# The Universe
# Celestron® and Image Processing Manual

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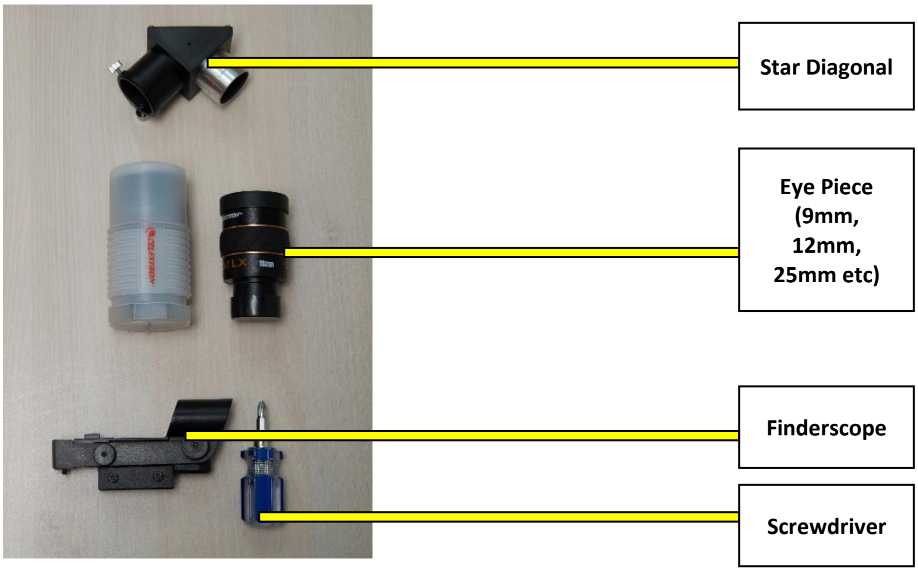
## Part 1. Telescope Setup

### 1.1 Key Components

## 1.2 Key Accessories



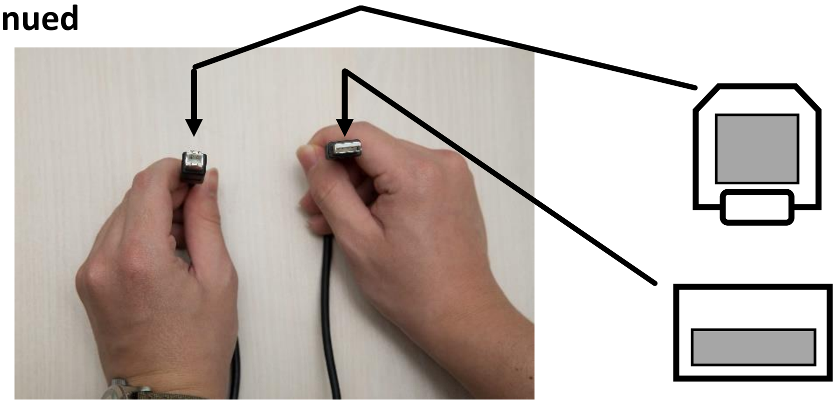

## 1.3 The Camera


**The ASI Camera**

The parts covered from sections 1.1 to 1.2 make up the Telescope but the camera is required to capture images and record onto your laptop.

There are 2 types of cameras: Coloured (MC) and Monochrome (MM) which will be indicated on the box containing the camera.

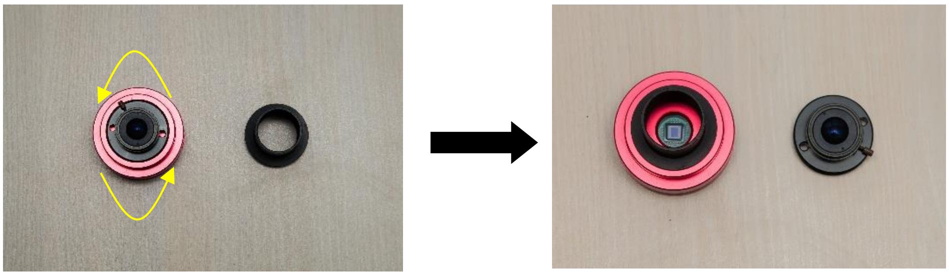
## 1.3.1 The Camera Continued

**The ASI Camera Box**

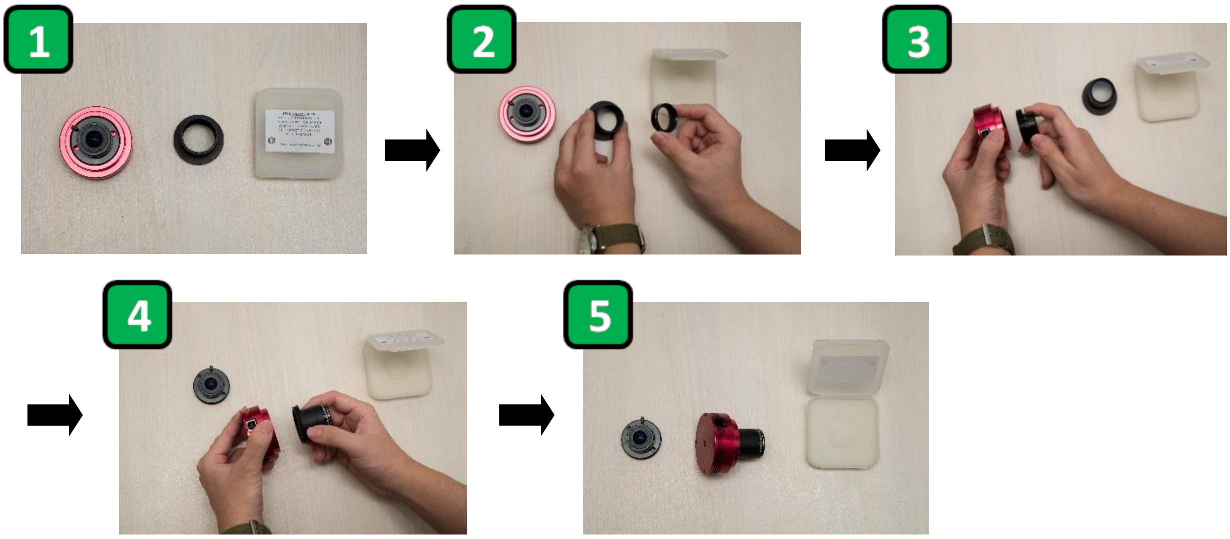
Within the box, the camera is kept together with an adaptor (switches between a camera lens and a telescope adaptor) and the connector cable to your laptop. The image of the connections (right) shows the camera and USB connectors on the left and right respectively.

## 1.4 Assembling the Telescope Camera



Rotate the outer circle of the camera lens anticlockwise to release it and replace with the black Telescope adaptor.

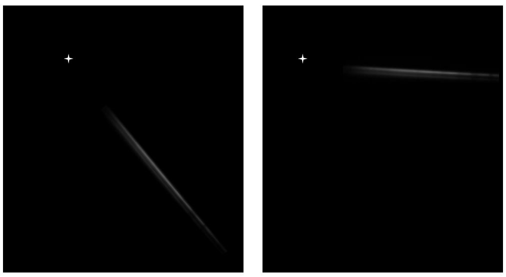
### 1.4.1 Assembling the Telescope Camera w/ diffraction grating




A diffraction grating (e.g. Star Analyser) can be used in addition to the camera to obtain the spectra of a particular celestial object. Process goes as follows: Attach grating to adaptor (picture 2) → replace camera lens with adaptor (pictures 3 & 4).

**Note:** You might want to adjust the orientation of the grating with respect to the camera such that the first-order diffraction line is in a desirable position which is easy for analysis.

Example:

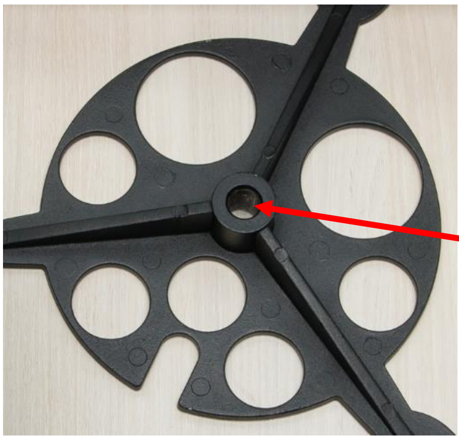


The spectra can be rotated into a horizontal line (right image) instead of being diagonal (left image). You can just find a reference point on the diffraction grating and screw it in at a different starting position to change its orientation till you get the desired orientation.

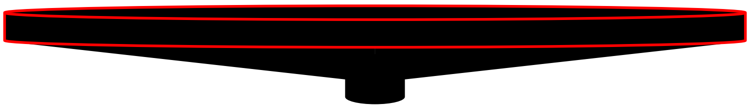
## 1.5 Outdoor setup of Telescope

Remember to add in the washer (metal ring) above the black knob

After setting up the Tripod stand (adjust to appropriate height, can just start with max), unscrew the black knob (take care not to lose the washer in the dark) and add in the accessory tray before screwing everything back.



**Side view of Accessory Tray**



**TIP:** Ensure that the protruding part of the tray is facing downwards when slotting it in, otherwise the tray will be loose and will not secure the Tripod properly

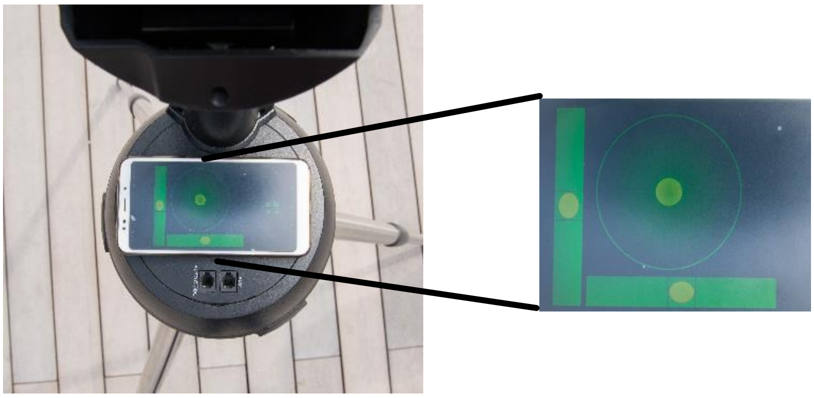
## 1.5.1 Setting up the Tripod and Motorised Mount

**1** On the underside of the Tripod, there are 3 screws to be tightened once the Mount is in place

**2** Ensure that the grooves (3 in total) of the Mount are aligned to the Tripod's

After fixing the Motorized Mount onto the Tripod (make sure it sits on the grooves nicely), screw in the 3 screws on the underside of the Tripod to secure the entire structure. Make sure it is stable before proceeding on to the next step.

**TIP:** You can use a spirit balance (or your phone app) to check for the balance of the structure after setting it up and before you attach the Telescope. Check the spirit balance spirit to ensure that the setup is levelled (right image) and stable so the Motorised Mount can track the movement of the night sky smoothly without you having to recalibrate throughout the session.

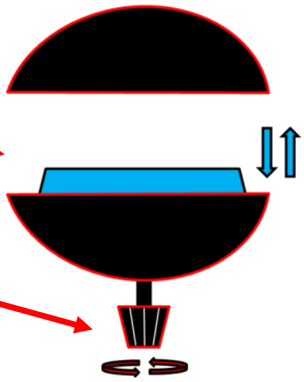


## 1.5.2 Attaching the Telescope

**1** You might need to first loosen the knob here to slide the Telescope in. For the actual mounting, it is advisable for a second person to assist and look at the groove while someone carries the Telescope and slides it in.

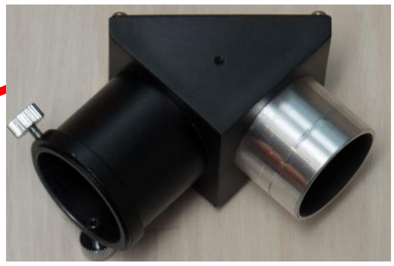
**2** Slide in the Telescope along the groove. Ensure it is a good fit and that Telescope is BALANCED (i.e. length of the tube is distributed evenly on both sides of the central pivot). Afterwards remember to TIGHTEN, otherwise your Telescope is going to fall off once you point it upwards

After setting up the Mount, you can slide the Telescope along the grooves on the Mount (see image below) and tighten the knob to secure the Telescope.



**Note:** When you turn the knob at the bottom of the Telescope dock, there will be a plastic block that can move up and down (highlighted in blue). This serves as the locking mechanism for the Telescope. Lower it completely before sliding in the Telescope to ensure that the Telescope sits FULLY within the groove.

## 1.5.3 Setting up the Eyepiece



1 Add the star diagonal to the visual back (the hole at the back)


2 Then add the eyepiece to the diagonal

After setting up the Telescope, remove the plug at the back of the Telescope and insert the star diagonal (silver part) into the dock. Tighten all necessary screws and then attach the eyepiece into the dock on the star diagonal. After which do one more check to ensure all screws are tightened.

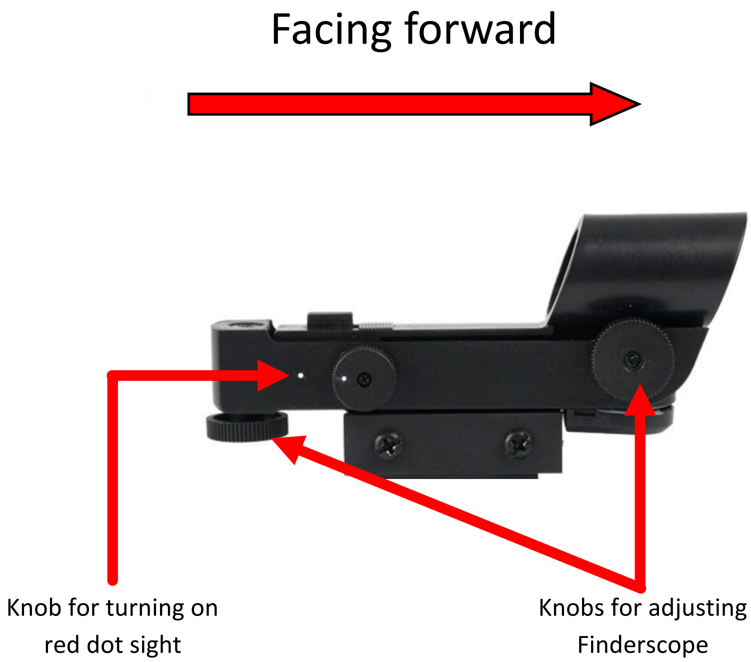
**TIP:** The left image shows the completed setup. Make sure to TIGHTEN all screws after attaching every new free piece, otherwise you risk dropping and breaking the delicate pieces of equipment.

## 1.5.4 Setting up the Finderscope

**1** Screw on the Finderscope.

**2** Turn on the red dot sight and aim at a faraway object (like a prominent sign of a building). Check that you can see the red dot and your target

Simply pick up the Finderscope and screw it onto the small mount found on the side of the Telescope. The knob for turning on the red dot sight is found at the back of the scope. Ensure that the Finderscope is not screwed on in the wrong orientation (the red dot sight portion facing the direction your Telescope is pointing at). Adjustment and calibration of the Finderscope will be covered in a later portion. For now, just secure the equipment.




**TIP:** The brightness of the red dot sight is adjustable; you will want to find a sweet spot and not make it too bright (will obscure your target celestial body) or too dim (too difficult to aim the scope). Adjust based on light conditions and your target. Staring for prolonged periods of time might require you adopt dimmer settings.

## 1.5.5 Swapping in the camera


**1** If you are attaching the camera, attach directly to the visual back (remove the entire star diagonal and eye piece)

**2** Connect the setup to your laptop and check if you get visuals

**3** Readjust focus using the focus knob

Once you managed to set up everything and found your target, you can then swap out the entire star diagonal (along with the eyepiece) for the camera (the adaptor goes into the dock in the Telescope). Connect to your laptop and check for visuals (prior to mounting the camera you should have already checked that it is working well by pointing the camera to something nearby). After you establish visuals, the target will most likely be out of focus and you will need to readjust the focus knob to get proper visuals.

**TIP:** Even though you already focused using the Eyepiece, when you switch over to the camera, it can be so out of focus that you do not even get a blurry image. Be patient and **adjust the focus knob slowly** while using a **low Exposure time** on your capturing software (to ensure that your focus adjustments do not take forever to be reflected on your screen as the longer the exposure, the greater the delay from adjustments to the changes being reflected onscreen). Experiment around and you will get better at it.

Sometimes however, no matter how you adjust the focus, the target (e.g. a star) just refuses to show up. In this case, you will want to use a low rotor speed and slowly move your Telescope around using the controls to find the target as it might be outside the field of view of your camera.

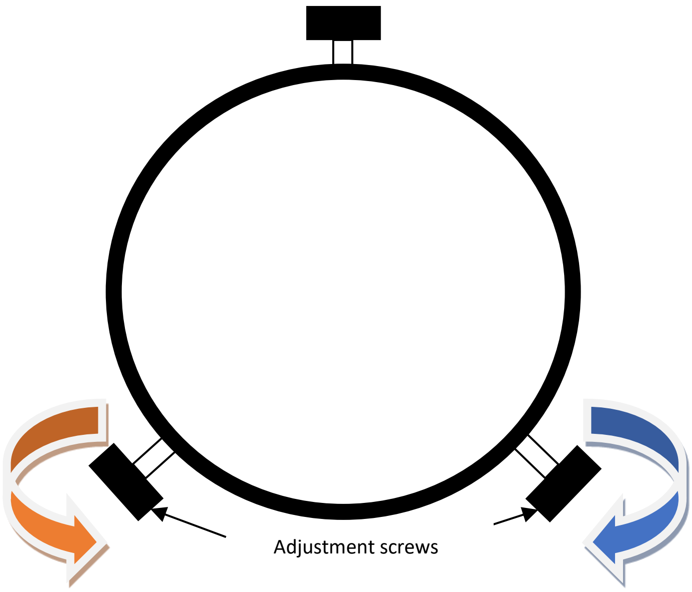
## Part 2. Telescope Alignment

### 2.1 Finderscope Alignment

The exact mechanism for adjusting the finderscope alignment on your telescope may be different from this guide, but the processes and principles remain the same. Typically, the finderscope will be held in place on its mount by means of screws or springs – these act as the controls to align the finderscope. In this segment, finderscopes shall include red-dot sights, iron sights and other sighting devices without optical magnification elements.

Alignment should be carried out with a series of targets, progressing from the *nearest* to the *furthest*.

1. Point the main scope at an easily identifiable shape on a nearby building, such as a satellite dish, communications antenna, or pylon.




2. Check the position of the target in the finderscope. Experiment with the position of the securing screws; moving a pair of screws in opposite directions at the same time, and observe how the finderscope moves in response. Adjust the finder scope such that the target is squarely in the centre of the finderscope view.
3. Point the assembly such that the finderscope is centered on a star in an empty patch of sky, then adjust the position of the main scope such that the star is centered in the main scope.

4. Adjust the securing screws on the finderscope mount until the main scope and finderscope are aligned.

### 2.2 Electronic Mount Alignment

In order to allow the telescope to track the movement of the night sky as time progresses, the mount needs to know where in the night sky it is pointing, and in what direction and how fast it should move.

This is achieved by correctly orientating the electronic mount's onboard computer to the night sky. As of writing, the mounts accessible to SPS students hail from the Celestron Nexstar series of electronic mounts, which conveniently support a method of alignment that does not require any prior background knowledge; the mount guesses the identity of the bright objects you point at. If you are using another mount that does not support a similar feature, you may find it useful to refer to the brief on two/three star alignment. Two/three star alignment requires the user to specify which objects are being used for alignment.

## 2.2.1 SkyAlign

This visual walkthrough will guide you through the SkyAlign process. The first image shows the layout of the buttons, following which are illustrations of the LCD display for brevity.


Startup Screen, with buttons displayed. Press ENTER to continue.

| | |
|---|---|
| Select Method<br>SkyAlign | Select "SkyAlign" and press ENTER. If you wish to use other methods, use the SCROLL keys on the numpad to the bottom. Navigation through most menus uses either the arrow keys or SCROLL keys. |
| Time hh:mm:ss<br>19:24:46 | Set time in hh:mm:ss. Press ENTER. |
| Select One<br>Standard Time | For Singapore, select standard time. |
| Select TimeZone<br>Zone 8 | Select time zone. GMT+8 is Zone 8. |
| Date mm/dd/yy<br>12/18/19 | Enter date.<br>**CAUTION:** Date is in American mm/dd/yy format! |
| Center Object 1<br>Press ENTER when… | Centre a bright star/planet in the main scope and press ENTER. The position of the scope is changed with the arrow keys. To change the motor speed (movement speed) of the telescope, press the MOTOR SPEED key followed by the number of the desired speed. |
| Align Object 1<br>Press ALIGN when… | Adjust the scope such that the object is dead centre. Press ALIGN. |

| | |
|---|---|
| Center Object 2<br>Press ENTER when… | Find another bright object and repeat the process. |
| Align Object 2<br>Press ALIGN when… | Align the 2nd object. |
| Center Object 3<br>Press ENTER when… | Find a final, 3rd object and centre it. |
| Align Object 3<br>Press ALIGN when… | Align the 3rd object. |
| SkyAlign<br>Please Wait | SkyAlign will now attempt to guess which objects in the night sky you have pointed at, and from there, calculate the correct orientation of the telescope. |

Upon completion of the alignment process, you are strongly advised to check that the alignment was successful by asking the telescope to point at an easily identified object such as Jupiter or Venus. If the object does not appear in the centre of the eyepiece, repeat the alignment process.

### 2.2.2 Two/Three Star Alignment

The prompts shown on your remote/controller may vary, but the principles of two/three star alignment are similar to SkyAlign, with one key difference; you need to specify which object you are pointing at. The start of the process typically will require you to specify the type of the object, such as a star or a planet, followed by its name. The centering and aligning process will likely be similar to that of the Skyalign process.

## 2.3 Target Confirmation

Even if you are using an electronic mount that has been aligned, it is still reassuring to ascertain the identity of what you are viewing using your own skills. As you gain familiarity with the night sky, you may come to recognize patterns and shapes; some of these patterns may coincide with asterisms or constellations as described by those who have come before you. With a chart of the night sky, you may find the following tools and techniques to be of use in finding your way around the heavens.

## 2.3.1 Asterisms

Asterisms are simply informal patterns of stars in the night sky. These can take the form of triangles and other polygons, or shapes resembling day-to-day objects like spoons and teapots. An easy asterism to start with in the night sky would be the Big Dipper in the constellation Ursa Major (the Big Bear).

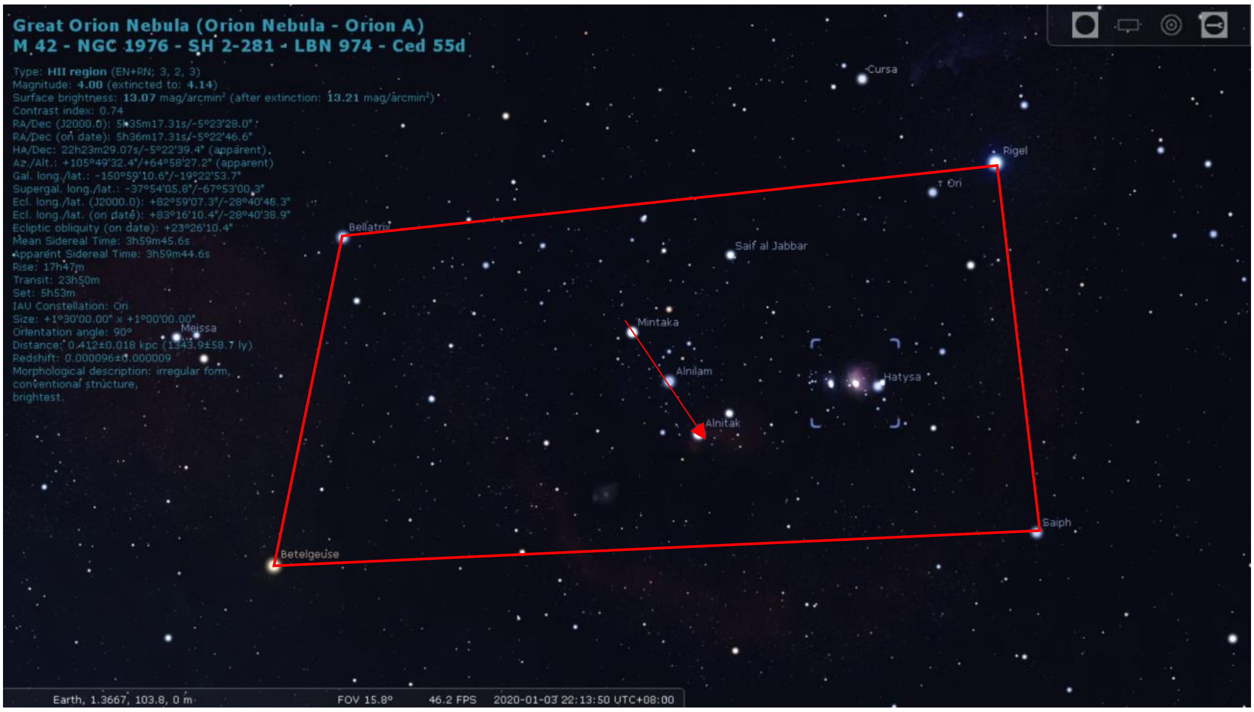

The Big Dipper is named for its resemblance to a dipper, or ladle. Conveniently, following the handle of the dipper all the way to the bowl, we notice that the tip of the bowl points towards the North Celestial Pole. This is especially useful for finding our bearings with respect to what is shown on a sky chart.

## 2.3.2 Constellations

Constellations, like asterisms, are patterns of groups of stars in the night sky, with the distinction of having official boundaries recognized by astronomers worldwide. For the most part, the boundaries of constellations are not of much utility in navigating the night sky. Instead, the brightest stars of constellations often form asterisms which are the basis for navigation. One notable constellation with the bulk of its brightest stars forming an asterism is Crux, the Southern Cross.

## 2.3.3 Star Hopping & Polygons

You may run into instances where there are no convenient asterisms to orient yourself against, or the object of interest is nestled deep in a region where there are few neighboring stars. Referring to your star chart, you may find that your field of view in the main scope is fairly limited due to your eyepiece's short focal length. In this case, it is recommended that you fiddle with the fine adjustments knobs for a while to figure out which way the field of view moves in response.

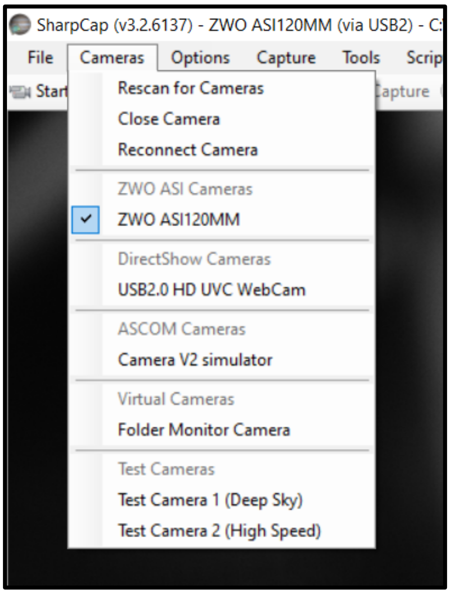



The object of interest in the image above is the Orion Nebula, in the constellation Orion. To find usable pattens, we note Betelgeuse (red) and Rigel (blue) forming opposing corners of a rectangle with a "belt" of three stars inscribed. By looking towards the right half of the rectangle after the belt, we see a smaller "dagger" of three stars; the Orion Nebula lies in the middle of the dagger. This is a simple example of star hopping making use of polygons and lines to find approximate distances to locations in the night sky.

# Part 3. Image Capture and Processing

After setting up and calibrating your telescope, you can now capture some images of your target object, e.g. Jupiter, and process it to obtain an image for your project or for interest. In this part of the manual, we will be going through the basics of image capturing via SharpCap and image processing via AutoStakkert and RegiStax.

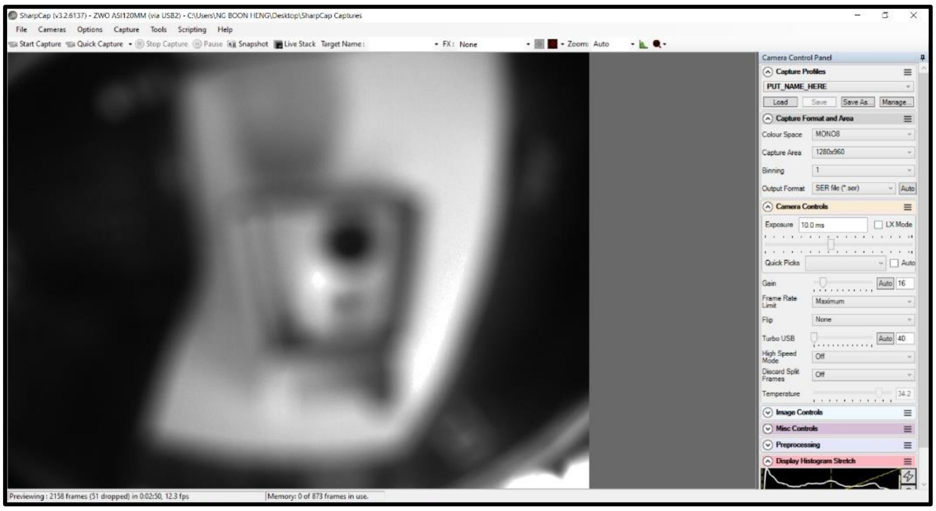
## 3.1 Image Capturing (SharpCap)




To connect to a camera, you would need to download the relevant driver[1] for the software to detect the camera, as shown on the left in the dropdown bar.

Select your camera and ensure that the camera detection is fine e.g. no black screen.

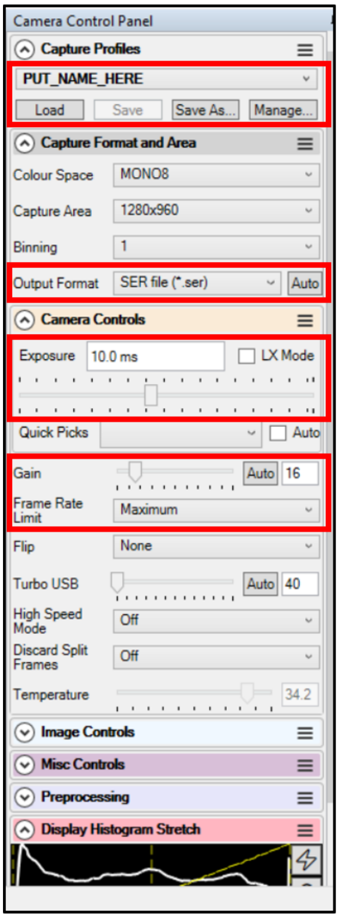
Do take note of artefacts that could indicate cracks or scratches on the fisheye lens or the sensor.

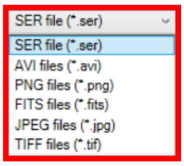


This is the interface for SharpCap[2], **AFTER** connecting to a camera.

[1] https://astronomy-imaging-camera.com/software-drivers

[2] https://www.sharpcap.co.uk/




Firstly, do remember to name your file and set the saving folder properly, to enable easy locating of files for image processing later.

Output format is preferred to be either **SER or FITS** filetypes. SER format saves the data in a smaller filesize, which is beneficial if you are going to process a large amount of data, e.g. tracking of planet.

Whereas for FITS format, it contains more information such as the parameters used in the data collection, which will be:

'Exposure' is one of the two main components that we would adjust during image capturing. Exposure is the amount of light which reaches the camera sensor.

Whereas the other main component would be 'Gain', where gain is a setting to control the amplification of the signal from the camera sensor[3].

With these two components, we would then proceed with image capturing.

But before doing so, do prepare **at least 50GB** worth of memory space in your laptop to minimise any loss of data near the end of your session.

[3] https://www.edmundoptics.com.sg/knowledge-center/application-notes/imaging/basics-of-digital-camera-settings-for-improved-imaging-results/


Under 'Capture', there are several options to choose from.

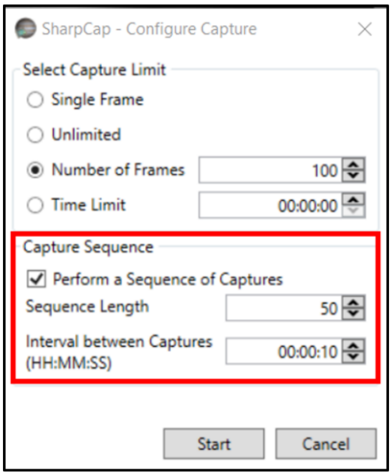
'Start Capture' starts the imaging of your target object and saves the raw data in the folder selected in the previous step.

In imaging, images can suffer from noise caused by the camera sensor and electronics[3], as well as variation of brightness across the frame[4].

'Capture Dark' is used to counteract the effect of noise. This is done by capturing a dark frame with the camera lens or telescope covered up[4]. Any signal captured from this dark frame will be attributed to noise.

'Capture Flat' is used to correct the variation of brightness. Brightness variation occurs when uneven amount of light reaches the corners/edges of the frame due to the optical configuration of the camera lens or telescope, resulting in those areas being darker[5]. A surface that is perfectly uniformly illuminated will be captured as a flat frame.

'Target Name' allows the software to help with the identification and naming of the target object, which only includes the Sun, planets and the Moon.

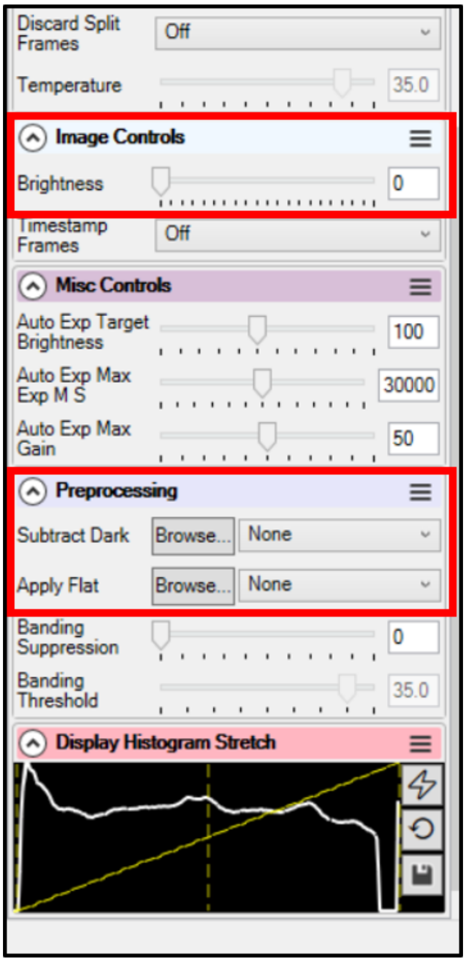



After clicking 'Start Capture', this dialog will appear where you can choose the number of frames to be taken. The additional option of 'Capture Sequence' allows us to take a series of images with a set interval between each capture.

The example here would result in a capture of 100 frames, 50 times with an interval of 10 seconds between each capture.

[4] https://docs.sharpcap.co.uk/2.9/17_CapturingandUsingDarkFrames.htm

[5] http://docs.sharpcap.co.uk/3.2/26_CapturingandUsingFlatFrames.htm



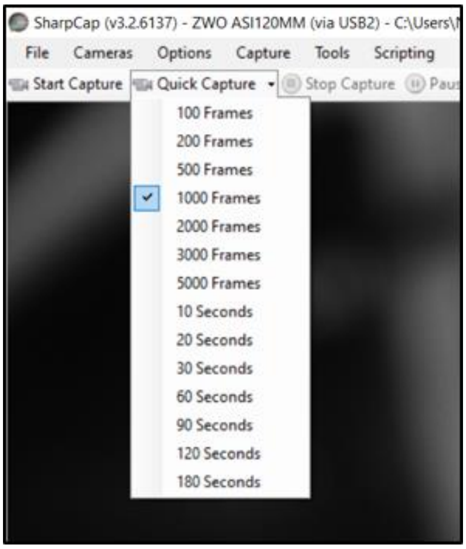

If your target object is too dark to be clearly seen on the screen, you could alter the brightness of the image.

However, this function only serves to aid you in focusing on your target object. It does not enhance the image taken. Hence, the raw data captured will remain the same regardless of the brightness setting.

If you did capture the dark and flat frames mentioned in the previous steps, you would then upload them into this section to correct for noise and brightness variation.

However, to do so, you would need to acquire the paid version of this software. Alternatively, you could try using **AstroImageJ** to apply the dark and flat frames.

The histogram displays a distribution of the brightness of the pixels. When doing planetary imaging, do ensure that at least **60-80%** of the pixels are usable. If the brightness is too high, you can reduce either exposure or gain, preferably the exposure due to the light pollution in Singapore.

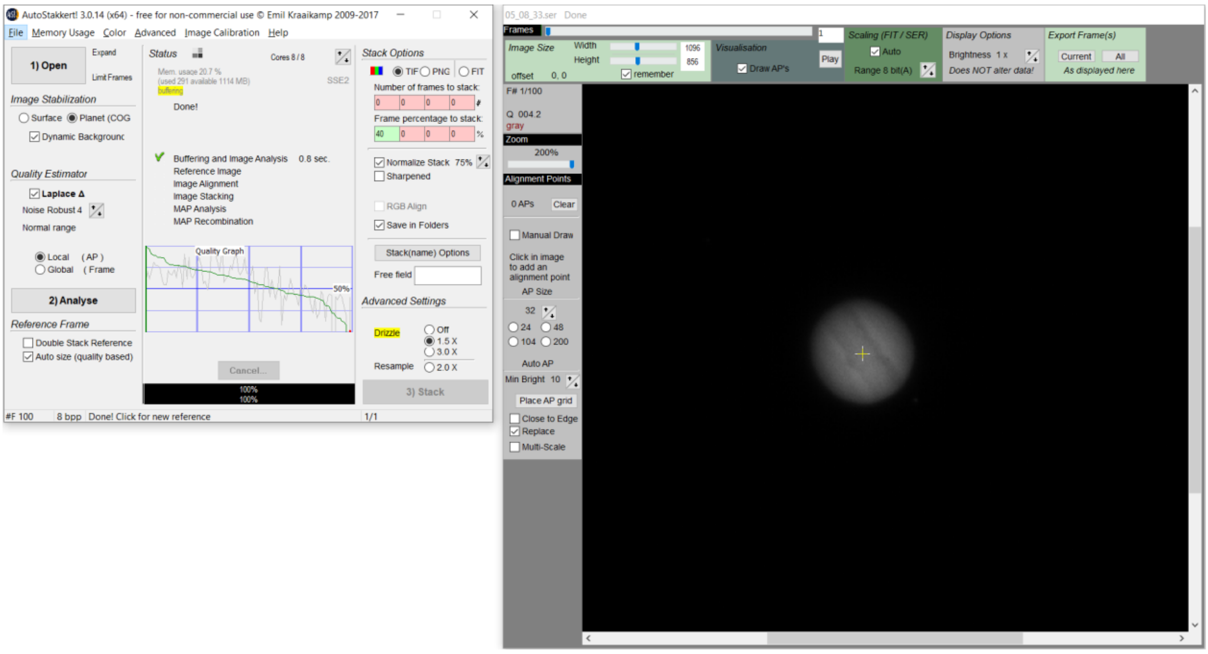



Other than manual capture, there is also the option of quick capture which provides a range of frames or timings to choose from.

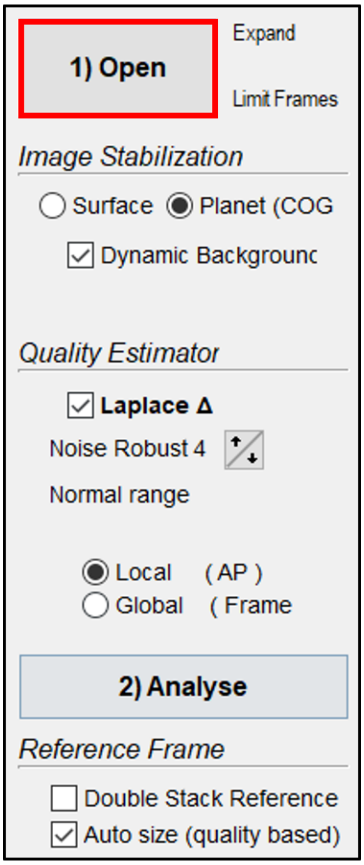
We would only suggest using this for a quick check of your edited settings.

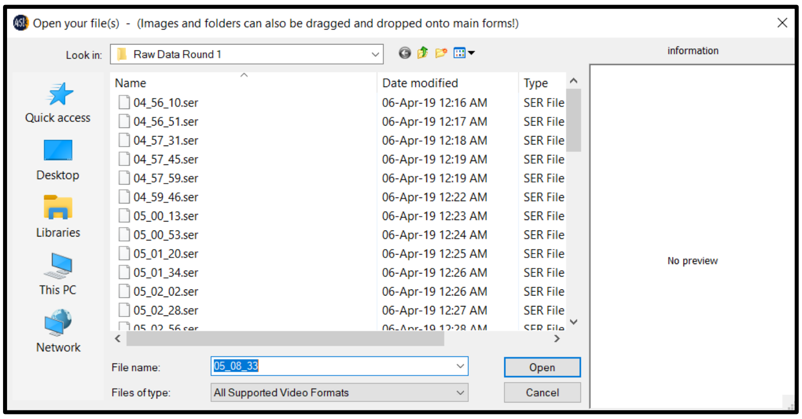
**This is the end of the imaging portion; we will now proceed with image processing!**

## 3.2 Image Processing (AutoStakkert)




This is the whole interface for AutoStakkert[6], used for image stacking.

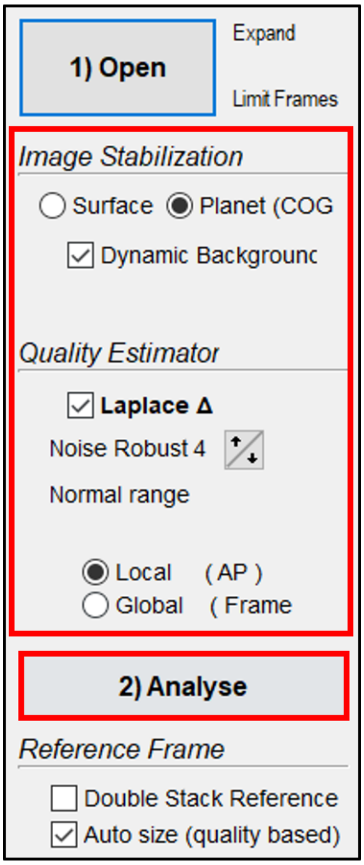



First, you would need to load your image by clicking the 'Open' button.

Select your file from the pop-up; preferred file type is either **SER or FITS** format.

[6] https://www.autostakkert.com/



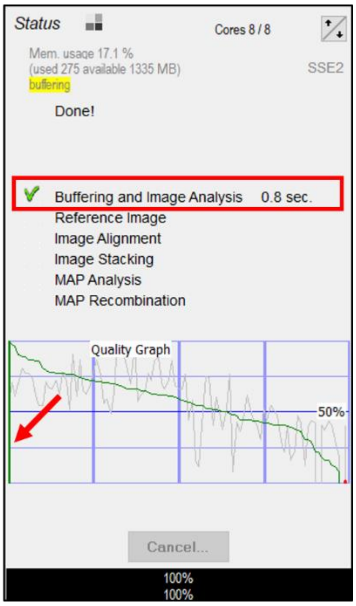

Secondly, ensure that the correct options are selected: **Planet & Dynamic Background**

Note that nothing was changed for 'Laplace Δ' & 'Noise Robust', hence they should be the same as the default state. Do feel free to research and play with them.

Thirdly, 'Local (AP)' is chosen instead as we would want to set Alignment Point (AP) on our target object and increase the accuracy of image stacking.

Lastly, click on 'Analyse' to get an idea on the quality of the frames captured by your setup.

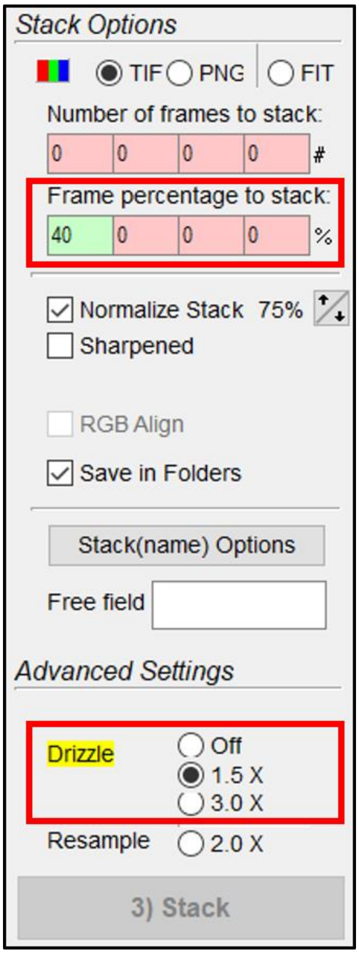
These options are relevant for Jupiter & Saturn. However, different options are required for Mars, do look up on that if you are planning to do anything related to Mars.




After clicking on 'Analyse', the middle panel of the smaller interface would run and produce a graph.

Ensure that the **single green tick** appears which signifies the end of the run.

The y-axis refers to the quality of frames whereas the x-axis refers to the number of frames. The green line, pointed out by the red arrow, can be shifted to measure the percentage of frames that are above a certain quality threshold.

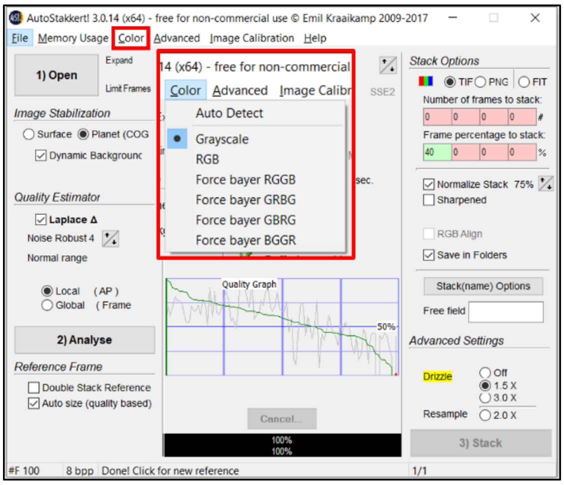



From the graph mentioned earlier, you can decide the **percentage of frames** you would want to consider in the image stacking **OR** you can decide on the **number of frames** to stack in the boxes above.

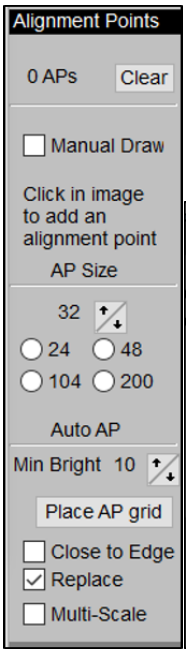
There are four boxes available for both number and percentage of frames to stack. This allows you to conduct **up to four batches** of image stacking with different numbers or percentages of frames selected for stacking.

By default, the 'Normalise' option would be ticked. This can be changed to 'Sharpened' if your images require additional sharpening, but this is usually avoided as we would sharpen the images in another software later.

For 'Drizzle', it allows extrapolation of information based on your images. This is only used when the number of frames used for stacking is low, e.g. ≤40% of frames.

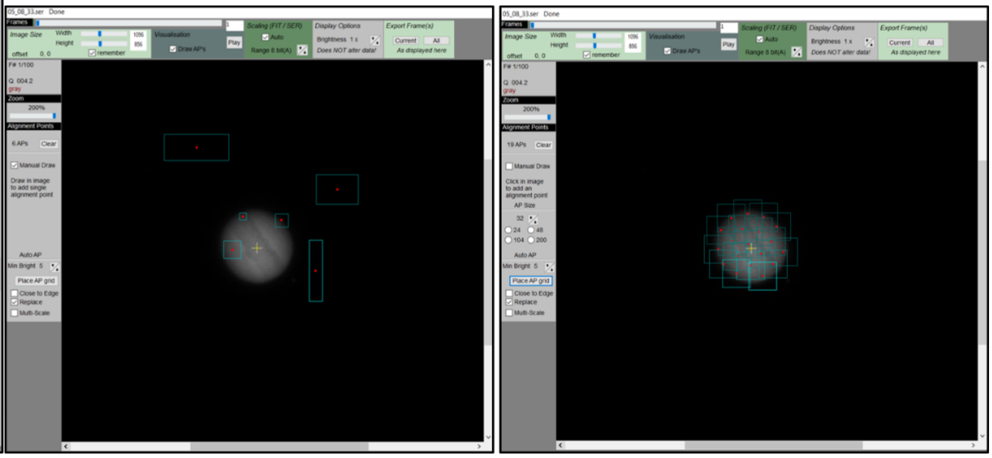



In the case where your image is coloured, you can change the colour settings as shown here.

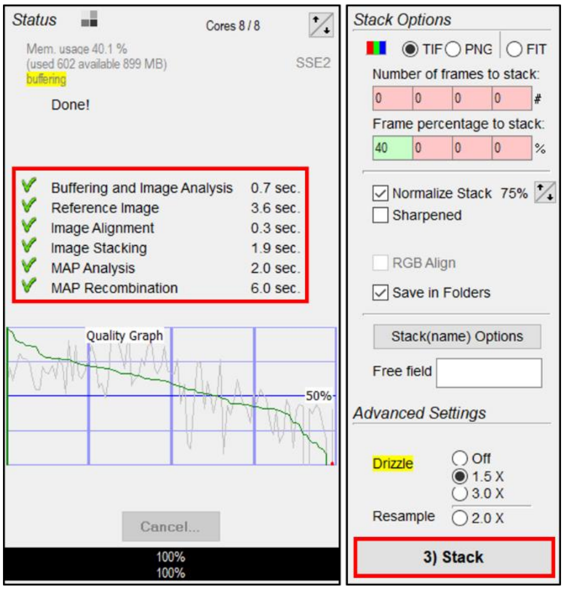



Now, onto the bigger interface. This is where we will place our Alignment Points (APs) on our images for stacking.

You can either draw the APs manually, place APs with several sizes or allow the software to help detect and place APs for you.



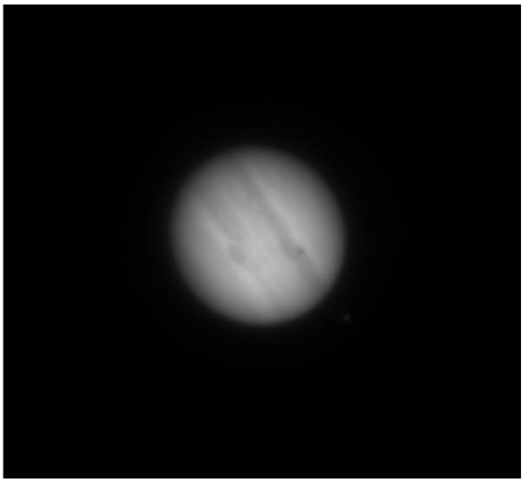
**Manual Drawing of AP** **Automatic Placement of AP by Autostakkert**




After placing the APs, the ‘Stack’ button would be available for us to click.

The stacking process can be quite long (ranging from 20mins to several hours) depending on the number/percentage of frames that are used to stack.

Do ensure that all the options are **green-ticked** to indicate a successful attempt at image stacking.

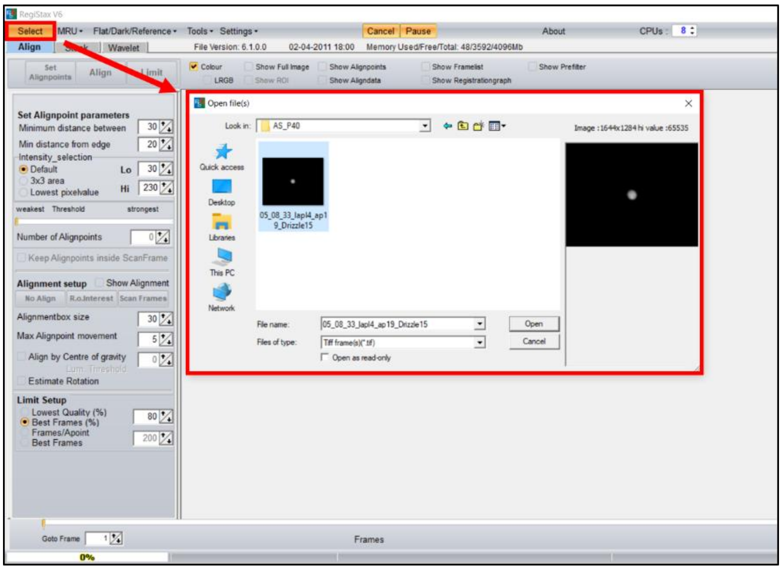


**Before Stacking** **After Stacking**

This is an example of the difference between the images before and after stacking.

**After image stacking, we can then proceed to image enhancement using RegiStax.**

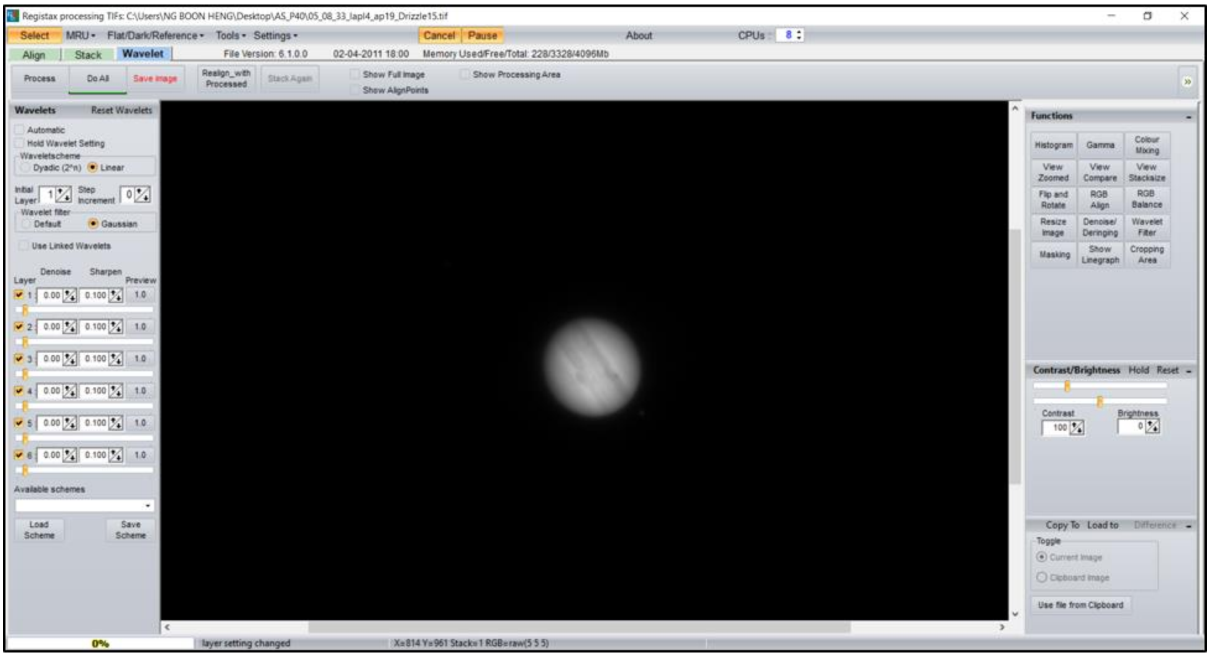
### 3.3 Image Processing (RegiStax)



Now, we will move on to the next part of the image processing, which requires a software called RegiStax[7].

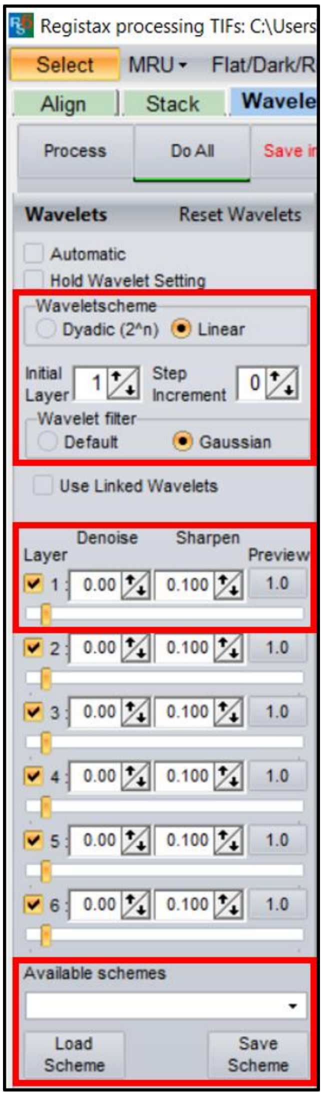
This software allows us to denoise and sharpen to enhance our images.

Firstly, load your stacked image from the 'Select' function.



This is the whole interface for RegiStax, **AFTER** you loaded your stacked image.

[7] https://www.astronomie.be/registax/




After loading your stacked image, you should see this panel on the left.

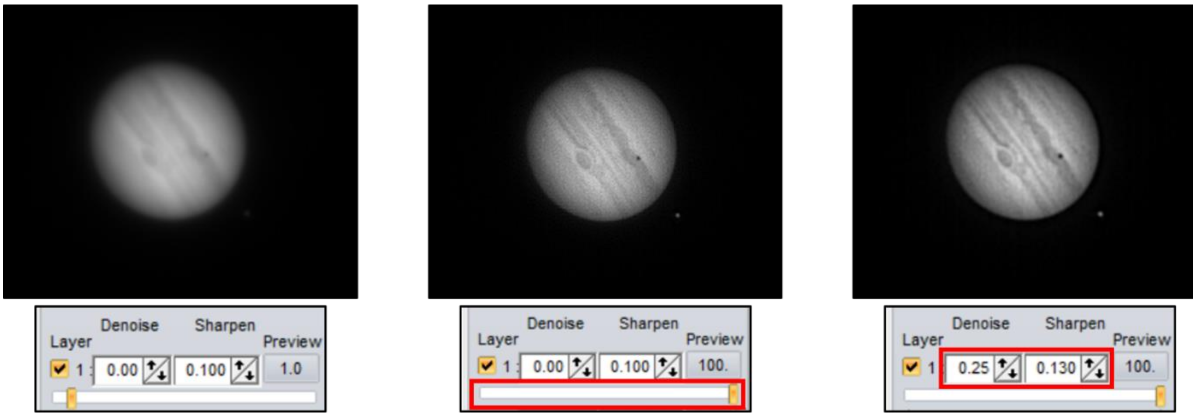
This allows you to change the denoise and sharpen settings to further enhance your image.

Do ensure that the 'Linear' and 'Gaussian' options are selected before proceeding.

For simple denoising and sharpening of images, one layer is sufficient. However you are always welcome to experiment with additional layers.

There is an option for saving and loading schemes where you can re-use the same denoise and sharpen settings.

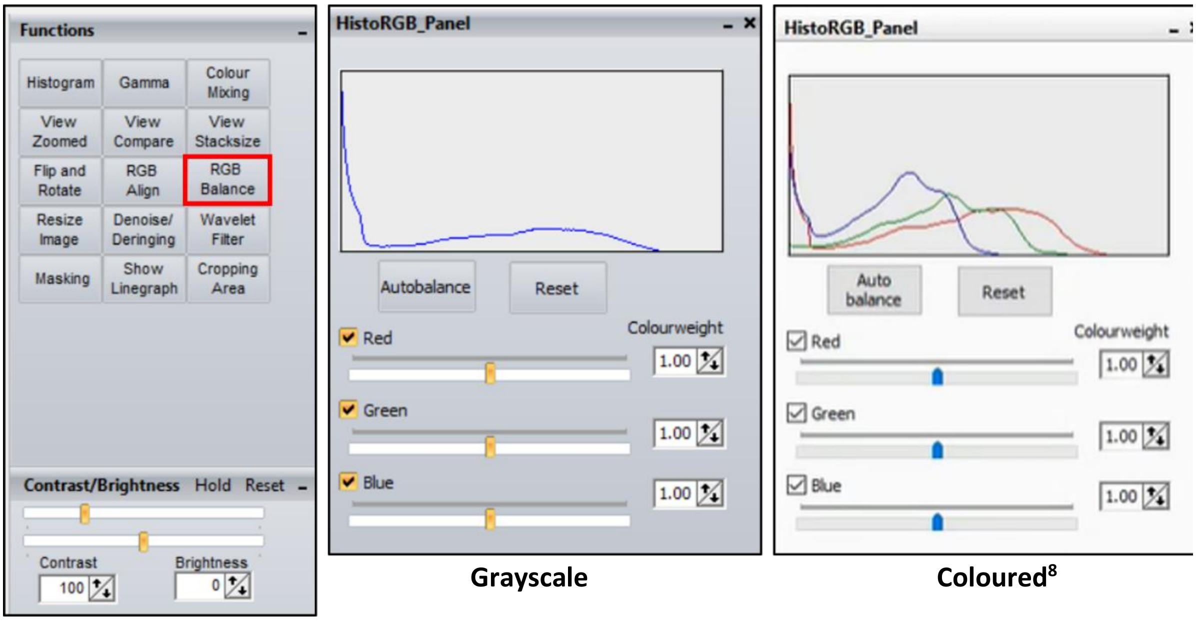
However, we do not recommend this as the background of the images can vary a lot, due to many factors such as lighting of the environment, camera specification and presence of clouds.




Working with only one layer, we would pull the bar to the maximum on the right.

Next, we can work on the denoising and sharpening of the images. This portion requires **A LOT** of trial and error. In our case, we found this set of values (0.25 Denoise & 0.130 Sharpen) working fine for our sample image.

Do note that the values of denoise and sharpen can differ a lot due to varying confounding factors (from data collection and image stacking).




**Grayscale** **Coloured**[8]

There is also a panel on the right of RegiStax which includes an array of different options.

Feel free to play around with them if you have the time.

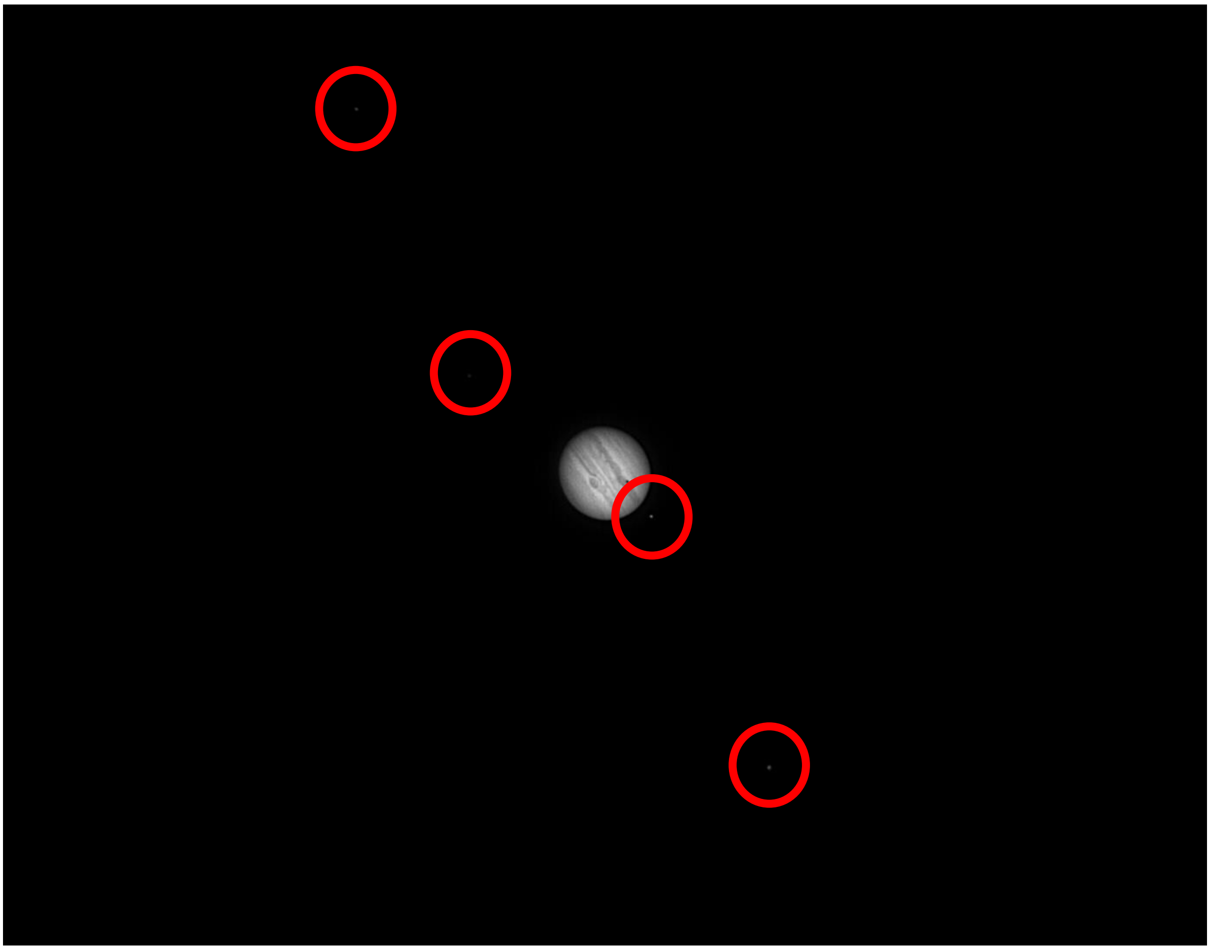
[8] Adapted from: https://www.youtube.com/watch?v=Rpnkkli4mwA&list=LLbTwu5cEYohW1u1Gd5orwaw&index=16&t=1366s

On the other hand, if you image is coloured, you might want to explore the 'RGB Balance' option to ensure that the colours on your image look natural.

**This is the end for the image processing. Here is our final processed image of Jupiter.**

Can you spot the 4 Galilean moons of Jupiter in this image?

**Answer is on the next page!**



Did you manage to find all 4 Galilean moons?

**Hope you enjoyed this manual, goodbye!**