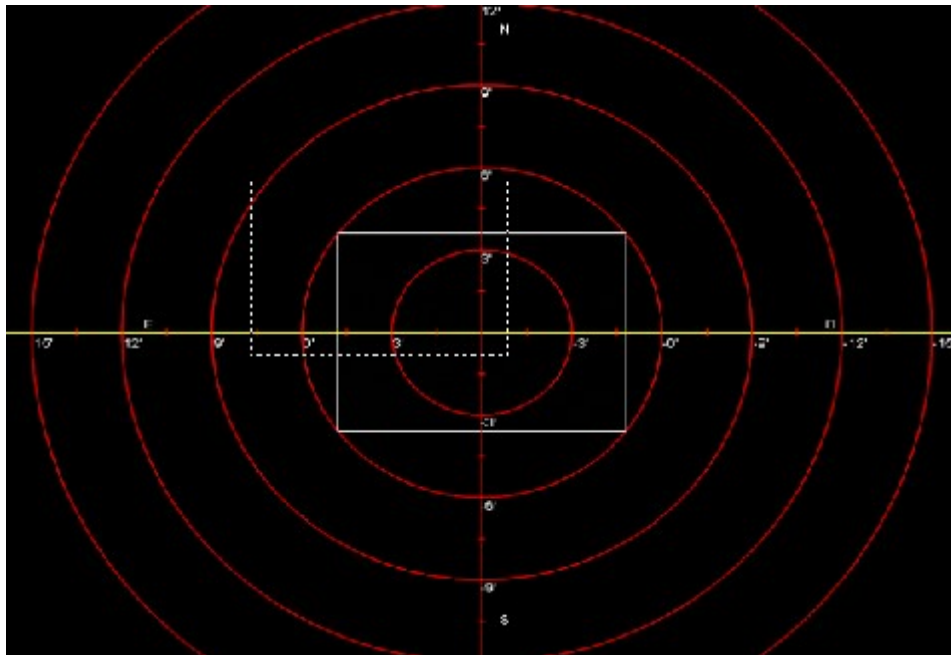
Video source:



Video format:



5.4. Subframes



When a star is selected (left clicking it in the camera image window) you can activate subframe zoom clicking on the magnifying glass icon on the lower right corner of the image window.

Selected star will be centered in the zoomed subframe and tracked as it moves.

Zoom factor can be changed from the [camera control panel](#).

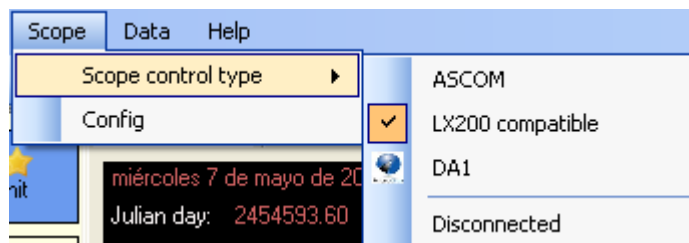
Aligning can be done with the main scope camera regardless of the camera to be used for autoguiding (usually in a guiding scope with shorter focal length).

When using Atik 161C for autoguiding, subframe zoom makes frame download faster.

6. Scope selection

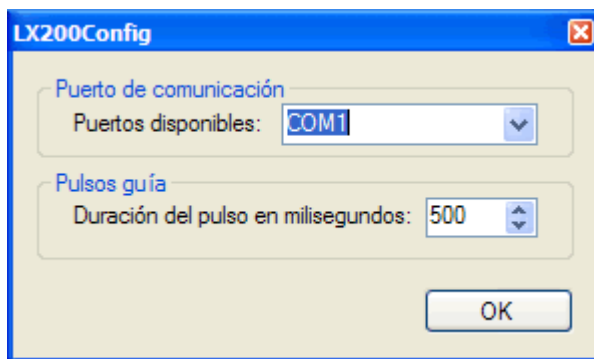
When a LX200, ACOM o DA1 protocols compatible mount is used, EQAlign can automate many operations: tracking motor start/stop during calibration process, centering star after an aligning correction, point scope to selected GoTo coordinates or Synchronize scope with selected coordinates.

Mount controller can be selected in the Scope menu:

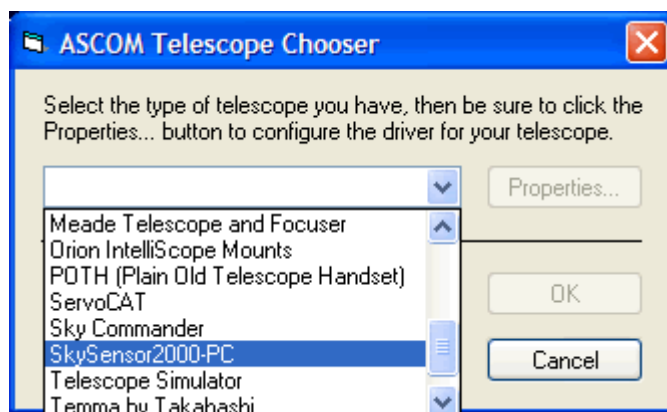


Scope Controller configuration dialog can be accessed from First Time Wizard as seen in [Basic Configuration](#).

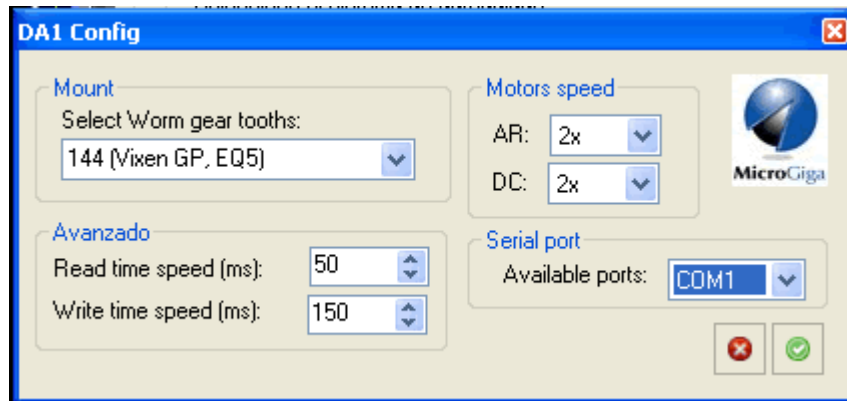
The Controller configuration dialog seen depends on the selected controller type:



LX200 Configuration dialog

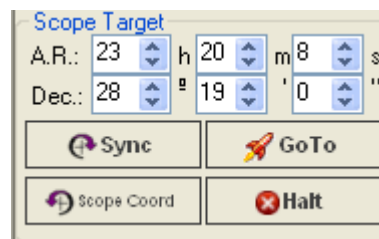


ASCOM Configuration dialog



DA1 Configuration dialog

Once scope connection is established, Scope target panel (lower right corner of the screen) can be used to point the scope to the selected coordinates (pushing GoTo button),



or synchronize scope with selected coordinates (pushing Sync button) or stop a GoTo displacement (Halt button).

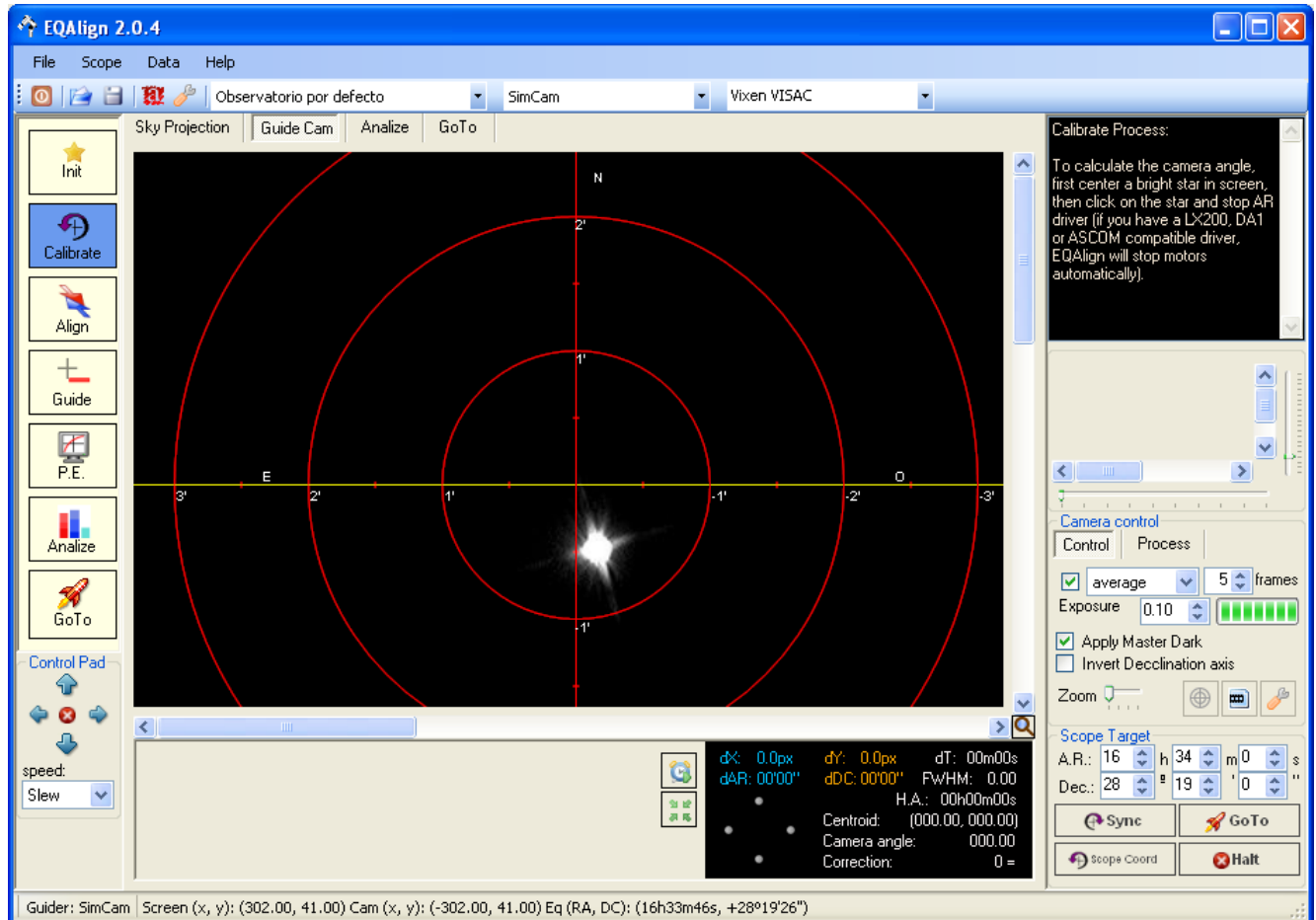
Coordinates can be selected typing in the RA and Dec controls or selecting a position in the [Projection window planisphere](#).

NOTE: autoguiding has not been tested for non-pulse guiding compatible mounts, like some Celestron models.


7. Camera roll angle measurement

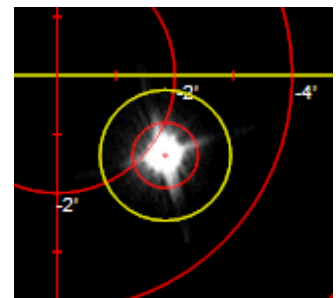
Before any measurement or autoguiding, EQAlign must know camera roll angle. Although this has to be done only once, due to German Equatorial Mount (GEM) designs, East-West direction inverts when passing from one side of the local meridian to the other. As roll angle measurement is quick, we recommend doing it every time measured star is changed.

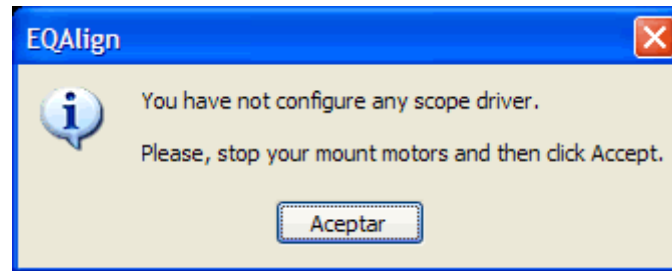
First, select Calibration clicking on the “Calibrate” button in the direct process button panel (left side).



a) Center chosen star in the image window using RA/Dec arrows in the control pad (or using your manual scope controls) and select the star clicking on its image. A little red circle and a bigger yellow circle will mark the selected star.

b) Push “Start process” button  below the image window. If a mount controller is not available, the following message box will ask you to stop tracking motor.






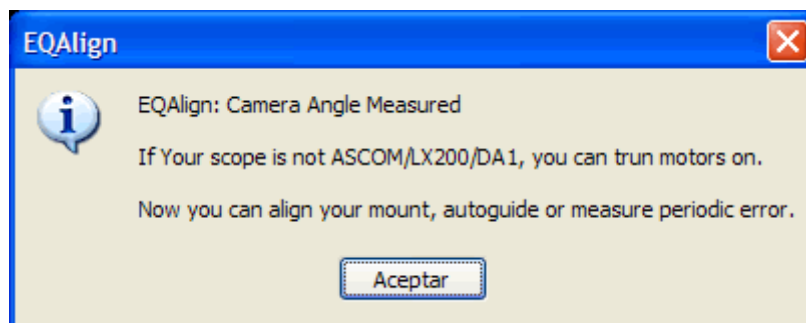
c) Stop tracking motors and click OK. When LX200, ASCOM or DA1 controller is in use, EQAlign will stop tracking motors for you.

NOTE: With some ASCOM compatible controllers stopping tracking motor is not possible. In this case EQAlign will send East direction guiding pulses to force star to “move” west. Depending on the particular ASCOM controller design, it is possible that the star moves east instead of west. This will affect North/South direction calculation, but this may be fixed Inverting Declination axis (See [“Camera control”](#)).

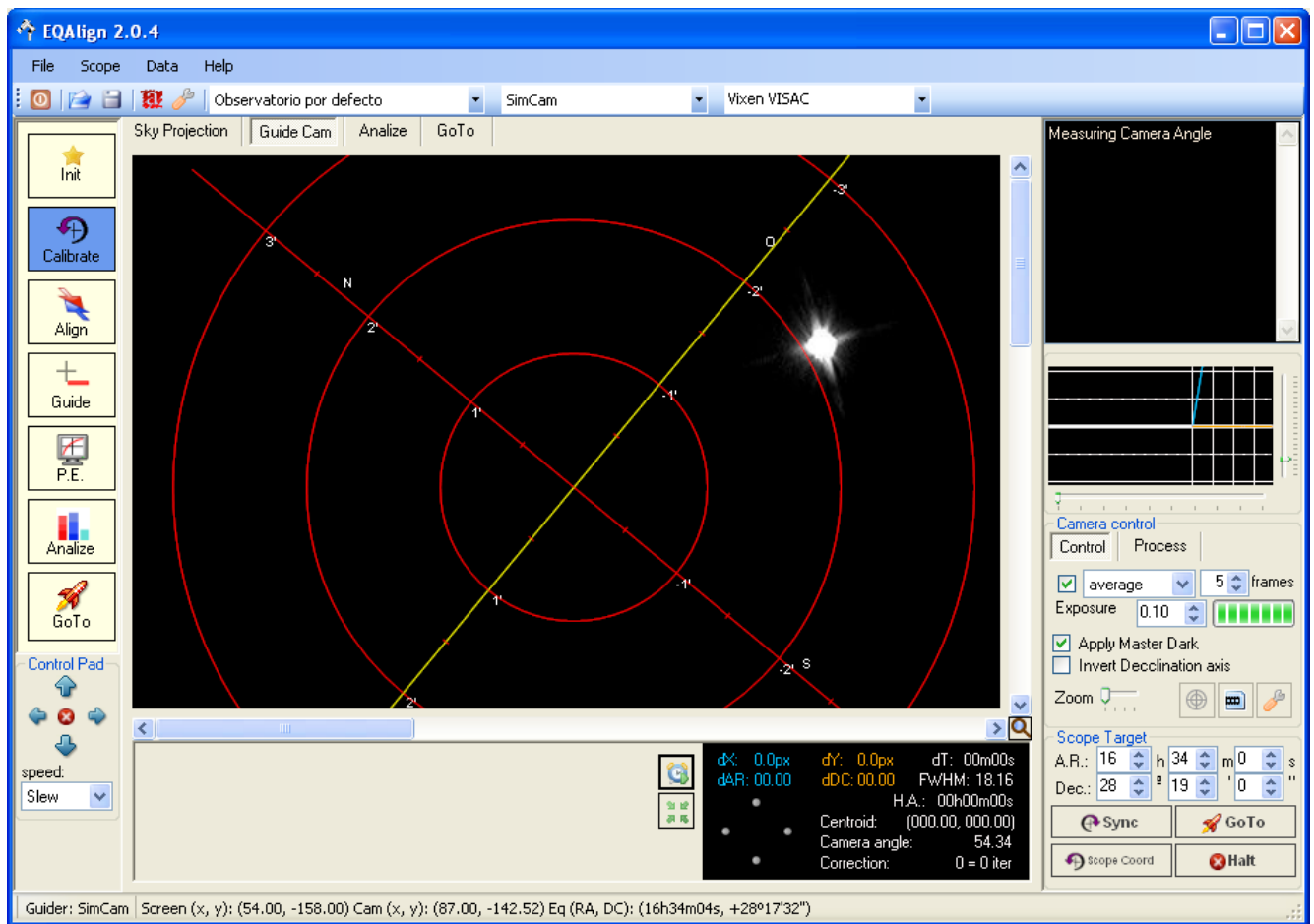
d) While star moves in west direction, EQAlign computes camera roll angle. Let star move for a while to minimize turbulence effect on angle measurement. EQAlign will stop measurement when star approach image edge, but process can be stopped before pushing “End process”

button  bellow the image window.

The following message will be shown:

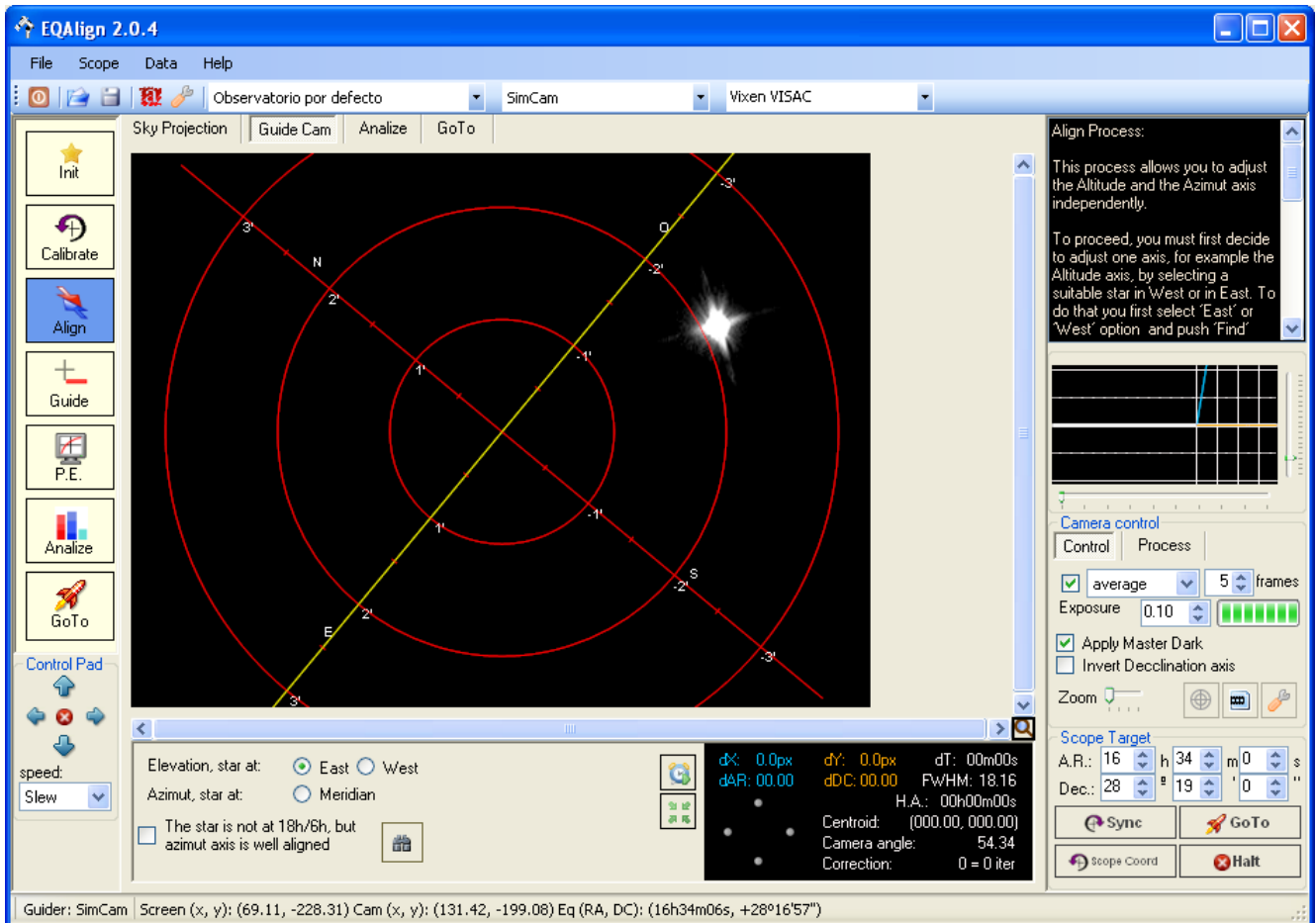


When LX200, ASCOM or DA1 controller is in use, EQAlign will start tracking motors for you, else you have to start tracking motors manually and click OK. If star has moved outside the image, push on left RA arrow to re-center it. Camera roll angle has been measured and the reticle in the image window is rolled to this angle.



8. Polar Alignment

Push on “Align” button in the direct process button panel (left side) to start aligning process.



Select which axis you want to correct (Altitude or Azimuth) and EQAlign will help you to select a satisfactory star near the east/west horizon (for altitude axis) or near local meridian (for azimuth axis).

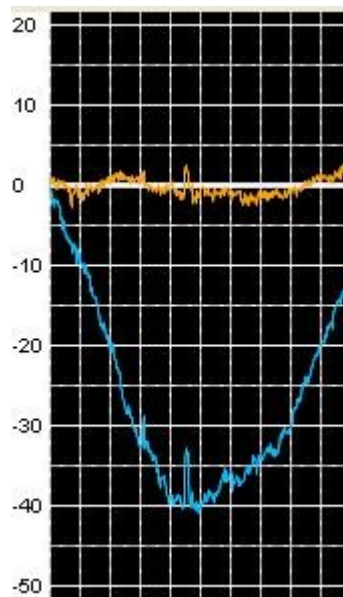
8.1. Some previous advises

In order to achieve a successful alignment, some points have to be observed first:

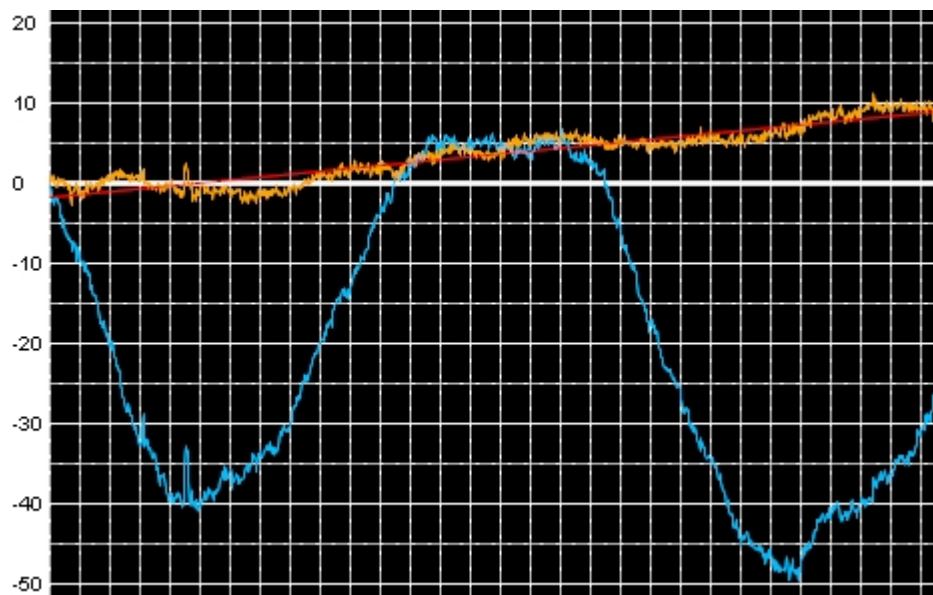
- Accurately level your mount. When mount is not leveled, corrections in one axis affect the other axis alignment.
- Mount must be well balanced; if not, measured drift may be partially due to gravity pulling down the unbalanced mount.
- Take at least 10 minutes measurements on each axis.

Sometimes it seems that drift angle is stable after 2 or 3 minutes measurements, but the truth is that drift has a very slow periodic component (due to periodic error) and a trend component (due to aligning error). We need to know the **trend** component to align mount.

Let's see an example: the following graph shows the first 5 minutes measurements




It looks like there is no drift at all and so the axis is correctly aligned.
Next graph shows the complete measurement series lasting 15 minutes:



Although it was not evident in the first 5 minutes, now star drift is clearly seen. From minute 10 on, trend line (in red) shows the correct drift angle.
It is very important to let recording go on for at least 10 minutes.

8.2. Altitude error measurement and correction

a) Aligning star selection:

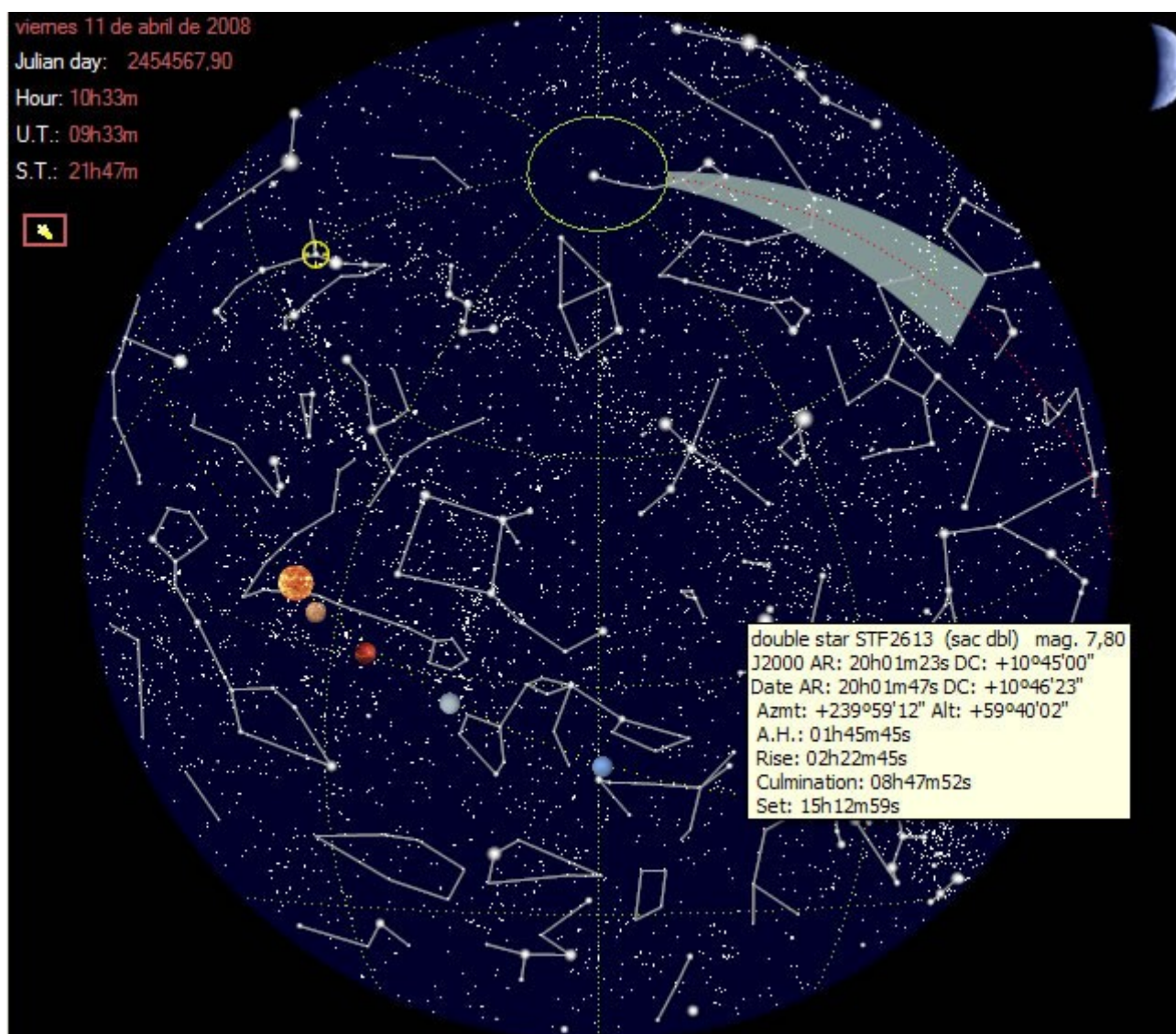
Select East or West option in the lower central panel and push “select star” button  to select an aligning star.



EQAlign will show the projection window highlighting the safe zone near east or west horizon. Select a star in this zone that you can see from your observing site and click on it. Remember that stars near 6h/18h hour angle will give you more accurate measurements.



Safe zone near east horizon (18h)




Safe zone near west horizon (6h)

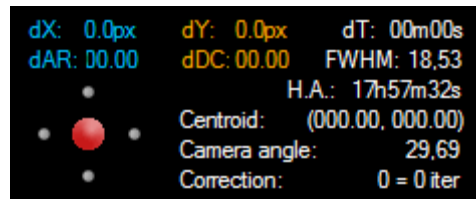
When you click on the selected star, EQAlign returns to Align screen. If there is an LX200 or ASCOM compatible controller connected, scope will be automatically pointed to this star; if not, you must manually point the scope to the selected star. Selected star coordinates will be shown in the Telescope target panel in the lower right corner of the screen.

Scope Target			
A.R.:	23	h	20 m 8 s
Dec.:	28	°	19 ' 0 "
Sync		GoTo	
Scope Coord		Halt	

b) Starting measurements:

Once the star is centered in the image window, click on it to set the "initial correction point" (a red circle will be shown) and push "Start process" button  below the image window to start measurements.

EQAlign will start star tracking, recording star movements from its initial position. Current measurements are displayed in the Measurement window (left of Telescope target panel):



dX: X-axis drift in pixels (in the X-Y rotated coordinate system in the camera image window)

dY: Y-axis drift in pixels (in the X-Y rotated coordinate system in the camera image window)

dRA: Right Ascension drift in arcseconds.

dDC: Declination drift in arcseconds.

dT: elapsed time since measurements start.

FWHM: FWHM value in arcseconds, computed from the star light curve fitting to a gaussian function. Star image must be clear to obtain a significant value.

H.A.: Hour Angle of the star.

Centroid: computed centroid coordinates in pixels (in the X-Y rotated coordinate system in the camera image window).

Camera Angle: last measurements of camera roll angle in degrees.

Correction: last computed correction in pixels. Expressed as number of pixels (positive or negative depending on axis direction) and number of iterations needed to make the necessary correction with the current image size. (When computed correction is greater than available pixel distance within the camera image).

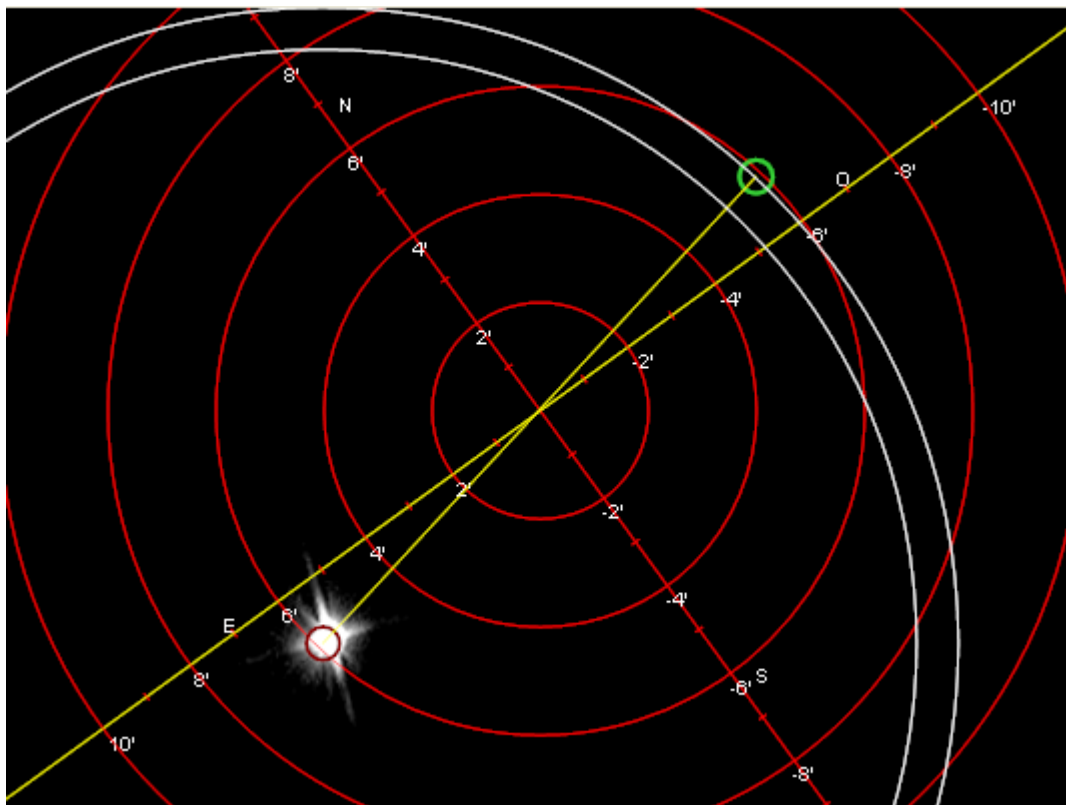
c) Error correction:

Let recording go on for at least 10 minutes and then stop pushing "End process" button



The following message will be shown in the help window (upper right corner of screen):

"Please place the star with the control pad into the init correction point (little red circle). If you have a compatible computerised mount, you can push the 'autoguide to init point' button. Then turn the Azimuth axis screw until the star fall into little green circle or near the perimeter of the larger white circle."



If measured error is larger than maximum screen possible displacement, correction must be done in several steps and the following message will be shown in the help window:

“The measured error is larger than the window dimensions. You must repeat the axis correction **n** times. The last correction you must carry the star from initial correction point (red circle) to the perimeter of the smallest white circle.”

Image window will look like picture above.

In this sample picture star has already been carried to the initial correction point (red circle) using RA/Dec control pad. In this case there are two white circles because correction has to be done in steps. Larger white circle indicates correction limit for the first steps and smaller white circle indicates correction limit for the final correction step.

For example, if EQAlign computes a 1440 pixel correction but maximum on screen displacement is 380 pixels (larger white circle radius) then doing 3 maximum displacement corrections (each one centering star in the initial correction point using AR/Dec control pad and then carrying star to the larger white circle using mount altitude screw) we will correct 1140 pixels, so we are 300 pixels short. We have to correct those 300 pixels in the last correction (using the smaller white circle, 300-pixel radius).


If there is a compatible computerised mount, you can push the ‘autoguide to initial point’ button



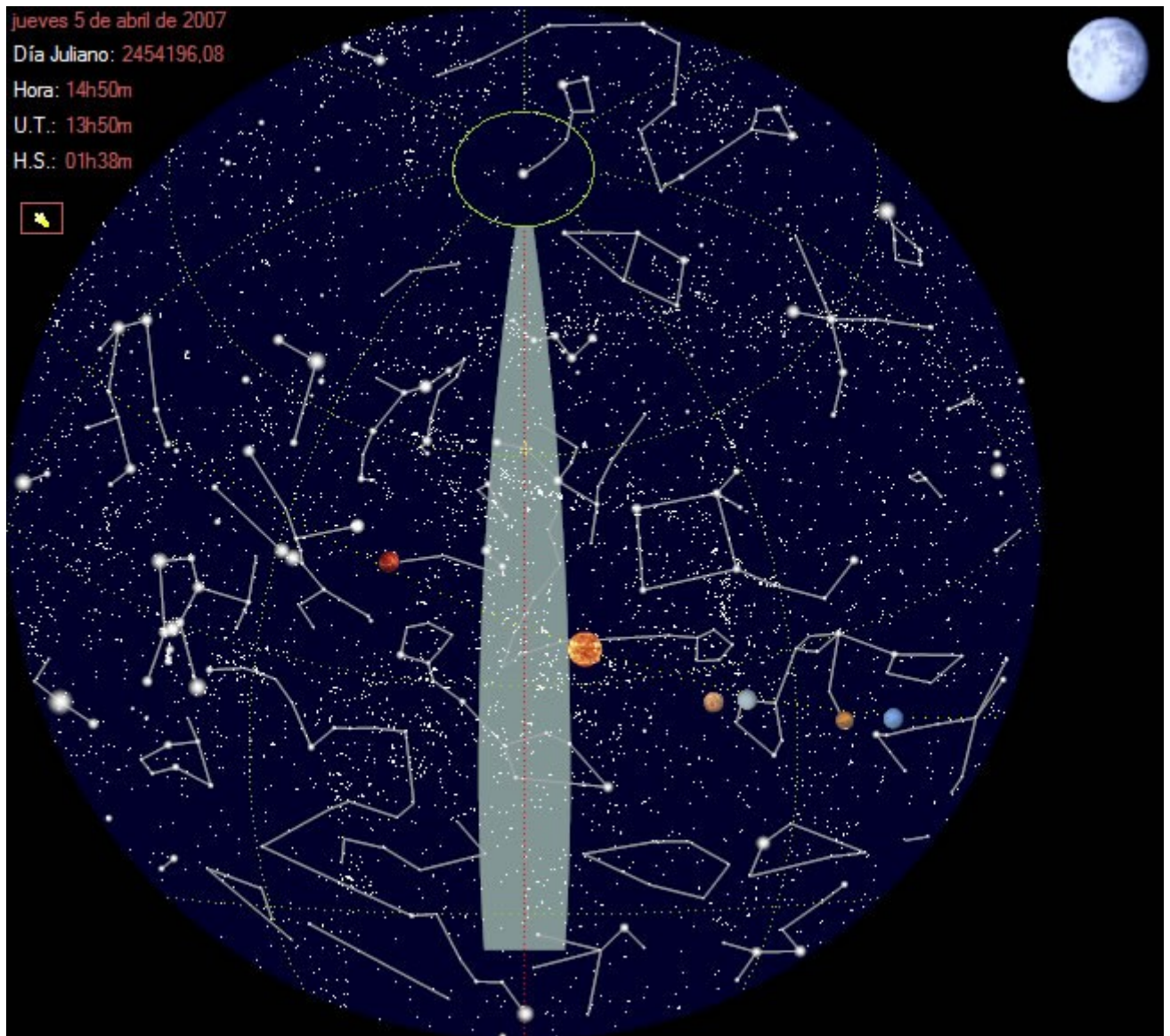
to center the star in the initial correction point to start each correction step.

8.3. Azimuth error measurement and correction

a) Aligning star selection:

Select “Star at meridian” option in the lower central panel and push “select star” button  to select an aligning star.


EQAlign will show the projection window highlighting the safe zone near the local meridian. Select a star in this zone that you can see from your observing site and click on it. Remember that stars near the meridian will give you more accurate measurements.




Safe zone near meridian (0h)

As for Altitude correction, when you click on the selected star, EQAlign returns to Align screen. If there is an LX200 or ASCOM compatible controller connected, scope will be automatically pointed to this star; if not, you must manually point the scope to the selected star. Selected star coordinates will be shown in the Telescope target panel in the lower right corner of the screen.

b) Starting measurements:

As for Altitude correction, center the star in the image window and click on it to set the “initial correction point” and push “Start process” button .

c) Error correction:

Let recording go on for at least 10 minutes and then stop pushing “End process” button . As before, EQAlign will guide you about the necessary corrections. The only difference is that now corrections must be done using mount Azimuth screw instead of Altitude screw.

8.4. Is that all? Is my mount perfectly aligned?

Theoretically yes, but not really. Why? Well, because in practice we won't be able to measure stars exactly at 6h/18h and 0h hour angle but we would take measurements of stars *near* these angles.

When correcting one axis, these approximations introduce contributions to the other axis error, smaller when star is nearer the correct hour angle and greater when it is farther.

Knowing that we can proceed as follows:

- 1) First we correct azimuth axis error. In this measurements there is some contribution to altitude axis error, but far smaller than azimuth error. Even less if we have previously roughly set mount altitude to local latitude. After these measurements, most of azimuth error will be corrected and remaining error should be very small.
- 2) Now we correct altitude axis error. The remaining (very small) azimuth error still contributes to star drift, but the main contribution is due to altitude error. Again, after this measurement, most of altitude error will be corrected and remaining error should be very small.
- 3) We repeat azimuth axis error correction. Now altitude error is so small that its contribution to star drift is negligible and azimuth axis will be accurately aligned.
- 4) Last we repeat altitude axis correction. Now azimuth error is almost null, so its contribution to star drift is null and altitude axis will be accurately aligned too.


Of course you can make more correction iterations but don't you want to take some shots?

9. Periodic error measuring and measurements analysis

EQAlign has a specific process for periodic error measuring and other for measurement data analysis (from periodic error, aligning or autoguiding)

9.1. Measuring periodic error

To activate Periodic Error measurement process just push “P.E.” button in the direct process button bar (left of screen). Once the star is centered in the image window, click on it to set the

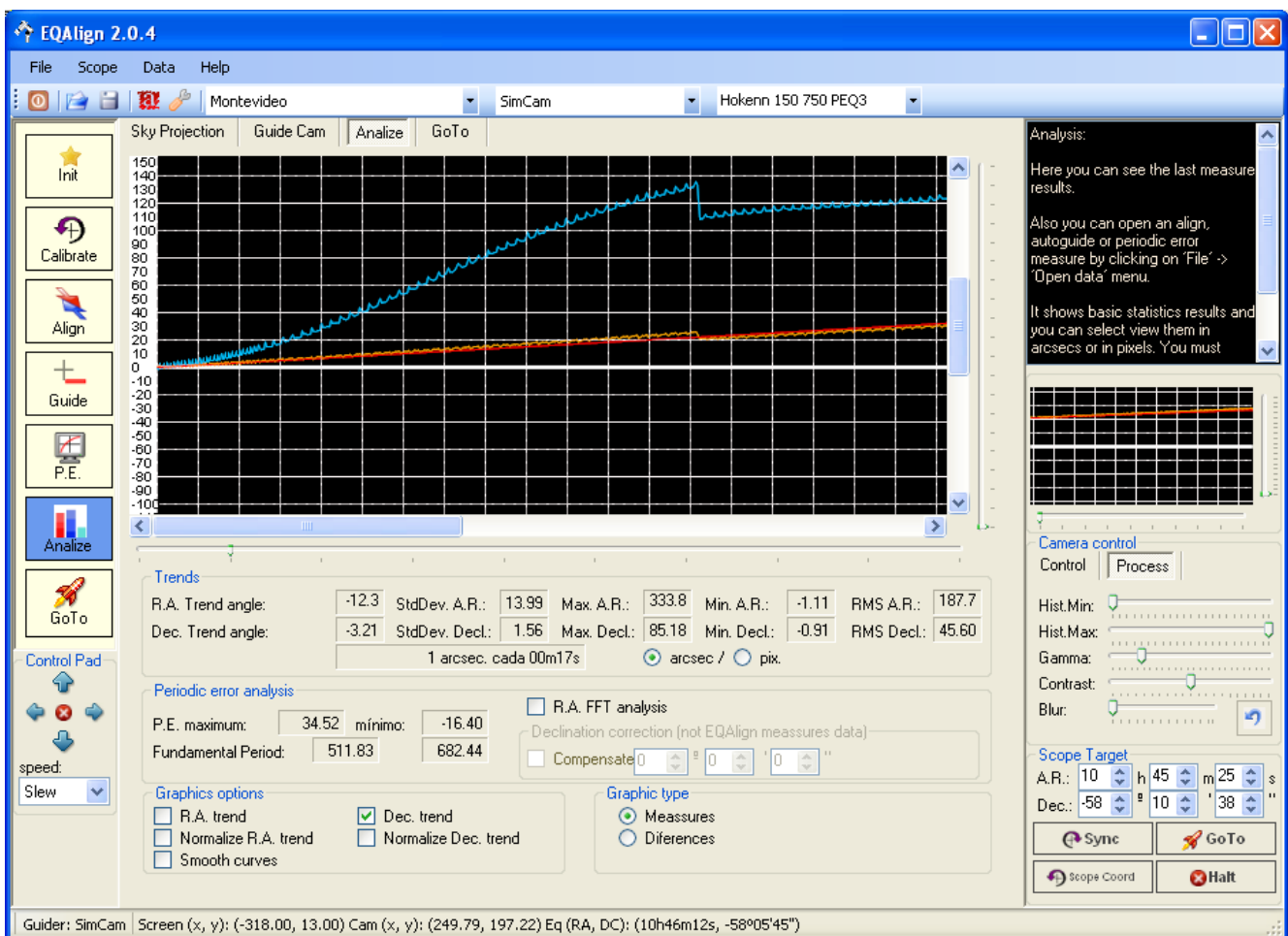
“initial correction point” (a red circle will be shown) and push “Start process” button  below the image window to start measurements. [Camera roll angle](#) must already be measured for the same hemisphere (east or west of local meridian).

In order to obtain accurate periodic error measurements; let recording go on at least for two complete mount periods. If you don't know your mount period, make a first measurement series of 16 minutes.

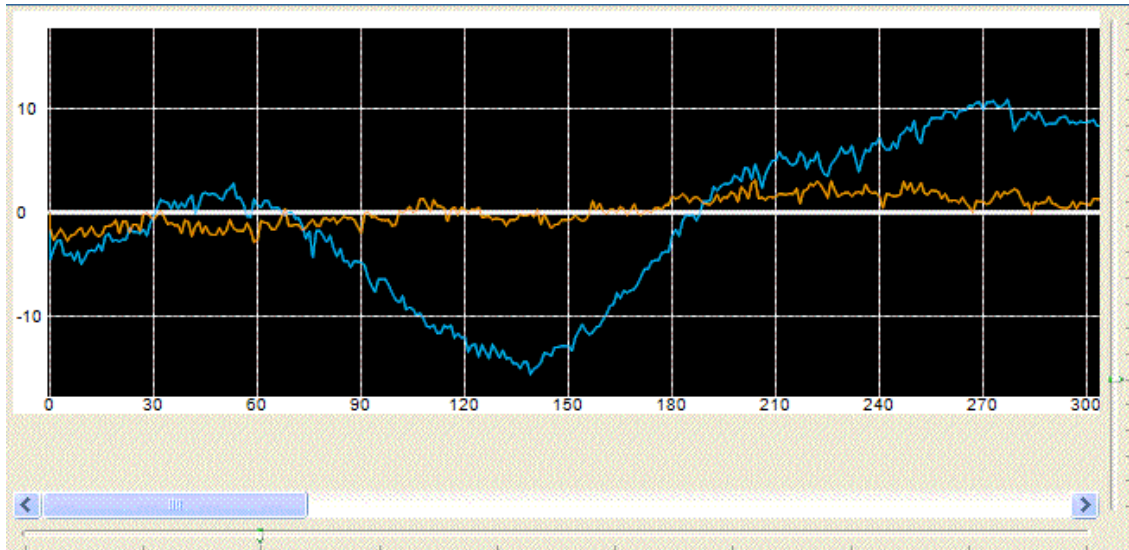
To stop measuring press “End process” button . We recommend [saving measurements](#) before measurement analysis (next).

9.2. Analyzing measurements.

To activate measurement analysis process just push “Analyze” button in the direct process button bar (left of screen).



There is a graph of measurement data in the upper part of the Analyze screen. The blue line represents Right Ascension data and the orange line represents Declination data. Horizontal and vertical scale can be adjusted using the two sliding bars, below and right of the graph. This is useful when you want to zoom in on a particular peak of the graph that may indicate a mechanical problem in the drive or mount.



The information panel is located below the graph:

Trends

R.A. Trend angle:	-6.34	StdDev. A.R.:	5.96	Max. A.R.:	30.13	Min. A.R.:	-12.4	RMS A.R.:	16.95
Dec. Trend angle:	28.91	StdDev. Decl.:	0.79	Max. Decl.:	0.22	Min. Decl.:	-243	RMS Decl.:	138.3

1 arcsec. cada 00m01s ☒ arcsec / ☐ pix.

Periodic error analysis

P.E. maximum: 19.88 mínimo: -8.26 ☐ R.A. FFT analysis

Fundamental Period: 255.71 Declination correction (not EQAlign measures data)

☐ Compensate 0 0 0

Graphics options

☐ R.A. trend ☒ Dec. trend

☐ Normalize R.A. trend ☐ Normalize Dec. trend

☐ Smooth curves

Graphic type

☒ Measures ☐ Differences

“Trends” group

Displays trend angle statistical information (lower values indicates a better alignment), Right Ascension and Declination maximum, minimum, standard deviation, and RMS. It also translates Declination trend angle value into time drift rate as minutes per arcsecond (or minutes per pixel). The longer this time, better the alignment.

When mount is perfectly aligned, Declination standard deviation, and RMS value are seeing indicators and Right Ascension standard deviation and RMS value are periodic error amplitude indicators.

“Periodic Error Analysis” group:

EQAlign performs a frequency analysis of the measurement data and displays here fundamental period values. A Right Ascension graph should theoretically have only one

fundamental period (and its harmonics), but in practice two or more (and their harmonics) are usually found.

If measuring star coordinates are selected (selecting it by clicking in the planisphere and we recommend to always do so), EQAlign translates RA values from pixels to arcseconds.

You can use EQAlign to analyze data recorded with other popular astronomical softwares (like K3CCD Tools) that don't translate RA values to arcseconds. In this case you must check "Compensate" option in "Declination compensation" group and specify star Declination coordinate.

"Graphic options" group:

- RA/Dec trend: Show/hide RA (blue) and Dec (orange) trend lines showing drift trends.
- Normalize RA/Dec: eliminates from each graph the trend component of drift, so you can see the periodic component.
- Smooth graph: eliminates turbulence effects to see a smother graph. Don't use this option when you are looking for mechanical problems that can be detected looking for jumps in the graphs. When you see a jump, you should verify if there is a simultaneous jump in the other axis. In this case jumps may be due to external causes (wind, touching the scope, etc).

"Graphic type" group:

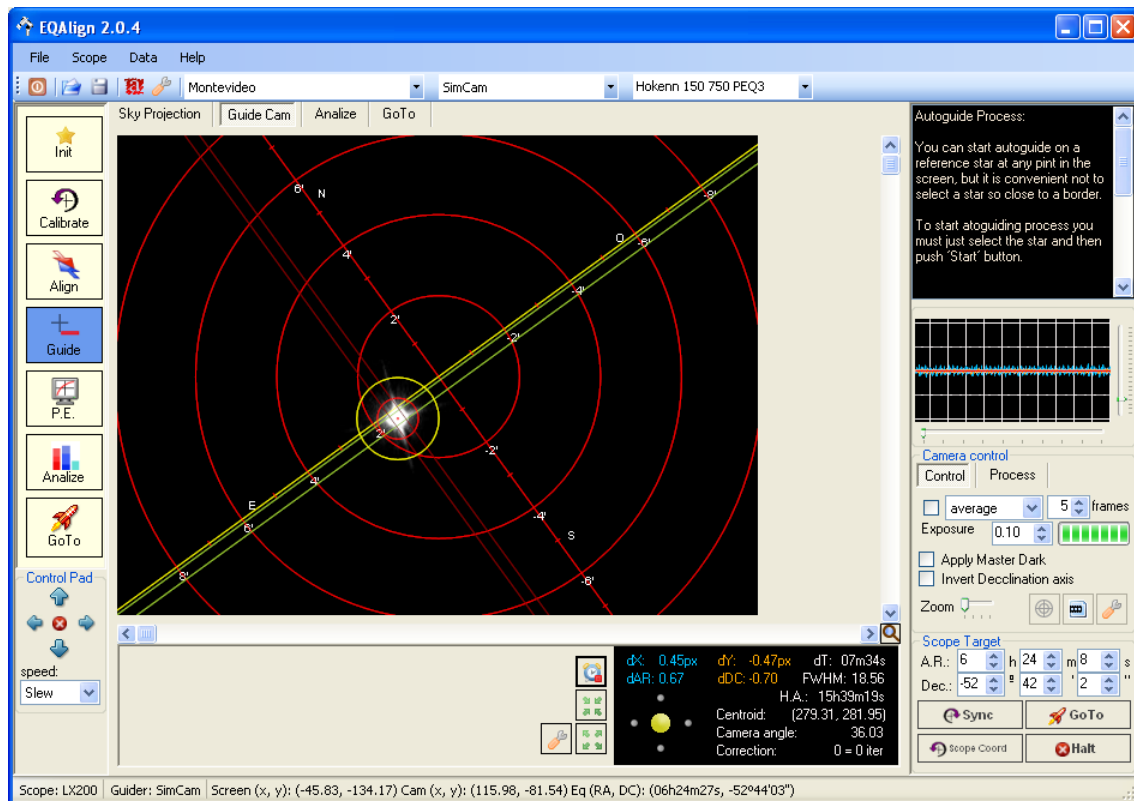
Selects between raw data (measurements option) or difference data. Difference data graphs display position differences in each axis between each captured frame and previous frame. This is another seeing indicator.

10. Autoguiding.


EQAlign has a built-in autoguiding system, so you can use the same software to polar align your scope and then continue controlling your mount with the guiding camera while taking shots with the main camera and your favorite capture software.

EQAlign autoguiding process is adaptive (control gain adjust itself) and predictive (it predicts the next error to be corrected) based in previous measurements and corrections.

To activate autoguiding process just push “Guide” button in the direct process button bar (left of screen). The following screen will be shown:

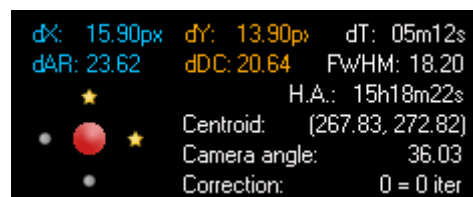


Just select a guiding star and press “Start process” button  below the image window. To

stop guiding push “End process” button .


When Autoguiding process is started, current star position is set as target position and RA and Dec tolerances are marked on the camera image window.

During guiding process EQAlign will show guiding information in the Measurement window.



In addition to the same measurement information shown during [error measurement process](#), the five dots on the lower left side of the Measurement window show how is autoguiding working:

The central big dot changes color from green to yellow or red according with the star position relative to its target position. It is gray when autoguiding is not active.
The surrounding four little dots show change to little stars when pulses are used.

To center the star on the image just press “Center” button  and EQAlign will use guiding pulses to bring the star to the center of the image.

If mount controller is LX200 compatible with several modes (guide, center, move, and slew), “center” speed will be used.

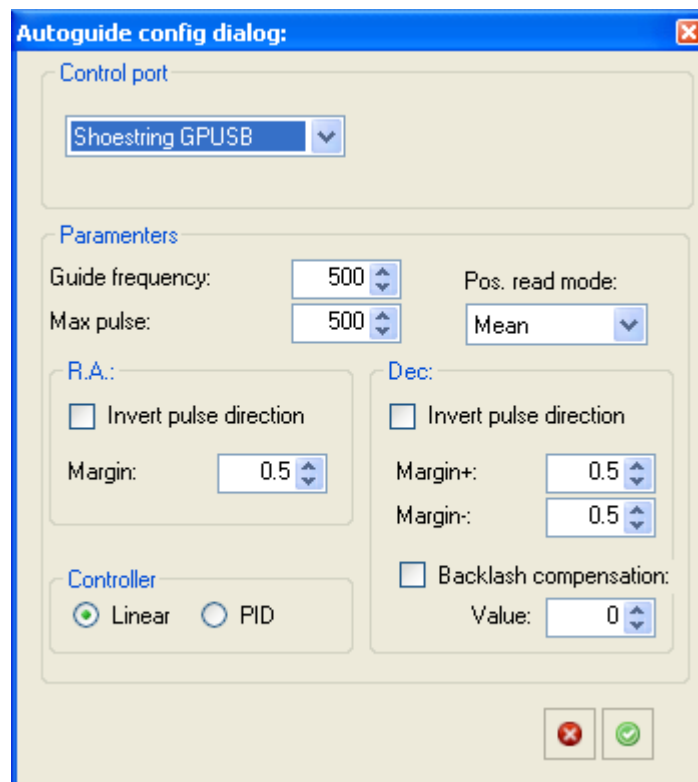
If mount controller is ST4 type (using relays), centering speed is the same guiding speed, so it may be slow.



button starts the self-calibration process. First select a star in the camera image window, not near an edge and the click on this button. EQAlign will send different pulses to the mount control drive to evaluate how does it respond to then and set autoguiding configuration parameters.



button shows autoguiding configuration dialog:

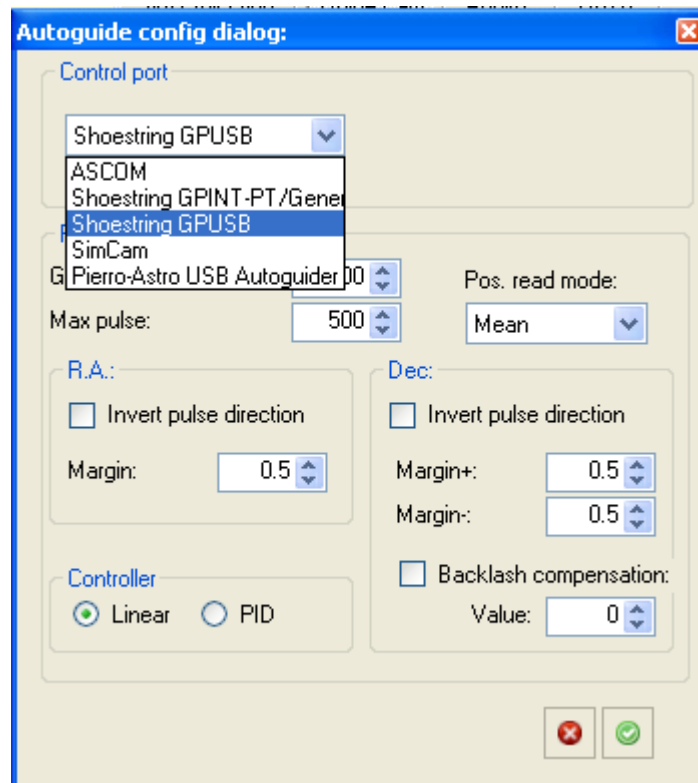


The "Autoguide config dialog" window contains the following settings:

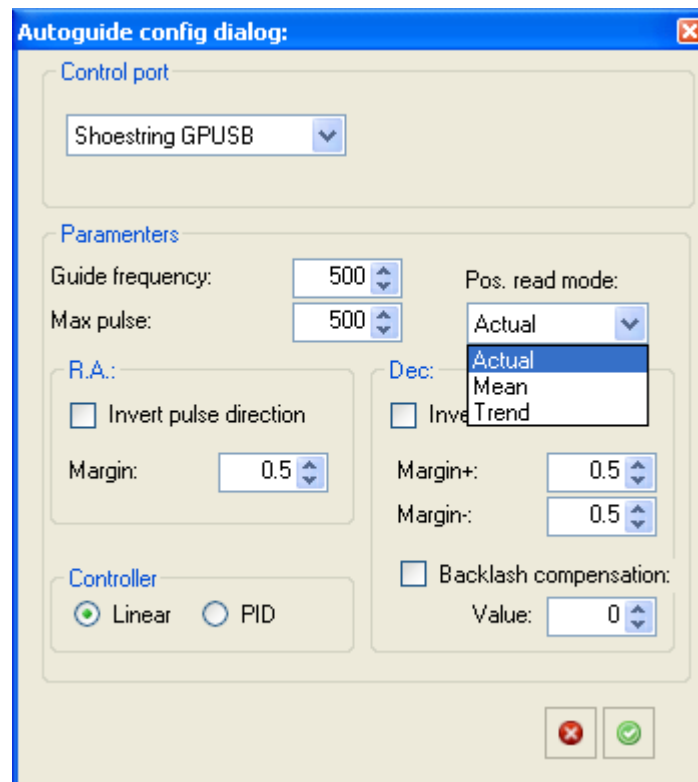
- Control port:** A dropdown menu currently showing "Shoestring GPUSB".
- Parameters:**
 - Guide frequency:** A numeric spinner set to 500.
 - Max pulse:** A numeric spinner set to 500.
 - Pos. read mode:** A dropdown menu currently showing "Mean".
- R.A. (Right Ascension):**
 - ☐ Invert pulse direction
 - Margin:** A numeric spinner set to 0.5.
- Dec (Declination):**
 - ☐ Invert pulse direction
 - Margin+:** A numeric spinner set to 0.5.
 - Margin-:** A numeric spinner set to 0.5.
 - ☐ Backlash compensation:
 - Value:** A numeric spinner set to 0.
- Controller:** Two radio buttons, "Linear" (selected) and "PID".
- Buttons:** At the bottom right, there are two buttons: a red "X" (Cancel) and a green checkmark (OK).

Here you can manually configure all guiding parameters.

Control port: you can use your scope serial port (Native serial port), ST4 compatible port (GPINT-PT or GPUSB from Shoestring or USB Autoguider from Pierri-Astro) or any ASCOM compatible controller. ST4 compatible controllers have the advantage of supporting simultaneous operation in both axes.



- Guide frequency: sets minimum delay time (in milliseconds) between guiding pulses. Default value is 500 ms.
- Max pulse: sets maximum pulse duration in milliseconds. EQAlign computes needed guiding pulse duration, but this parameters limits maximum sent pulse direction. Default value is 500 ms.
- Invert pulse direction: depending on ASCOM driver design or wiring to ST4 port, sometimes it is necessary to invert RA and/or Dec axes direction.
- Margin: In RA axis sets error allowance in arcseconds (smaller errors won't be corrected); in Dec axis different positive and negative margins can be set, so we can "allow" greater errors in the direction against drift (if mount is not accurately aligned) which will be "corrected" by drift alone. You must find the best values for these parameters depending on scope focal length, and pixel size. Autoguiding process continually evaluates seeing error and compute minimum allowance, but you can set greater values here.
- Backlash compensation: sets time duration (in milliseconds) of guiding pulse to run out drive backlash in Dec axis. Whenever the motor direction reverses, this time is added to the correction. This is not necessary on RA axis because the sidereal tracking constantly runs out the backlash.
- Position Reading mode: sets how EQAlign computes error: based on real error readings, averaging last error values or using error trend values (linear fitting). You should try which one works best for your equipment. If not sure use **Actual**.

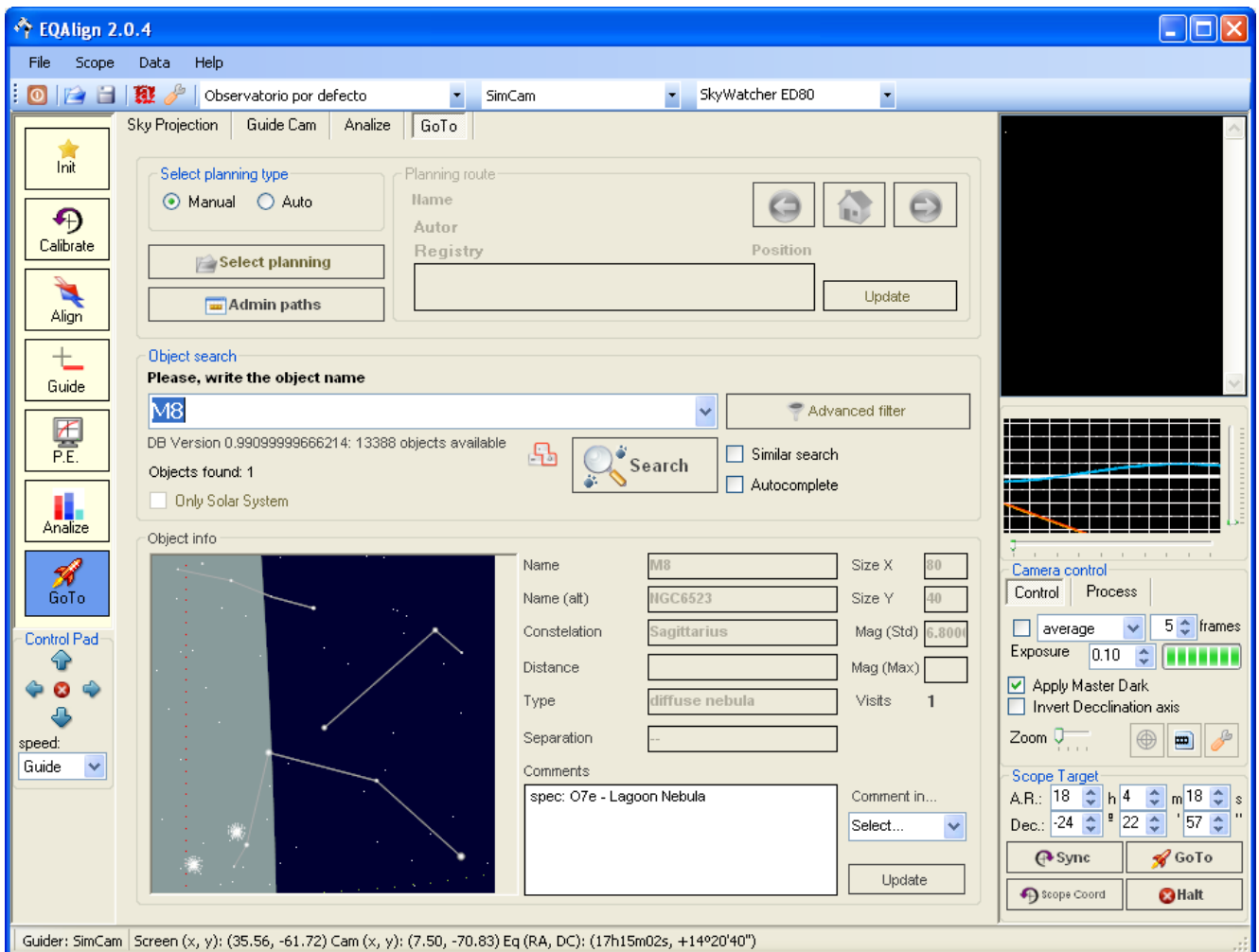


11. GoTo System

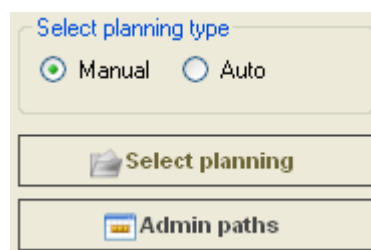
EQAlign has a built-in object database search system.

To activate this feature just push “GoTo” button in the direct process button bar (left of screen).

The following screen will be shown:



In addition of a classic GoTo system, with EQAlign 2 you can create sky tours for didactic purposes or just for better observing night planning.

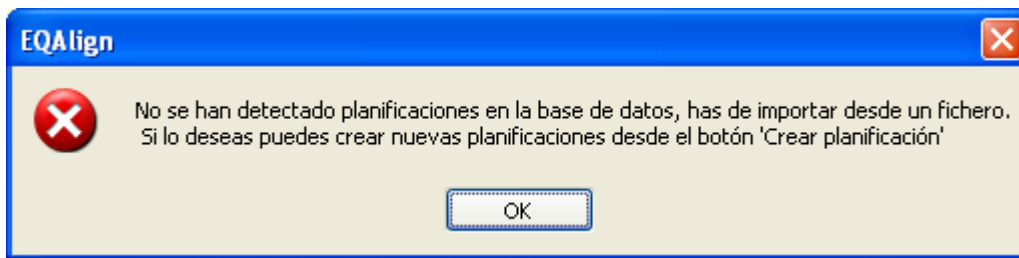


In the GoTo screen, select four type:

- Manual:** No route is loaded. Just search objects one at a time. This is default option.
- Auto:** This option allows importing or loading a previously stored route.

11.1. Route planning

When Auto option is selected “Select planning” button is activated. If there is no stored route the following message will be shown:



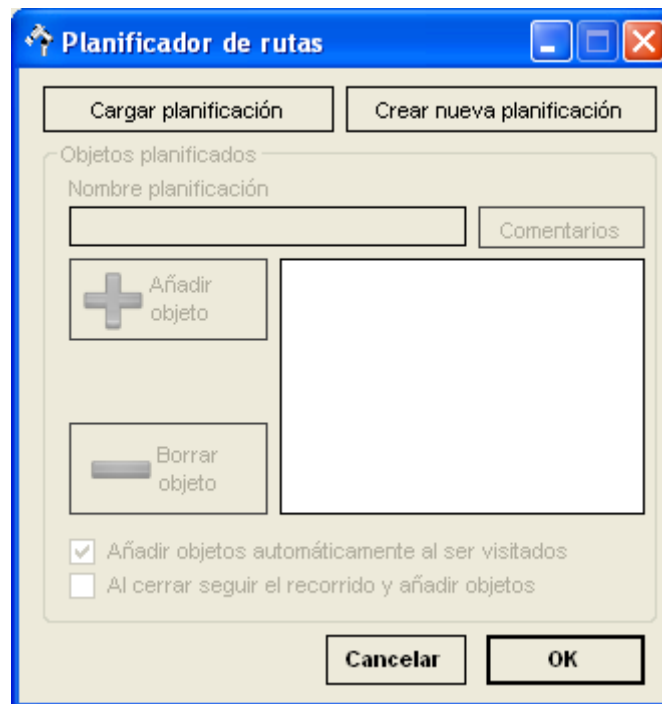
Path selection dialog will be shown.



It contains a list of stored routes. Here you can:

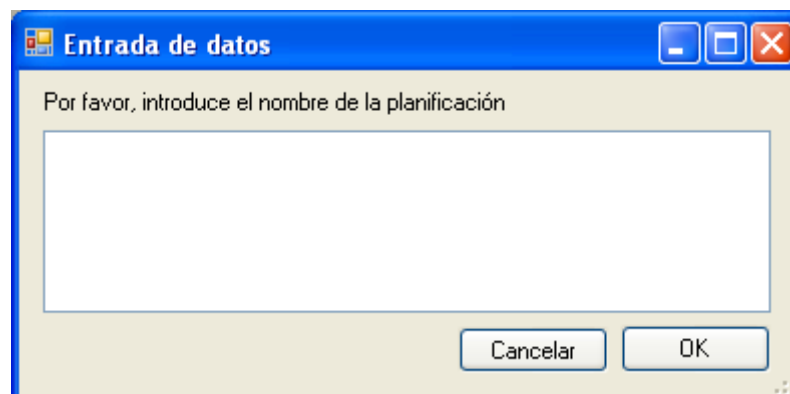
- Delete:** deletes a route.
- Export:** stores a route in *EQAlign Route* format (XML based). This allows route sharing between EQAlign users.
- Import:** loads a route from an *EQAlign Route* file to the database.

To create a new route or load a saved route, press **Admin path** button. It shows **Route planning** dialog

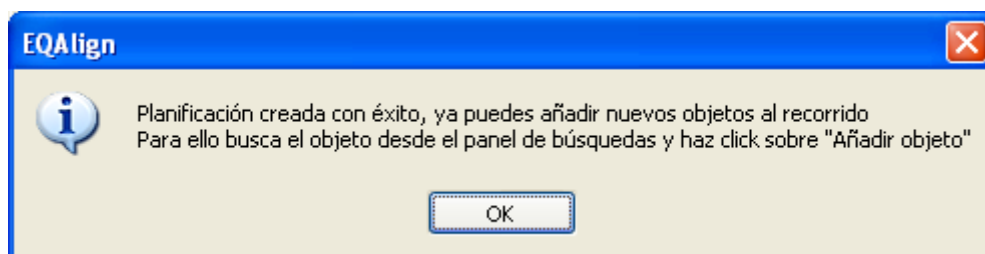


Here you can:

- **Load route:** loads a route stored in the database. It shows **Path selection** dialog where you can select a route or import one.
- **Add route:** creates a new route. A **Data entry** dialog will be shown, enter a name for the new route.

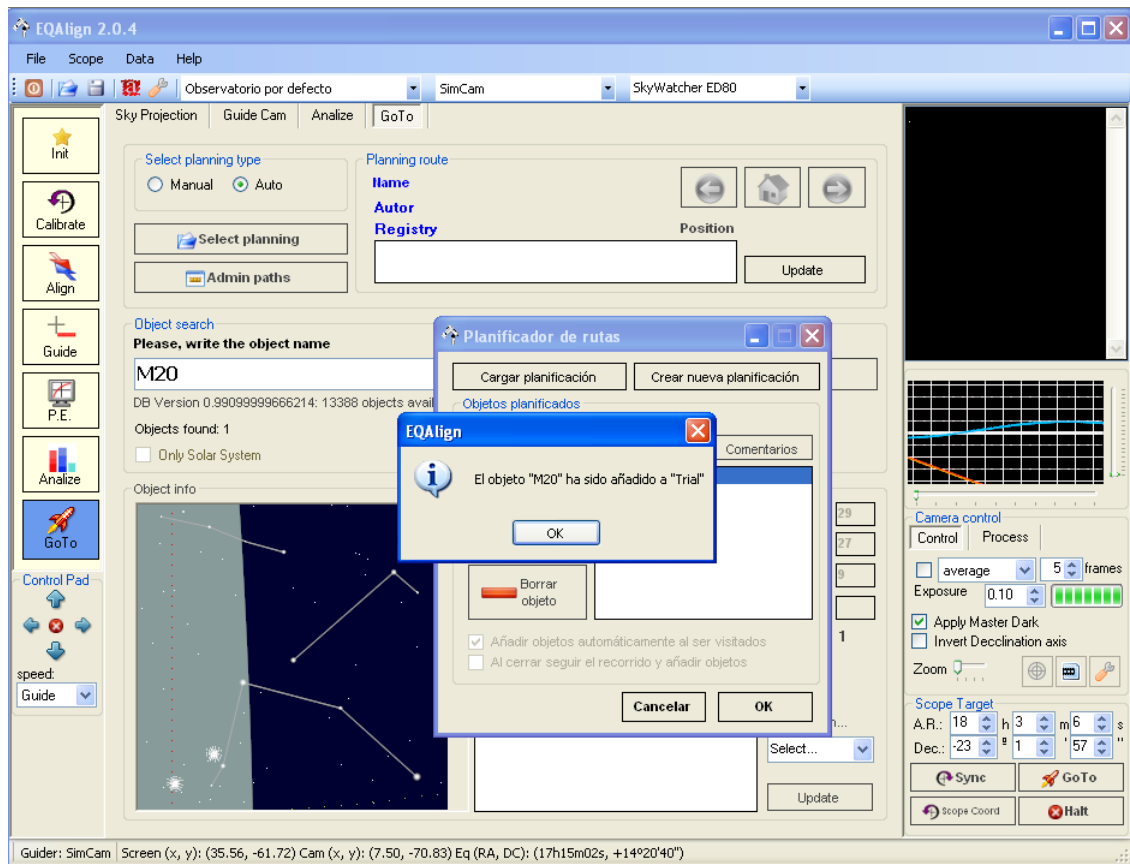


The next message confirms route creation:



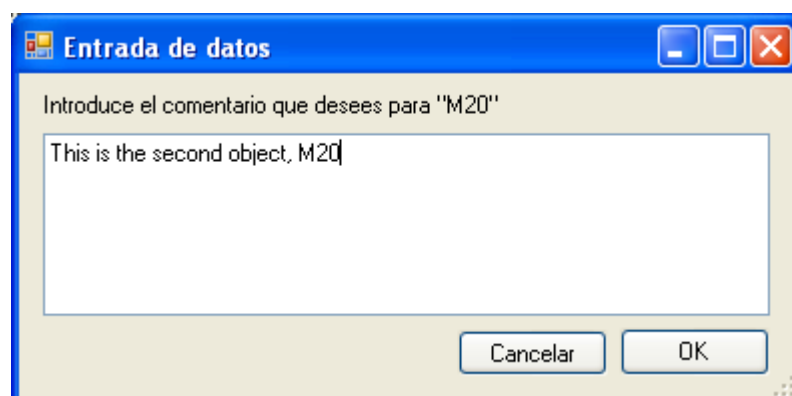
Comments, Object Add and delete buttons will be activated.

- Comments:** here you can enter comments about the route or edit a previous comment.
- Add object:** adds an object to the route. To do this, first search the object in the main screen, once located press this button. Object name will be added to the list and a confirmation message will be shown.



- Delete object:** deletes an object from the route.

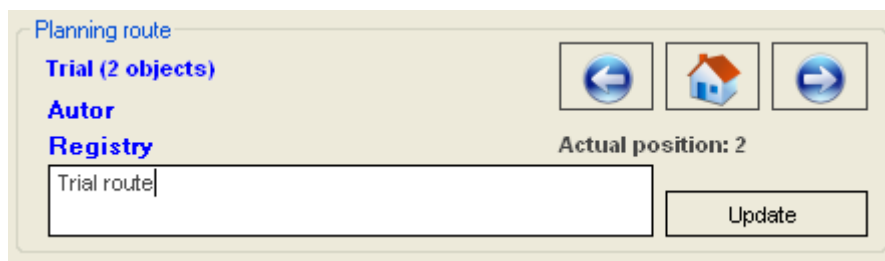
Double-clicking on an object of the list you can edit a comment about that object.



When your route is complete press OK button. Now you can load it using **Load route** button or **Select planning** button in the main screen.



When a route is loaded, **Planning route** option group is activated in the upper main screen. Here route information is displayed: route name, number of objects, author and route comment. Route comment can be edited and updated (update button).



The first object will be automatically loaded. Click GoTo button in the Target panel (lower right corner) to point the scope to it.



The following buttons let you load the previous, first or next object of the route.



11.2. Object search

When **Manual** option is activated (or just when you are creating or using a route) you can use EQAlign object search. Just enter object name and press <enter> or click **Search** button.

Similar search and **Autocomplete** option can be toggled on/off.

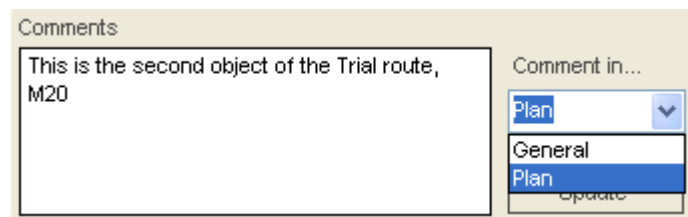
We are developing an advanced query filter (Advanced filter button will be active in future versions).

When several objects meet the search criteria, you can select one from the result list. Then a sky projection centered in the object and object information will be shown in the information panel (lower part of the screen).

If the object is above the horizon, scope coordinates will be updated. If you press **GoTo** button, scope will point to the object.

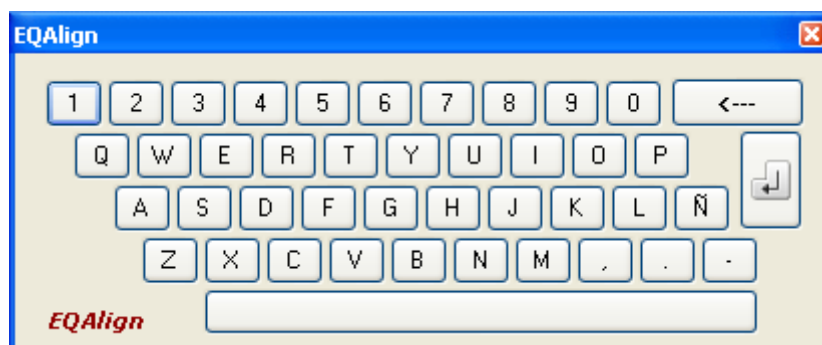
In the white panel you can edit two kinds of comments about the object:

- General**: general comments about the object.
- Plan**: comments about the object in the current route.

**Keyboard utility**

Typing object names in the dark may be quite difficult, so EQAlign includes an on-screen

keyboard utility. It can be activated pressing  button.



12. Database updating.

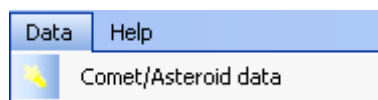
EQAlign database stores all star and DSO catalogs and comments and asteroids data.

12.1. Object catalog updating.

We are developing EQAlign object catalog editing capability, but this feature is not available yet. It will be available in future versions.

12.2. Comments and asteroids data update

This feature is available in "Data" -> "Comet/Asteroid data" menu



The **Orbital Elements** screen is shown:

Orbital Elements:

Data MPC data load

Orbital Elements

☒ Comet ☐ Asteroid

Object Id.: 170P/Christensen

Period of the perihelion: 2453762.02638889 26/ 1 /2006 12:38

Perihelion distance : 2.929553

Eccentricity: 0.303946

Magnitud absoluta: 12 Slope param: 4

Equinox: 2000

Argument of the perihelion: 225.4022

Nodal longitude: 143.0203

Inclination : 10.1256

Delete object Insert/Update cataloged object

7/ 5 /2008 1:19:25 Compute Scope Coord

Cometa 170P/Christensen
 J2000 AR: 08h20m46s DC: +18°08'40"
 Date AR: 08h21m15s DC: +18°07'13"
 Distancia al Sol: 4.67046862822279
 Distancia a la Tierra: 4.80225530895751
 Elongación: 76.4749576806361
 Magnitud prevista: 22.10
 Azmt: +292°14'32" Alt: -01°59'41"

In this screen you can search, insert, update orbital elements or delete minor planets.

To search an object type part of its name in "Object Id" and press <enter> or click **Search** button. Orbital Elements of the object will be shown and position at selected date and time can be calculated clicking on **Compute** button.

Clicking on **Scope Coord** button computed coordinates will be updated in the Scope target panel.

If an Internet connection is available, orbital elements of comets and asteroids can be automatically updated. If a connection is not available, update can be done from a MPC compatible file.

Click on MPC data load tab:

Orbital Elements:

Data **MPC data load**

Comets

From disk file:

From internet:

Asteroids

From disk file:

From internet:

Warning: this file contains more than 150.000 entries. Process only the first

7/5/2008 1:19:25

Cometa 170P/Christensen
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Select Comet or Asteroid MPC file from disk or use the Internet links.

Because Asteroids files have more than 150,000 entries, you can choose to process only a few entries (1000 by default).

New entries will be added to the database and old entries will be updated.

Appendix: J.Scheiner Method theoretical background

The method.

(Extracted from [ref.\[2\]](#))

During the second part of the 19th century several methods to align the hour axis were developed. One of the first practical was the drift alignment method by J. Scheiner published in the year 1889. Probably this is the most frequently used method for the sake of its simplicity. To carry it out only an eyepiece with a reticle is needed. The corrections for the azimuth and elevation of the hour axis are determined separately, the azimuth in the meridian and the elevation at the local hour angle $t = \pm 6h$. Among many other similar descriptions here the method is printed in the version of the Astronomical League:

1. Choose a bright, easily located star close to the equator (to maximize the drift rate) and near your meridian. Center it on the crosshair of your eyepiece.
2. Track the star until its drift in declination becomes noticeable. Ignore any drift in right ascension. If the star drifts northward, move the polar axis east. If the star drifts southward, move the polar axis west. Repeat, making finer adjustments, until the drift becomes negligible.
3. Choose another bright, easily located star near the eastern or western horizon and center it in your crosshair eyepiece.
4. Track the star until its drift in declination becomes noticeable. Ignore any drift in right ascension. If you are looking east and the star drifts northward, move the polar axis down. If you are looking east and the star drifts southward, move the polar axis up. (Reverse the corrective action if you are looking west.) Repeat, making finer adjustments, until the drift becomes negligible.

J. Scheiner expressly pointed out that the refraction has to be disarmed ("unschädlich"). Ignoring this hint then the observations might be possible somewhere on the meridian and in the East or the West. But this method relies on the fact that the observation of the movement in the d direction takes place at the local hour angle of $t=0$ and $\pm 6h$.

If the above instructions are followed and one observes in the vicinity of the horizon the effect of the refraction contributes most. Nevertheless, refraction effects can be avoided choosing a star with enough declination (depending on site latitude).

Theoretical background.

(Partial translation from [ref.\[1\]](#))

The following equations show hour angle and declination errors for a given aligning error (azimuth and altitude errors):

$$\begin{aligned}(1) \Delta h &= \Delta H \sin(h) \tan(\delta) + \Delta A (\sin(\phi) - \cos(h) \cos(\phi) \tan(\delta)) \\ (2) \Delta \delta &= \Delta H \cos(h) + \Delta A \cos(\phi) \sin(h)\end{aligned}$$

, where

Δh	hour angle error	ΔA	Azimuth error
$\Delta \delta$	declination error	ΔH	Altitude error
h	star hour angle	δ	star declination
ϕ	observing site latitude		

Differentiating (1) y (2) with respect to time, we obtain the difference between apparent (h') and true (h) hour angle, and also the difference between apparent (δ') and true (δ) declination.

But $h = \omega t$, where ω is hour angle change rate per unit of time, which is 2π radians in 23.93 hours (or 1436.04 minutes), then $\omega = 0.0043754$ or, $1/\omega = 228.55$, then:

$$\begin{aligned}(3) d\Delta h/dt &= (\Delta H \cos(h) \tan(\delta) + \Delta A \sin(h) \tan(\delta)) \omega \\ (4) d\Delta \delta/dt &= (-\Delta H \sin(h) + \Delta A \cos(\phi) \cos(h)) \omega\end{aligned}$$

In principle this is valid anywhere in the sky, but drift measurement in Right Ascension (or hour angle) assumes the use of an exact tracking drive, which is not always possible (en less if we consider periodic error effects).

However, we can compute ΔA and ΔH measuring only declination drift $d\Delta \delta/dt$ if we make some considerations:

Let's suppose that we measure declination drift of a star in the meridian. Because in this case $h = 0$, then $\sin(h) = 0$ and $\cos(h) = 1$; replacing in (4):

$$(5) d\Delta \delta / dt = \Delta A \cos(\phi) \omega \Rightarrow \Delta A = d\Delta \delta / dt / (\cos(\phi) \omega) = 228.55 d\Delta \delta / dt / \cos(\phi)$$

That is: **Azimuth** error is $228.55/\cos(\phi)$ times greater than declination drift of a star in the **meridian**.

In the same way, measuring the declination drift of a star with a hour angle $\pm 6h$ from the meridian, $\sin(h) = \pm 1$ and $\cos(h) = 0$. Replacing in (4):

$$(6) d\Delta \delta / dt = \pm \Delta H \omega \Rightarrow \Delta H = \pm d\Delta \delta / dt / \omega = \pm 228.55 d\Delta \delta / dt$$

That is: **Altitude** error is 228.55 times greater than declination drift of a star at **6h from the meridian** and is 228.55 times greater than declination drift of a star at **-6h from the meridian** but in the opposite direction.

We have to make a last consideration. In order to correct Azimuth we must know that correction from equation (5) is valid only for stars on the horizon plane, but there we can't find any suitable star because of refraction effects. Applying some spherical geometry, it can be shown that For a star above horizon, correction factor can be multiplied by \sin of the declination difference from the star to the zenith (zenith distance). So Azimuth correction equation is:

$$(7) \Delta A = 228.55 \sin(\phi - \delta) d\Delta\delta/dt / \cos(\phi)$$

Equation (6) and (7) solve aligning problem using declination drift measurements only from a star in the meridian (hour angle 0h) and a star with hour angle 6h or 18h.

References

Ref.[1] Polachsenjustierung (Polar Align):

<http://www.astro-electronic.de/polachse.pdf>

Ref.[2] The atmosphere as a prism

http://eq.one-arcsec.org/e/Methods/framMethods_e.html

Ref.[3] Die Scheinermethode (The Scheiner method):

<http://www.baader-planetarium.de/download/scheiner.pdf>