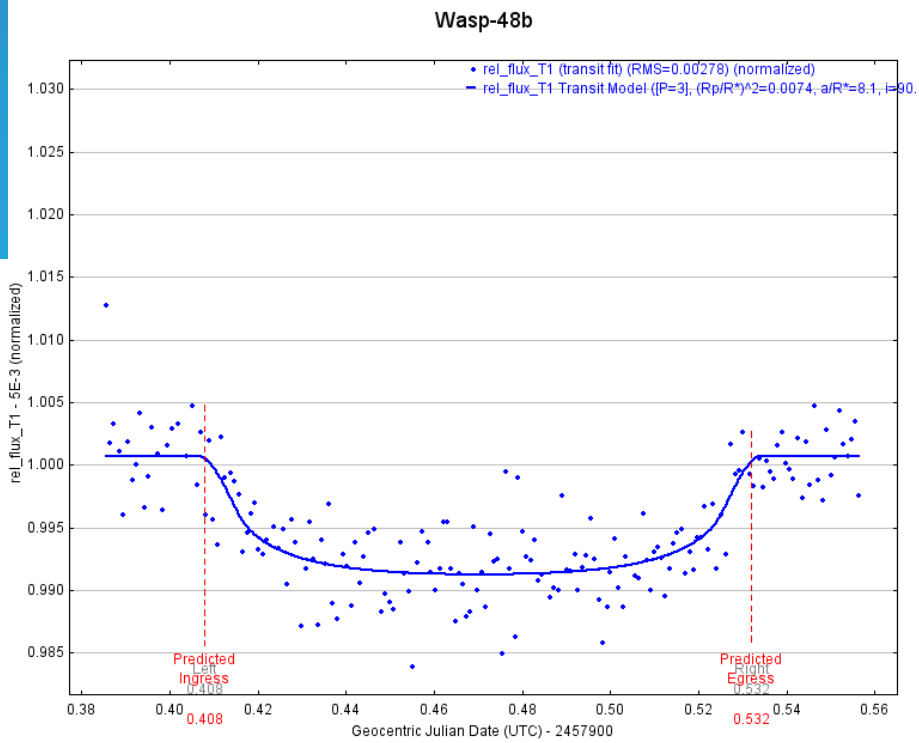

STEP BY STEP TUTORIAL ON ASTROIMAGE J

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Summary :

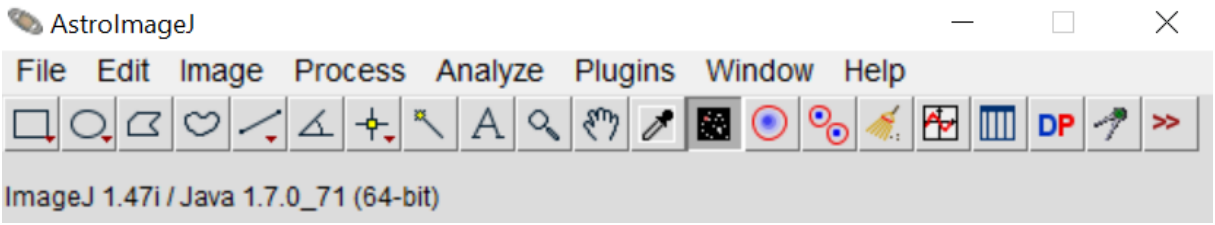
I/ Introduction

This guide is a step by step tutorial aimed at obtaining a light curve on AstroImageJ. Following the steps is essential in order to obtain the desired result.

First of all, the accuracy of the curve depends not only on good photometric treatment. Indeed, the type of camera, telescope, and the weather influence the quality of the images taken. Thus, we must consider the dataset uncertainties and understand that he is not sure of getting what you want despite all goodwill.

This tutorial presents all the image processing steps (including calibration) that can be performed on the software. It is possible to speed up the processing process by doing steps on software on PRISM but in our case we show that everything is possible on AstroImageJ.

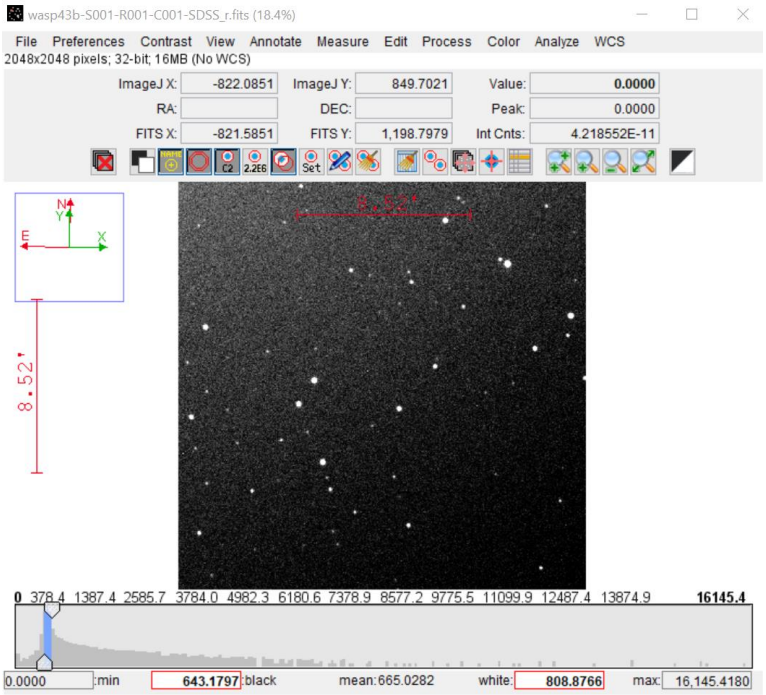
AstroImageJ looks like this at startup:



Most of the tools in this software will not be useful for our study, we are only using part of the software.

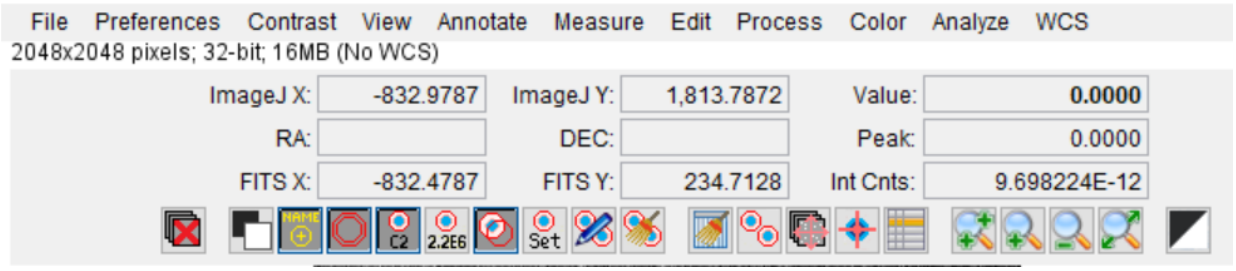
- Opening an image

In the File tab, you can first open an image by clicking Open. This window will then appear :



II/ Image calibration

Let's take a closer look at the controls that will serve us

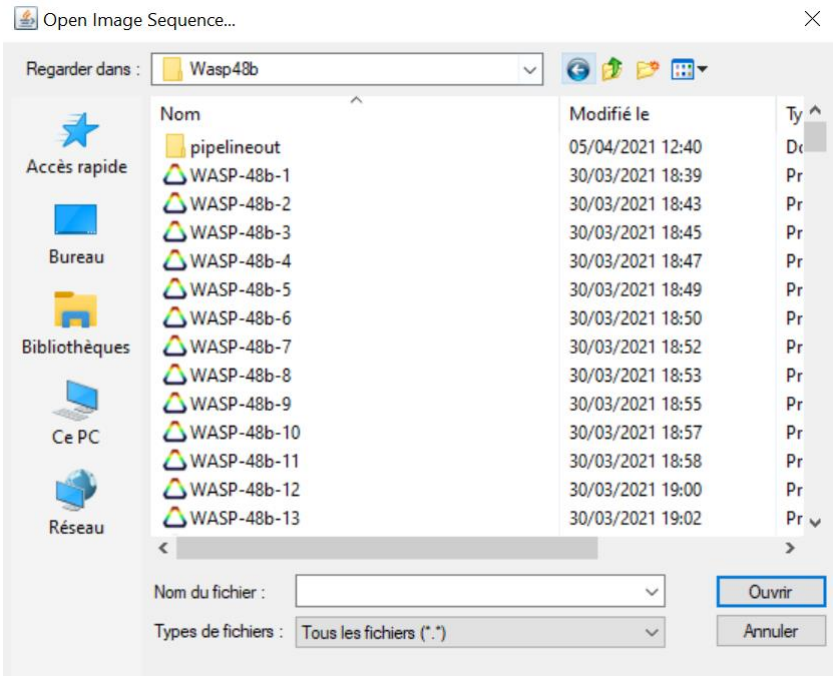


As we can see the RA and DEC boxes are empty. These correspond to the equatorial data system. This celestial coordinate system is a reference system (therefore independent of the position of the observer). If these data are not visible and you observe the mention "NO WCS" then you will have to calibrate the images.

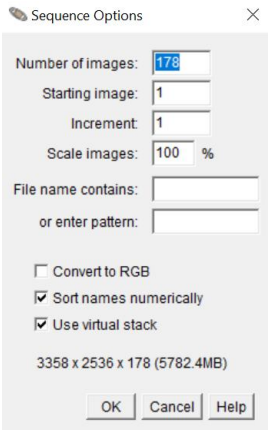
You have two options: preprocess the images on another software like PRISM or do it with AstroImageJ. We will present here the processing with this software for the reasons mentioned in the introduction.

- Opening of the sequence of images

Close the window containing the image and return to the AstroImageJ start bar. In the File tab, go to Import then Image Sequence. This window will then open :



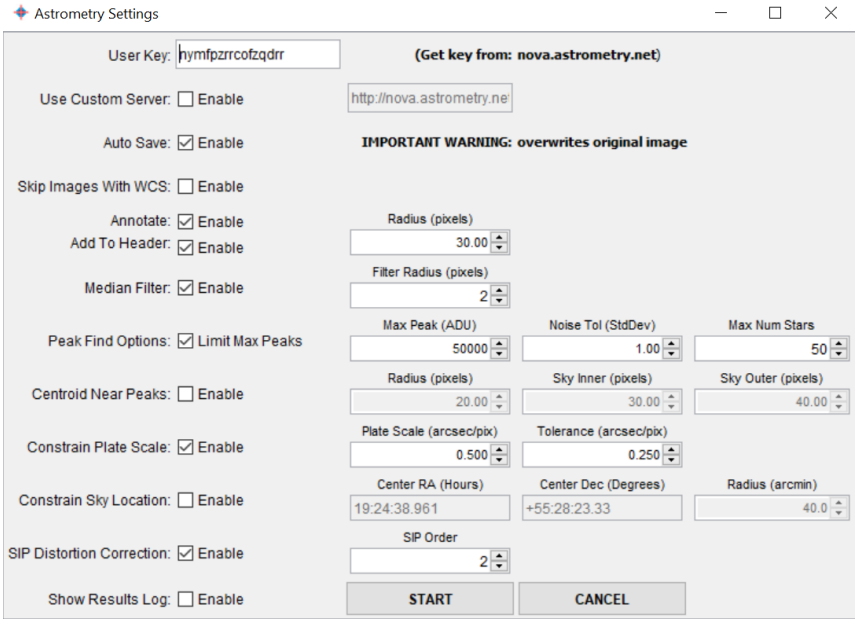
Select any photo, press Open and a new window will appear :



You must then enter the exact number of images in your dataset, check the same boxes and press OK. A window with the selected image opens as it did the first time. Now we will be able to start the calibration.

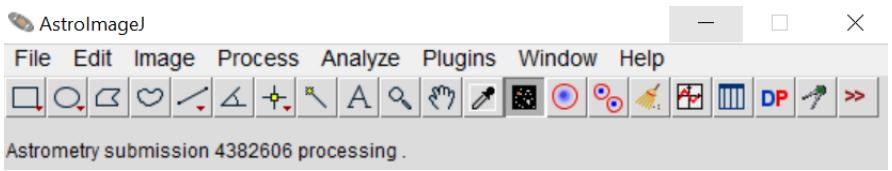
- Alignment of images to a reference system

In the WCS tab, go to "Plate solving Astronometry.net with options" and you will then have to enter the following parameters :

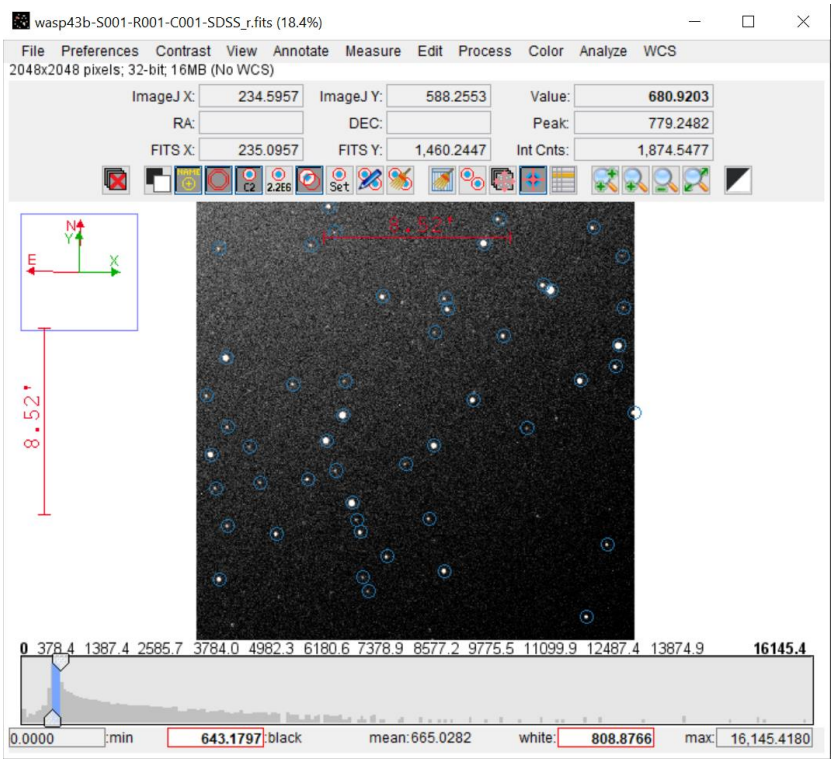


Warning : it is very important to enter this User Key and to check Auto Save.

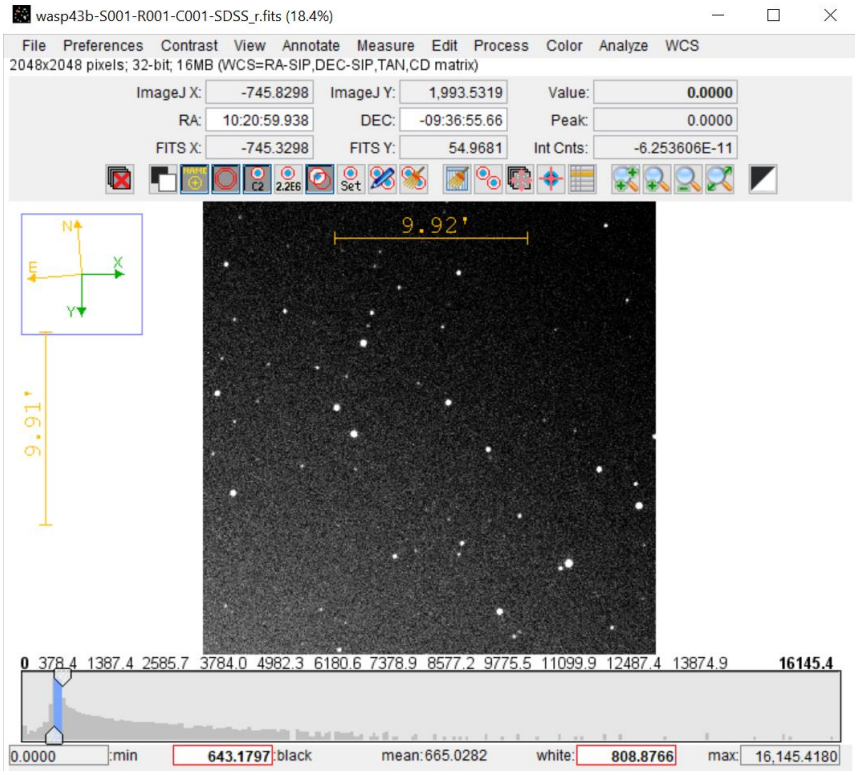
Once the parameters have been entered, click on Start and the calibration will be able to begin. You will be able to know if your manipulations are correct if you observe on the command bar this sentence:



You will also be able to observe blue circles around the stars: calibration is in progress.



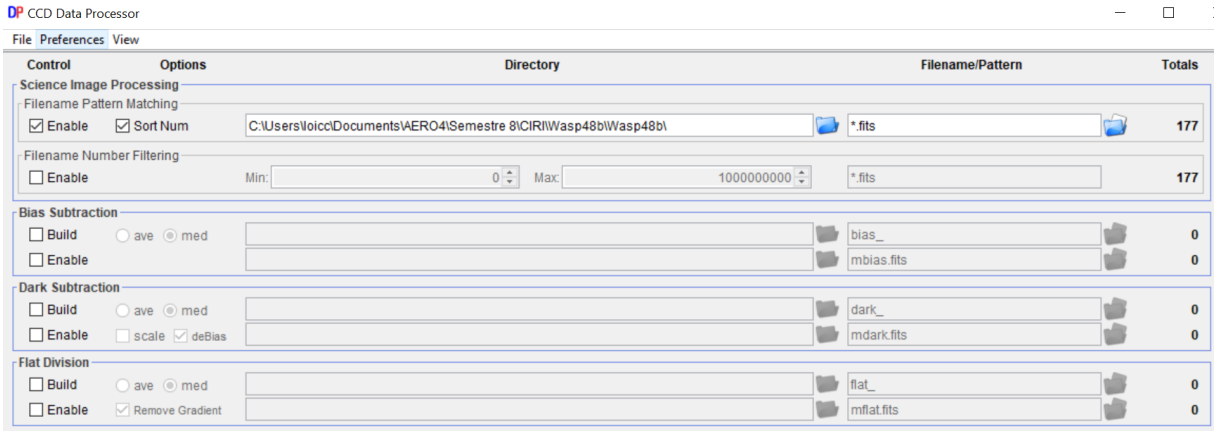
Once the calibration is complete for a photo, you will get this result with yellow lines. You can also observe that there are coordinates for RA and DEC now.



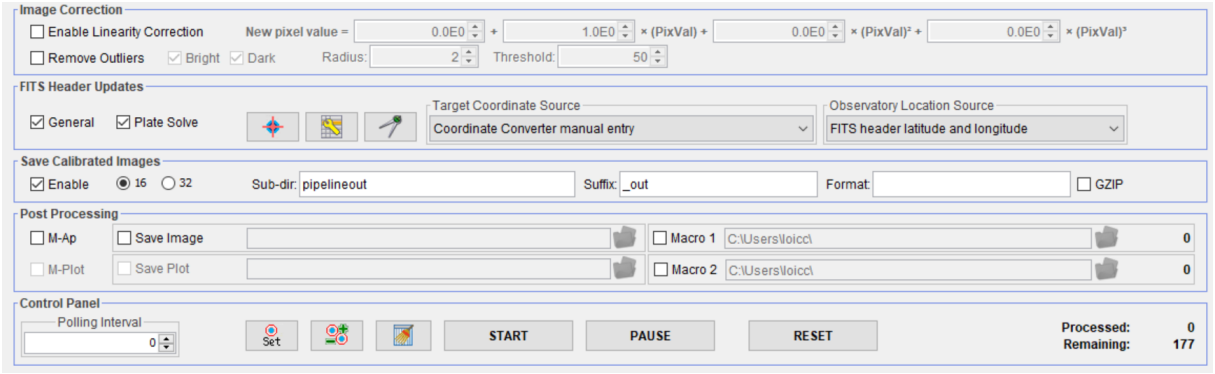
Once all the images are calibrated and all have RA and DEC, you can proceed to the next step. Check this data carefully, an image without this information will not be taken into account during the processing steps that will follow.

III/ Image preprocessing phase

Close the window and return to the software start bar. Click on the blue and red DP (CCD Data Processor). Two windows open, one of which is of particular interest to us.



In Science Image Processing, click on Directory to select the folder where all your calibrated images are located. You can optionally add bias, dark and flat (obtained with PRISM) if your dataset contains them (handling is the same).

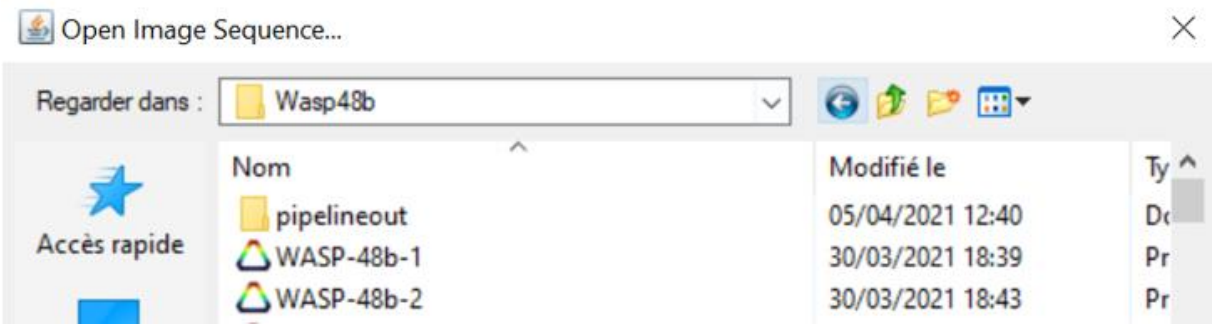


Going down to the bottom of the page you can check the appropriate boxes for FITS Header Updates and choose the right parameter for the “Target Coordinate Source” command.

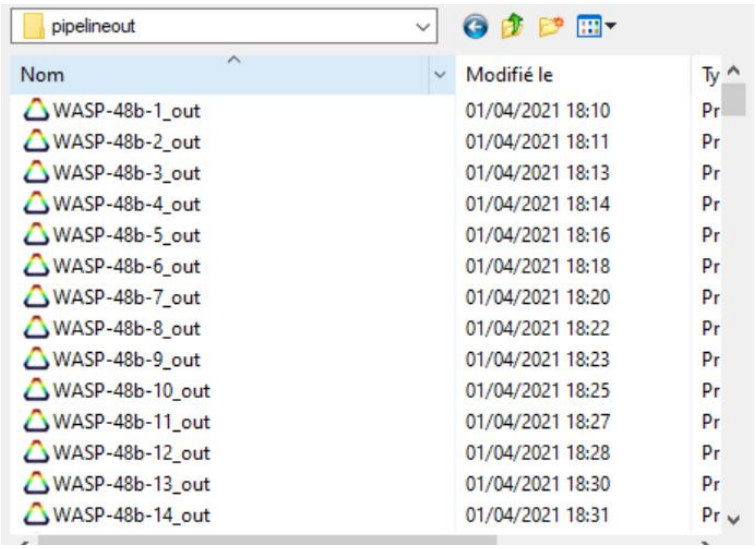
Once everything has been prepared, you can now click on START and the treatment will start. During this phase make sure that the software does not stop until you see "Remaining: 0". If during the execution of the treatment, AstroImageJ returns you an error message, check that you have carried out each step correctly and chosen the correct parameters.

- Opening of the pre-processed image sequence

When processing is complete, close the CCD Data Processor window and return to the start bar. You will repeat the previous command. Go to the File tab, Import then Image Sequence.



Unlike last time, you have a "pipelineout" folder created. Click on it and you will have access to all the processed photos. All processed images contain the suffix "_out".



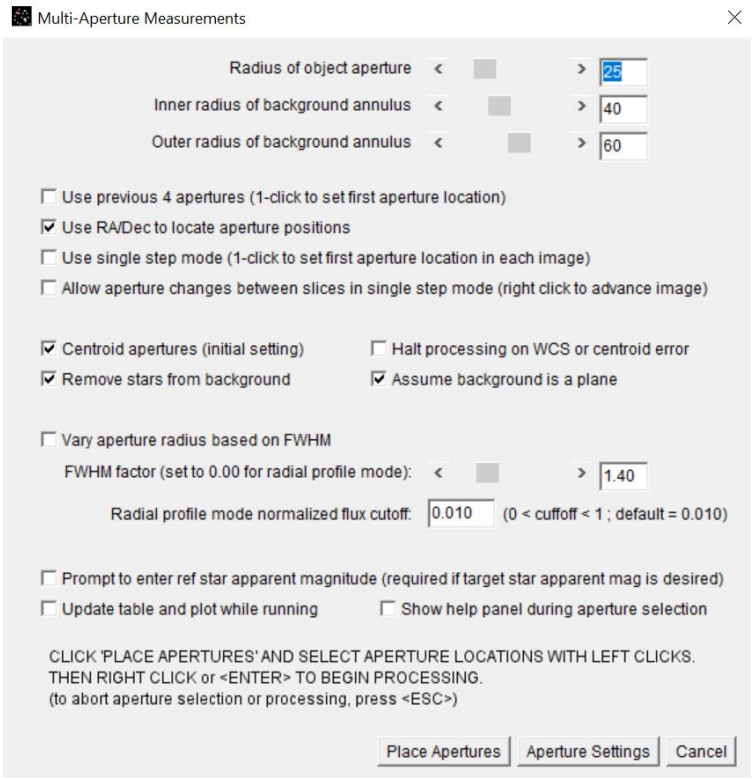
Select any image, indicate the total number of images processed and click OK. Your image opens and we will now move on to studying your exoplanet.

• Identification of our target star
Before taking the photometric measurement, you need to know the location of your exoplanet. To find out, enter the name of your exoplanet on a browser and find its RA and DEC.
Then go to the site https://aladin.u-strasbg.fr/AladinLite/ and enter the coordinates. It will give you a picture of the location of your exoplanet. Compare with your photo on AstroImageJ to find it. Once you know where it is, we can start the next step.

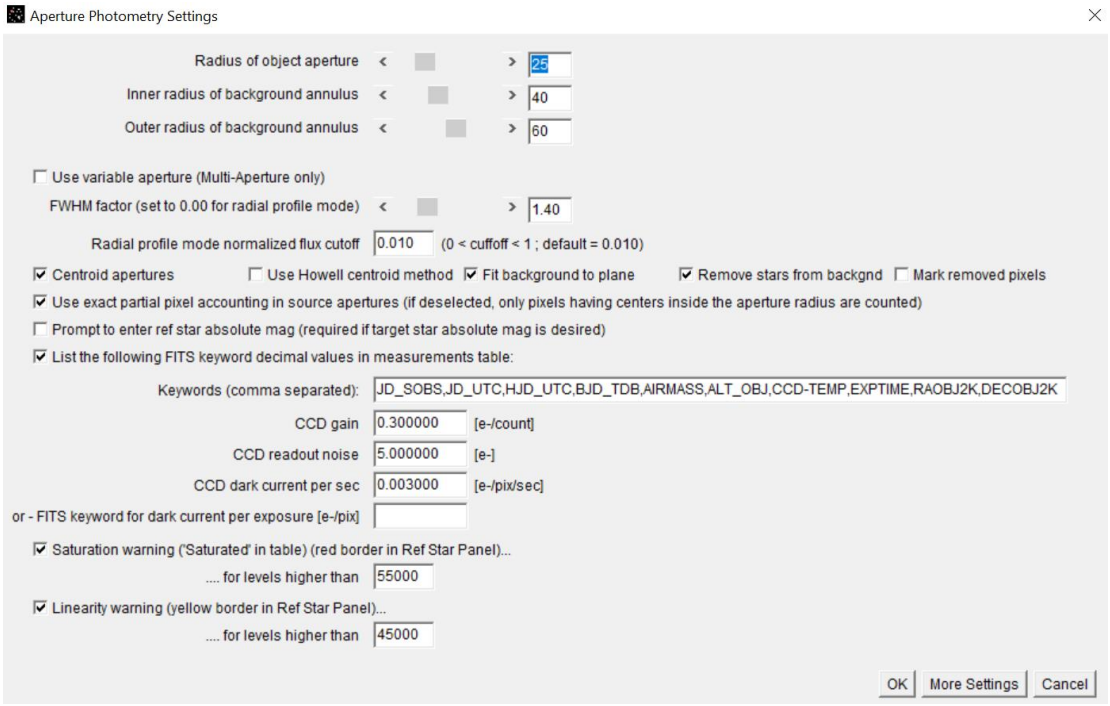
IV/ Multi-aperture photometry

Go back to your window with your image and select the "perform multi-aperture photometry" box (both red and blue circles)

This window is displayed. You must uncheck and check the boxes as indicated otherwise you will not get results.

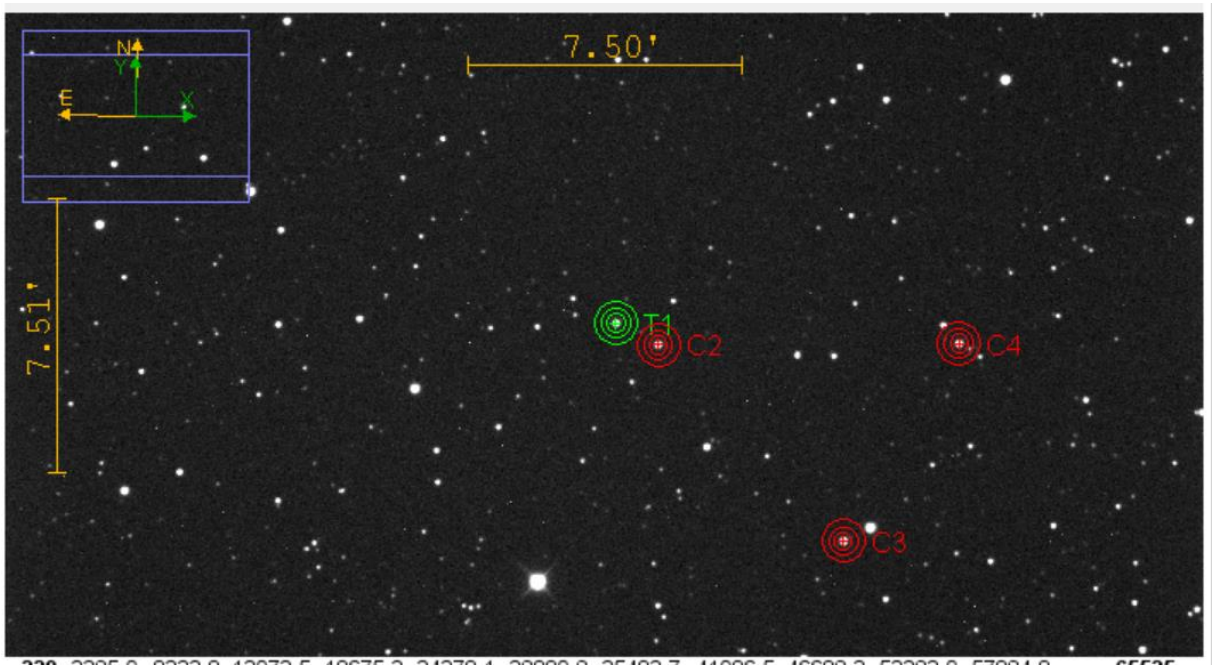


Once everything has been followed, click on "Aperture Settings". This window will appear and you should have the same settings. For the CCD part, it depends on the camera so by default, if you don't know them, enter those ones.



Click on OK then "Place Apertures". You will first take as T1 (for Target) the star around your exoplanet. Then, you have to take several targets to refine the calculations. It is important to take close targets.

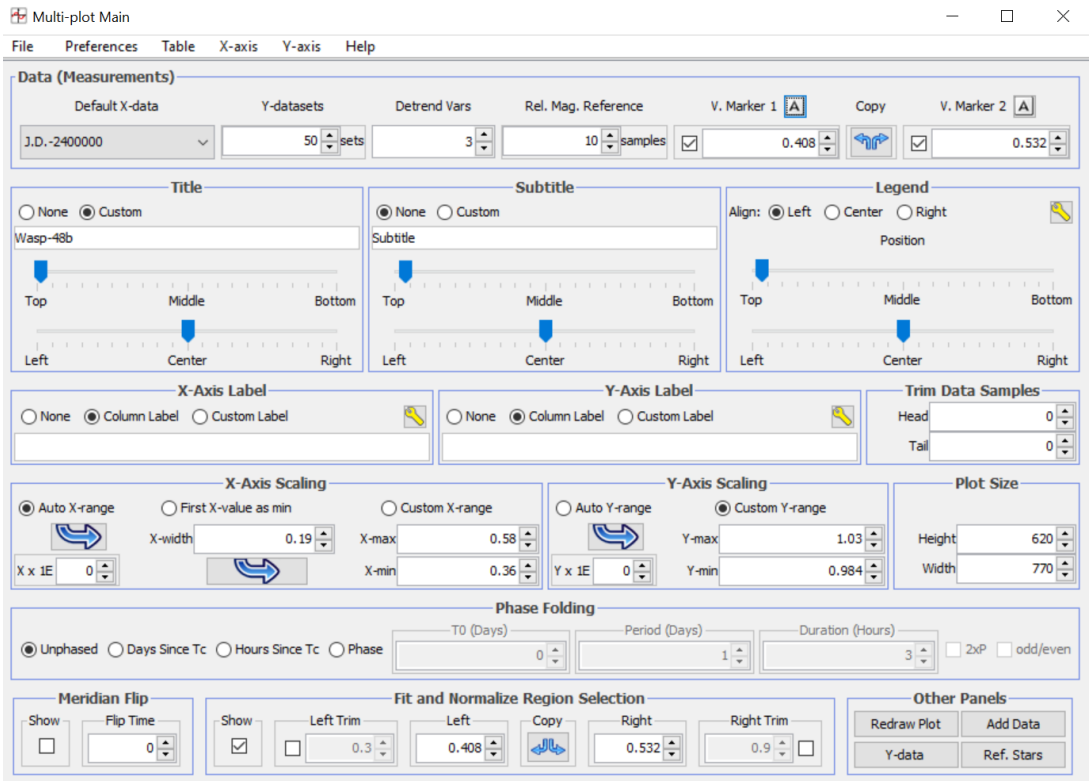
For this, it is necessary to choose stars which have a similar magnitude and characteristics. Look closely at the "Peak" and "Int Cnts" that appear when you hover your mouse over a star. They should be fairly close to the values of your T1.



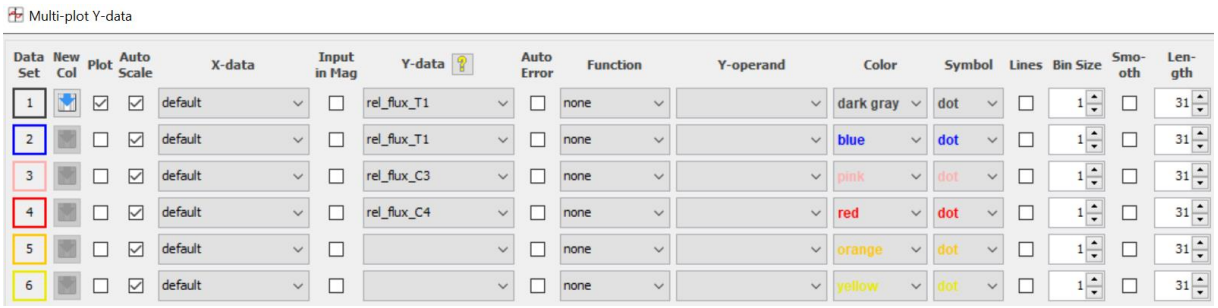
For example, you will get this. Once the choice of targets is complete (no need to take more than five), click on "Enter" on your computer and the analysis will begin.

V/ Obtaining the light curve

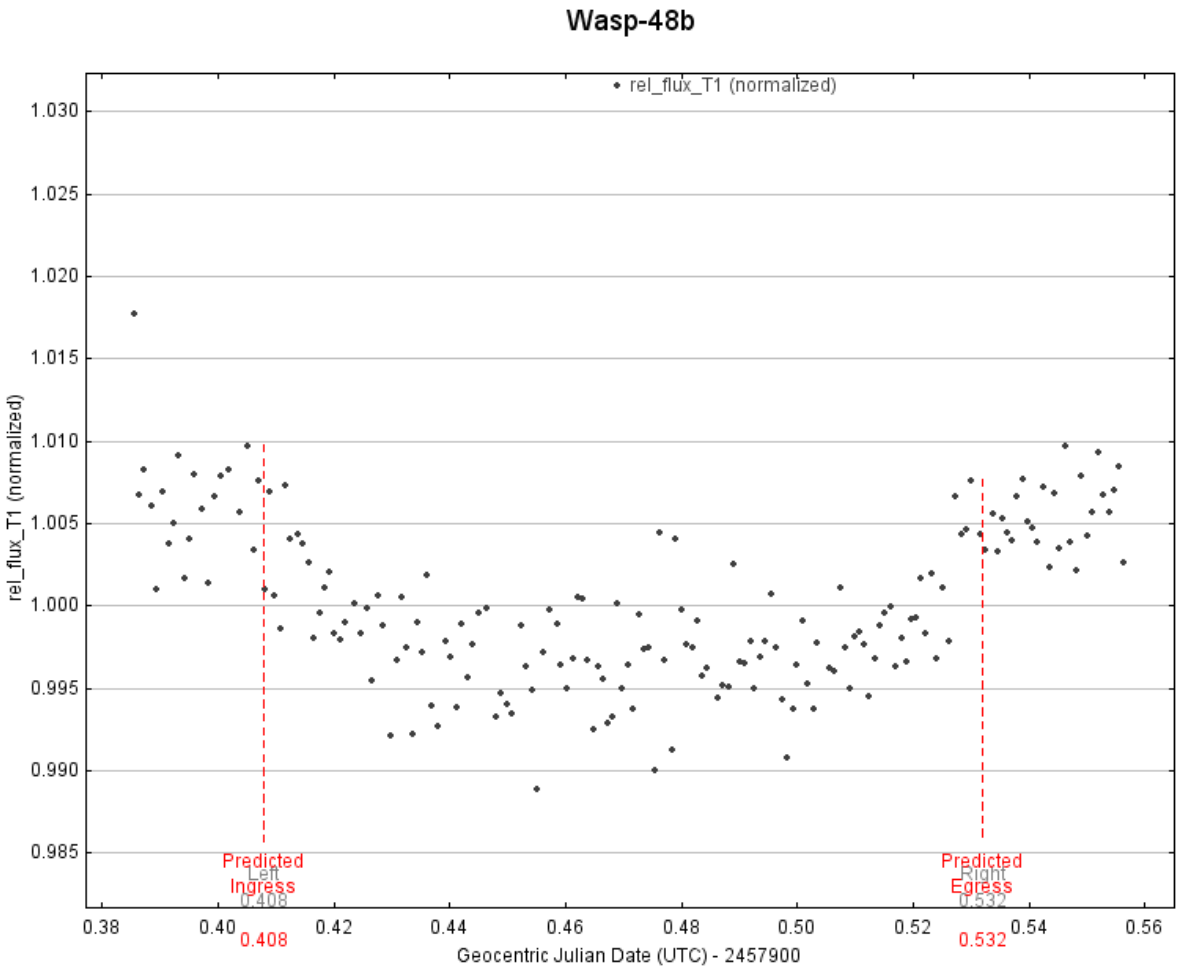
The scan ends and many windows open. The window below interests us because it allows us to configure the graph. We can determine the X-range and Y-range, give a title and especially fit and normalize region selection. This information will show the precise times when the transit starts and ends.



For the "Multi plot Y-data" window, this is used to plot the graphs. What interests us is Target 1 because it is our study star. In the Y-data column, select rel_flux_T1. Then check the Plot box and you will get your first graph.



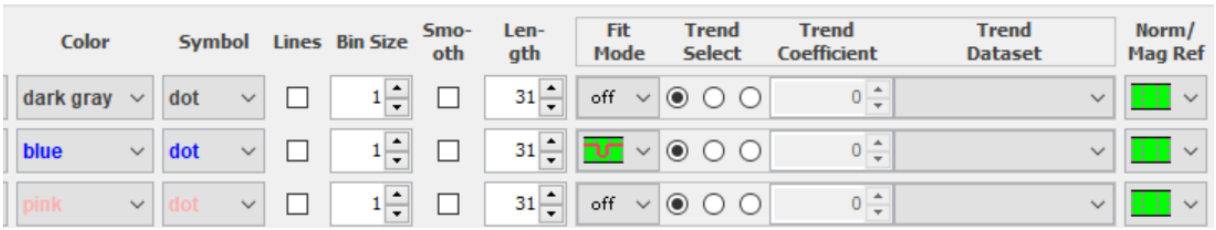
Here's what you can get. The study does not end here though. Indeed, here you have obtained a normalized scatter plot of the values of the target star. This is not the end result.



• Exoplanet transit light curve

We must therefore return to the Multi plot Y-data window and slide to the right of the window to obtain the parameters that interest us. Head to the Fit Mode column. You can observe that for the first line, corresponding to our normalized light curve, it is selected on "off".

For the second line we will select another fit mode, corresponding to the transit and more suited to the light curve. So choose the one you see in the screenshot.



A new window will appear. Take time to observe that the parameters are present (circled in green). If you have aligned your images with the World Coordinate System, all boxes are filled in automatically.

You just have to go down to the Plot Settings section. Uncheck the Residuals and check the boxes as on the screen (Show Model and Show in legend). This will allow you to achieve the smoothed transit light curve you want.

Go back to the first columns and return to Y-data. For the second line, select rel_flux_T1 as for the first line, then check the Plot box.

If all the steps have been followed, you will then have the same thing as on the second line.

You can now admire your light curve corresponding to the transit of your exoplanet around the target star. Congratulations, you have succeeded!