AstroImageJ Tutorial -- Relative and Absolute photometry

The optical lightcurve of MT Cas

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For this tutorial you should have access to the following:

- This document!
- Access to a computer with access to `carina`.
- The internet. Lots of internet! The web is the best source of information if you know how to filter out the "bad stuff"
- `AstroImageJ` and `ds9` software installed. `Topcat` might also be useful.
- Your favourite data analysis software installed. This could be `MATLAB`, `Python`, or if you really can't get creative `Excel`.
- Bookkeeping skills!
- The data!

Pick a dataset. For this tutorial we will generate a lightcurve of MT Cas taken on the night of 20 November 2022 using the West 14 telescope. Find the file names/numbers in the observing logs webpages.

In this case the directory where the data is stored is :
`/mnt/archive/west-14/2022/22_11_20/`

In what follows, ensure you understand the individual steps before moving to the next one. It is really important that you keep track of what files are in which directory, or you will reach a point where everything will be mixed up and confusing. Stay organised. Save your data at the end.

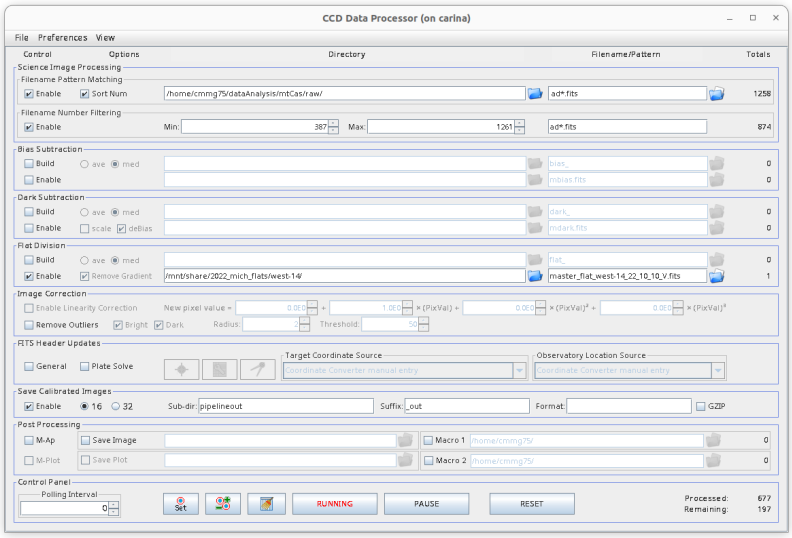
The files with an "`ad`" in front of the image number have been debiased and have their astrometry information in the fits header. If you don't know what any of this means, ask Google, and if all else fails, your demonstrator. We will perform relative photometry on images starting from ad0387.fits to ad1261.fits. But first we will have to flat field each image using the master flat master_flat_west-14_22_10_10_V.fits found in
`/mnt/share/2022_mich_flats/west-14/`

1. Open `AstroImageJ`

2. Make a directory and copy the relevant night from the archive into it. Remember: bookkeeping! Give the directory a sensible name.

3. In the main `AstroImageJ` window, click on the "CCD Data Processor" icon. Familiarise yourself with the new panel that just popped-up.

4. We will now flat-field all of the images using this panel. See the attached screenshot for the settings you need. Make sure you know what is happening, if not ask! `AstroImageJ` will flat-field the individual images, and finally save them in a subdirectory called `pipelineout`.



5. Load the flat-fielded images into `AstroImageJ` by choosing **File > Import > Image Sequence**. Select the folder containing the images in the newly created `pipelineout` directory. Make sure you select “Virtual Stack”, or bad things may happen to the computer!

6. After doing this all the images should be loaded into the `AstroImageJ` stack. You can inspect the individual ones by using the scrollbar on the bottom. Play around and get familiar with the images (try zooming in/out, inspect sources, play with contrast).

7. Next we need to correct for the frame-to-frame motion of the stars. Load a new image stack from the `pipelineout` directory, and go to **Process > Align stack using apertures or WCS**. A new “Stack Aligner” window should open. Enter the values you found before for the radius of the object and inner/outer background annuli. Untick everything else except “Use only WCS headers for alignment (no apertures required)”, and “Show help panel during aperture selection”, just in case. Press “Ok”

8. A new set of images should have been created in a subdirectory called `aligned`. Close all `AstroImageJ` windows and open this image stack.

9. We now need to inspect the seeing profile. Locate a relatively isolated bright star (but not saturated[1]). Next zoom in until you can only see your star and choose **Analyze > Plot seeing profile**. A new plot should appear giving the radial brightness profile of the selected star. Marked on the plot are also the source and background radii. Note these 3 numbers down somewhere: the source radius and the background annuli.

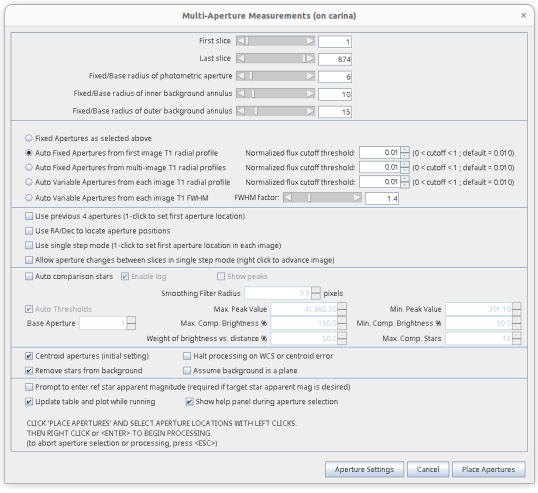
[1] Saturated? What’s this?

Repeat this step on other stars to make sure you get similar numbers. Once happy, move on to the next step.

10. We are now nearly ready to perform relative photometry, but which one is our target? We are interested in making a lightcurve for MT Cas. To find out which one it is we could launch `ds9`. Once launched go to **Analysis > Image Servers > DSS (SAO)**. A new window will open asking for coordinates. Use SIMBAD on the internet to find the correct coordinates for MT Cas. Press “Retrive” after that. An archival image will open up in `ds9`, centred on our target of interest. Use the zoom in/out function to look around the image, and compare it to the one open in `AstroImageJ`. Can you locate the target? If not, ask around!

11. Identify some relatively bright stars close to the target that will be used as calibrators (3-4 should do). Once identified, you need to note down their magnitudes in the same (or similar) pass-band as the images. In this case, all images have been taken in the V-band. In ds9, load the Guide Star Catalog 2.3. Do this by going to **Analysis > Catalogs > Optical > GSC 2.3** Note down the magnitudes of your calibrator stars for later, and remember which ones they are (i.e. locate them in the AstroImageJ stack). Also ensure that the calibrators and target are clearly visible in all individual images in the `AstroImageJ` stack. You should at least check the first and last image in the stack. If not visible, you can delete the image(s) in the stack where the calibrator and/or target are missing from the aligned directory, or choose different calibrators. Note: To select targets using the Mouse Cursor, go to the "Edit" menu in ds9, choose the "Catalog" cursor type. Clicking on a source in the ds9 display highlights the corresponding row in the Catalog Tool. Multiple sources may be selected by holding down the SHIFT key while clicking them.

12. We are ready to perform relative aperture photometry. In the image window find the “perform multi-aperture photometry” button and press it. You will be prompted with a new window, where you have to set the usual object aperture radius as well as the inner/outer background annuli. Here is a screenshot of example settings:



Make sure you understand and are familiar with those settings, then press “Place Apertures”.

13. Now we need to first select our target on the first image. After that select the calibrator stars you identified in step 11. These will be our comparison stars and used to perform the relative photometry, as well as calibrate the absolute photometry (if you noted down the magnitudes from the catalogue). Once finished selecting the comparison stars press “Enter”.

14. Let `AstroImageJ` do its magic. It will go through all images and extract the source counts, as well as background counts based on the aperture radii defined by you. You should see the lightcurve being generated in real time, as well as a Measurements table being created. If this crashes at some point, read the error message and try to figure out where the problem arises from. If you tried and are still stuck, ask around.

15. Once completed, find the “Multi-plot Reference Star Settings” panel. Click on “Show Magnitudes” and enter the relevant values for the calibrator stars that you noted down in step 11 and press “Enter”. If one oh the Reference Star Selection is not green, then you may be better off unticking that star (but why?).

16. Find the “Measurements” window with the tabular data. Select **File > Save As** and save the table.

17. Well done! ! You have now produced your own calibrated lightcurve of MT Cas. Now look at the lightcurve and try to figure out what it is we are looking at (note that the units plotted in `AstroImageJ` are normalised!!). Make sure you use the web to do some research. Can you guesstimate, by eye, a periodicity in this lightcurve? Find out why this object varies the way it does. Ask around and discuss. You should also