



FAULKES TELESCOPE

# Photometry of star clusters with SalsaJ

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Life Cycle of Stars

# Photometry of star clusters with SalsaJ

## Introduction

Photometry is the measurement of the intensity or brightness of an astronomical object, such as a star or galaxy by adding up all of the light from the object. For example, a star looks like a point of light when you look at it just with your eyes but the Earth's atmosphere smears it out into something that looks like a round blob when you use a telescope to look at it. In order to measure the total light coming from the star, we must add up all of the light from the smeared out star.



Photometry is generally used to generate light curves of objects such as variable stars and supernovae, where the interest is the variation of total light energy output by the system over time.

It can also be used to discover exoplanets, by measuring the intensity of a star's light over a period of time. Deviations in the light output can indicate objects in orbit around the star.

These instructions explain how photometry can be carried out on groups, or clusters of stars, from images taken with different filters, in order to plot a colour magnitude diagram. An explanation on

magnitudes can be found at the end of this document in Appendix 1.

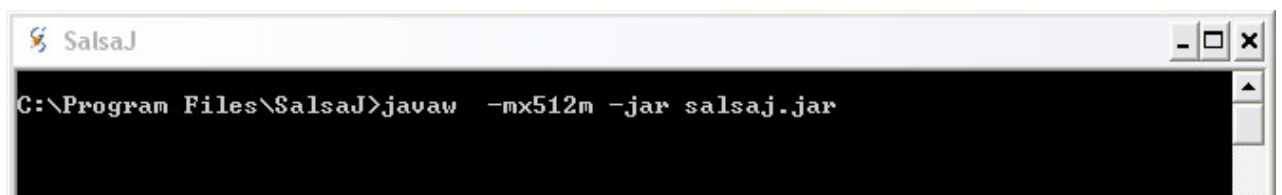
## Loading Images

- First, launch SalsaJ

When the program opens, you will see two windows appear. The first is the Menu bar which contains many options and shortcuts that you can use.

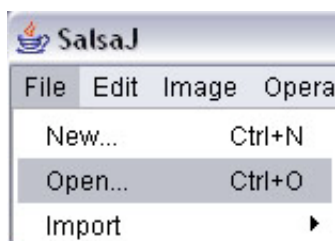


The second is a Window Command window. You do not have to do anything with this window but do not close it, if you do SalsaJ will close and you will lose all your unsaved work.



- Next, load your images. When carrying out photometry on images in two wavebands (e.g. B and V), it is best to open both images at the same time. This ensures that you select the same stars for photometry in each image later on.

Go to **File>Open**



Browse to the folder you have saved your images in, select the image and click open.

- Your image will now load into SalsaJ but it will be very dark. Make the image more visible by adjusting the brightness.



Click on the Brightness & Contrast button in the menu).

Adjust the sliders in the window that appears, or press the **Auto** button to scale the image automatically. Pressing the Auto button several times will toggle through different presets.

- Open your second image file following the steps above. You should now have your two FITS files open in SalsaJ.

## Photometry

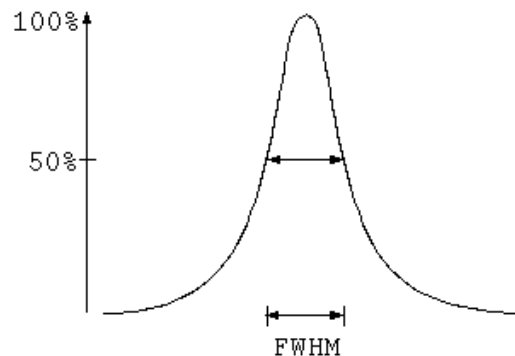
Before we can start the photometry, we have to work out our analysis radius - this defines the radius of the circle that is used to count the pixel values in the image. The radius of the circle is very important - if the radius is too small, it will not count all the light coming from the star and if it is too big, it may count too much background sky or other stars in the image. Therefore you may not get accurate measurements.

SalsaJ automatically sets the radius as the Full Width Half Maximum (FWHM) of the stars in the image.

## FWHM

The FWHM is used to describe the width of an object in the image. Stars in astronomical images have a specific profile when plotted as a graph of pixel values and that profile should be the same for each star in the image.

FWHM is displayed graphically like this:



In order to do photometry with FT images, we recommend you work out your own star radius in order to get more accurate results.

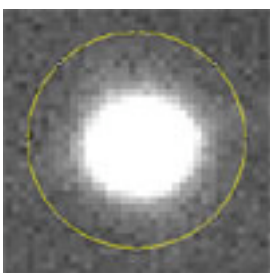
To do this you must conduct a simple experiment, collect data and plot a graph - using Microsoft Excel (or another spreadsheet package that can plot graphs) makes this exercise much easier and quicker.

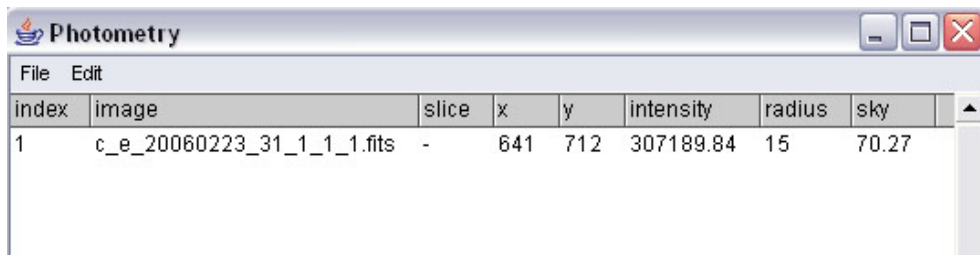
The idea is to test several different aperture radii and compare the intensity values you get for each radius by plotting a graph of radius against intensity.

To do this, go back to SalsaJ, then to **Analyse>Photometry Settings**. At the bottom of the new window, change the **Star Radius** to **6**.

Next, go to **Analyse>Photometry** and another empty window will then appear.

Using the mouse, click on a star in your image (you only need to do this for one of your wavebands). You will see a circle appear and in the new window a data entry is added.





| index | image                      | slice | x   | y   | intensity | radius | sky   |
|-------|----------------------------|-------|-----|-----|-----------|--------|-------|
| 1     | c_e_20060223_31_1_1_1.fits | -     | 641 | 712 | 307189.84 | 15     | 70.27 |

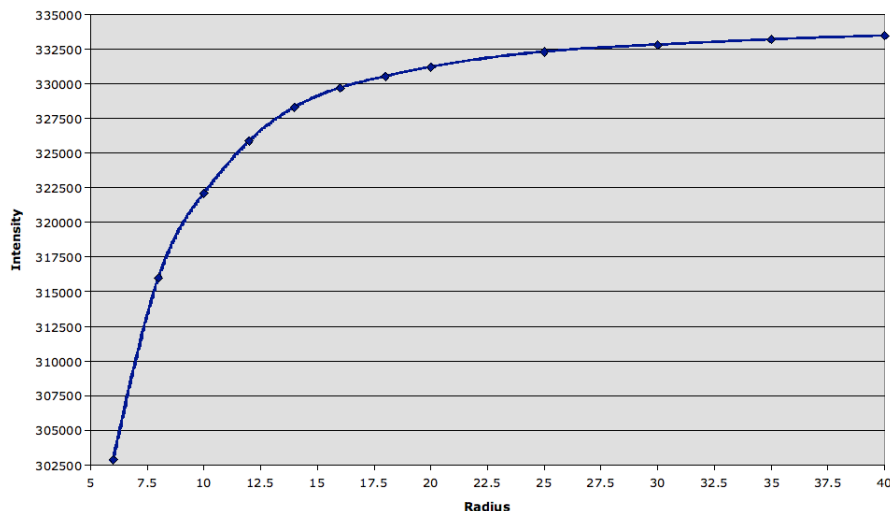
The intensity of the object is calculated by adding up all the pixel values within the radius of the aperture.

In Excel (or other package) create two columns for **Radius** and **Intensity** then, add radius 6 and the intensity value from SalsaJ.

Now increase the radius in SalsaJ by 2 and measure the intensity of the same star again. Add the new data to your spreadsheet. Repeat this until you reach a radius of 20, then start increasing the radius by 5 each time until you reach 40. You should have a set of results that looks like this:

| Radius | Intensity |
|--------|-----------|
| 6      | 302877.6  |
| 8      | 315993.42 |
| 10     | 322090.67 |
| 12     | 325863.39 |
| 14     | 328294.36 |
| 16     | 329688.48 |
| 18     | 330517.92 |
| 20     | 331191.98 |
| 25     | 332291.85 |
| 30     | 332795.54 |
| 35     | 333179.15 |
| 40     | 333457.04 |

When you plot a graph of this data, you should get something that looks like this:



You can see the rapid rise of intensity as the radius of the aperture increases. This is because more of the star is included in the increasing radii of the apertures. The graph begins to flatten out when we have all of the star in the aperture, but keeps rising gradually as more and more of the background sky is included.

From this graph, we can see that the best radius to use is about 15 - this is around the point where most of the star's intensity is included in the aperture, but minimises the amount of background sky in there.

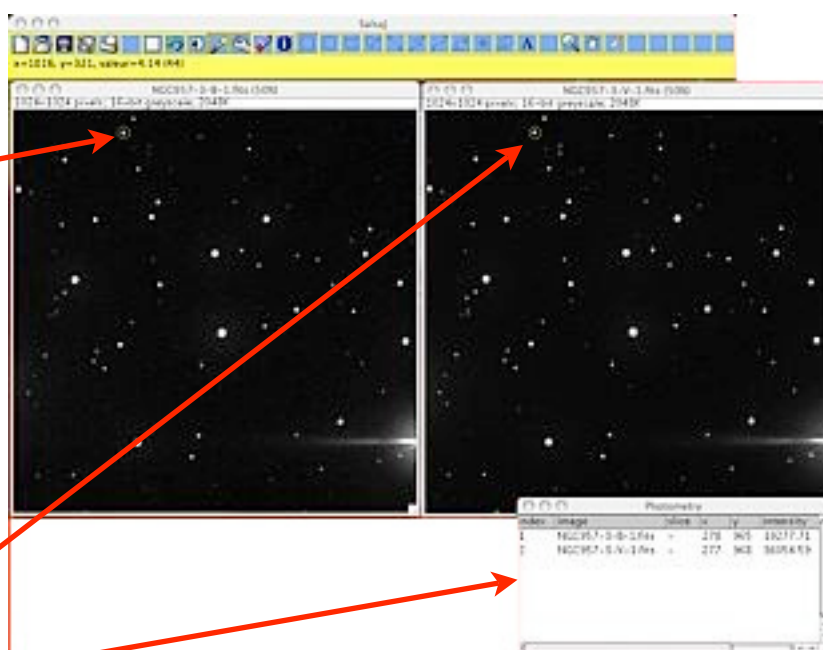
Once you have chosen the best aperture radius, this can be set for the remainder of your photometry analysis on this image. It is advisable to carry out this exercise every time you come to work with a new set of images as the FWHM of objects change due to the seeing conditions at the time of observation so new aperture radii will need to be calculated for new images. However, if you are carrying out photometry on the same star cluster, but in two different wavelengths (such as B and V), then you should use the same radius for both images to ensure that you are comparing 'like with like'.

The easiest way to carry out photometry on 2 datasets is to arrange the images in Salsa J so that they are side by side.

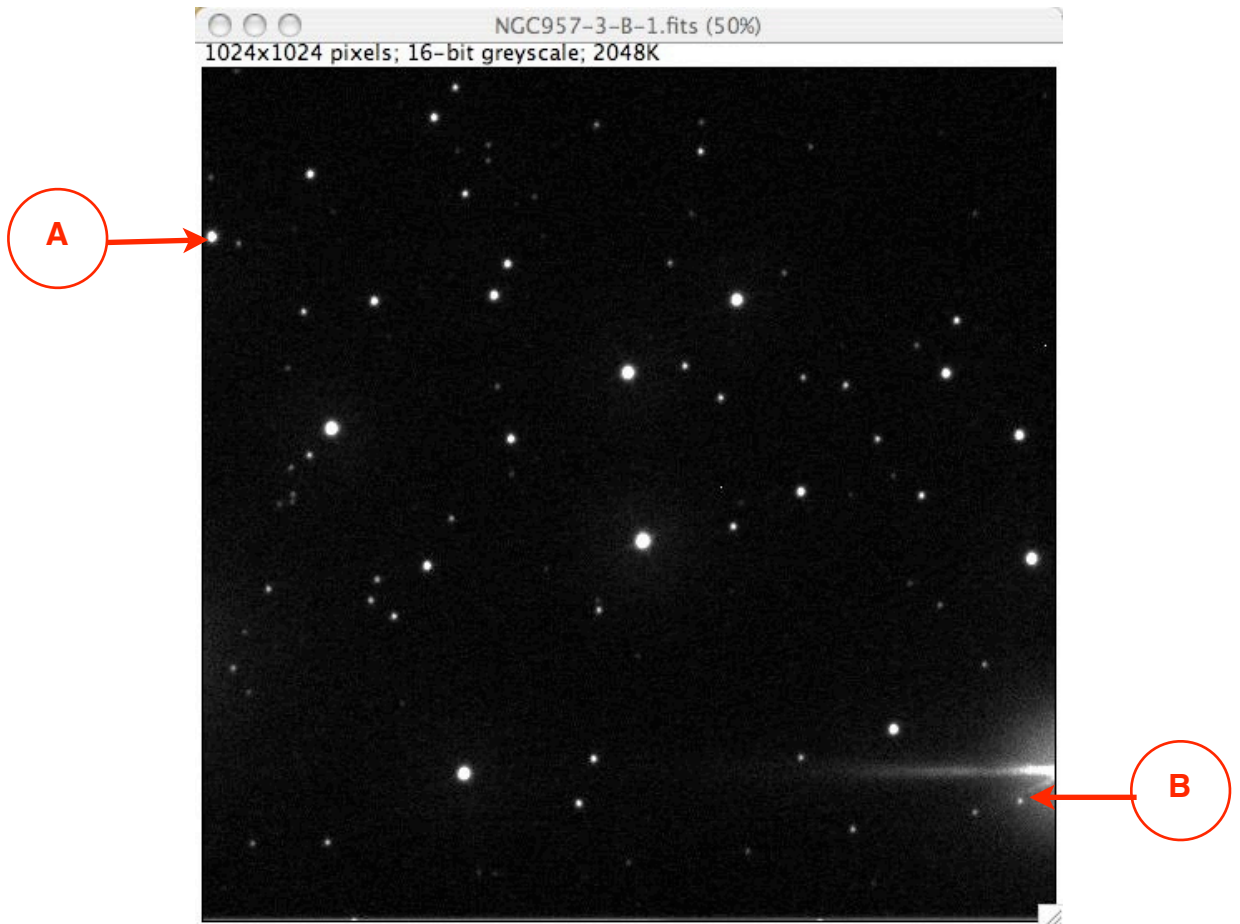
Begin in the top left-hand corner of your first image - here we have selected the star in the B band image.

Click on the star so that its intensity and position values appear in the pop-up 'Photometry box'.

Next, click on the **same star but in your second image** (here the V band image). The values for this star will now appear in the 'Photometry' window.



Repeat this method for all the visible stars in the image. You should however avoid selecting stars who are on the edge of the image (since the aperture will go off the edge of the image - Star A below) and those who are in a bright halo (Star B below). The more stars you include in your analysis, the better.



### **Analysis of results**

Once you have a list of intensity values for each star in the cluster from SalsaJ, you can plot the colour magnitude diagram of the cluster either by hand or by using a spreadsheet package such as Excel. For best results, up to 40-50 stars should be analysed, so plotting the graph by hand could be rather time-consuming.

#### **Plotting a Colour-Magnitude diagram by hand:**

If you are plotting the graph by hand, firstly copy the contents of the 'Photometry' pop-up window into a table with the following columns.

| <b>Star</b> | <b>B intensity</b> | <b>V intensity</b> | <b>B magnitude</b> | <b>V magnitude</b> | <b>B-V</b> |
|-------------|--------------------|--------------------|--------------------|--------------------|------------|
| 1           |                    |                    |                    |                    |            |
| 2           |                    |                    |                    |                    |            |
| 3           |                    |                    |                    |                    |            |

The B intensity and V intensity columns contain the intensity values as measured by SalsaJ, and as obtained from the Photometry pop-up window in SalsaJ. The B and V magnitudes can be calculated in the following way:

$$\text{B magnitude} = -2.5 \cdot \log(\text{B intensity/exposure time})$$

$$\text{V magnitude} = -2.5 \cdot \log(\text{V intensity/exposure time})$$

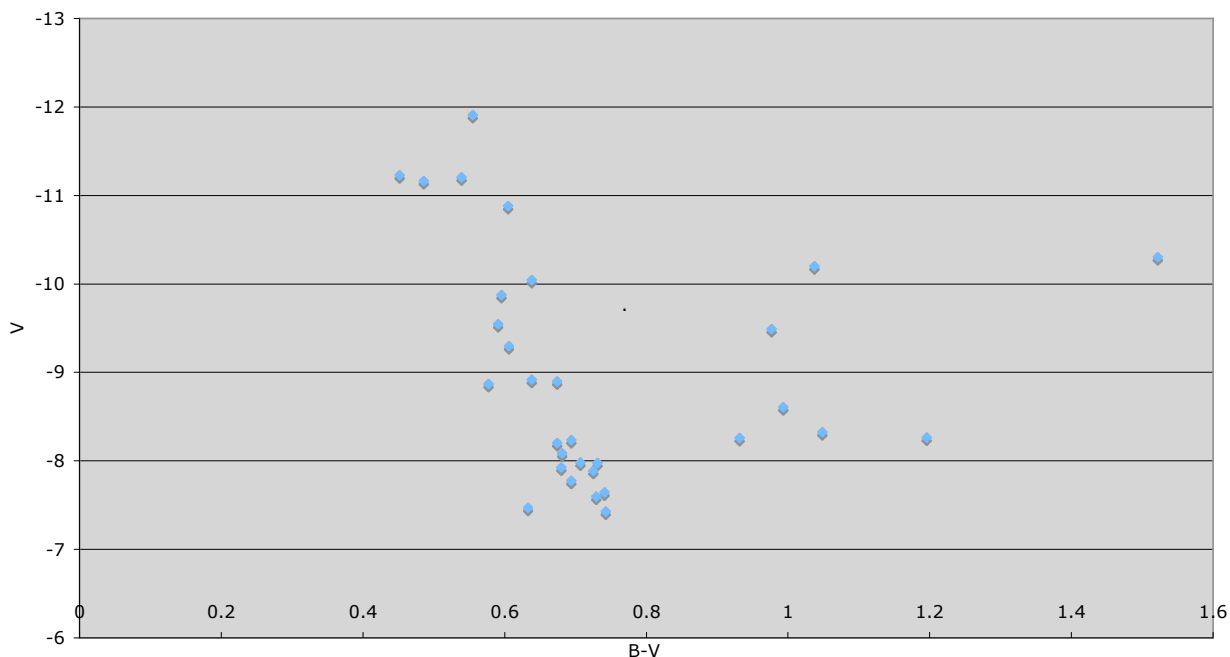
So, for example, the B magnitude of a star of intensity 8128.59, measured with SalsaJ from a 10s exposure FITS file would be:

$$\begin{aligned} \text{B magnitude} &= -2.5 \cdot \log(8128.59/10) \\ &= -2.5 \cdot \log(812.859) \\ &= -7.275 \end{aligned}$$

The final column in the table, 'B-V' should then contain the results of subtracting the V magnitudes from the B magnitude values. This value (B-V) effectively gives the colour of the star. The higher the B-V value, the redder a star. The lower the B-V value, the bluer the star.

Now plot a graph of V vs. B-V with V on the y axis and B-V on the x axis. Reverse the y axis so that the brighter objects are towards the top of the graph, as shown below (the lower the V magnitude value, the brighter the star).

Colour magnitude diagram for open cluster NGC 957





## Appendix 1: Magnitudes

The magnitude of an astronomical object is simply a measure of its brightness as seen on Earth. By measuring the intensity of light reaching the Earth from the object, a value for its magnitude can be determined. This value is known as the object's apparent magnitude and is given by the letter 'm'.

When you measure the apparent magnitude of an object from observations taken with a telescope and CCD camera (or photographic plate), this is known as an '*instrumental magnitude*'. It's the most basic value for the magnitude that you can measure and it can't be compared to other people's measurements of magnitudes since, as the name suggests, this type of magnitude value depends upon the instruments that have been used to measure it e.g. the telescope, CCD camera, filters etc.

In order to be able to compare your magnitude values with other people's you need to calibrate your results so that you are comparing like with like. You can do this by observing your object **and** a standard star. Standard stars are stars which have had their magnitudes in different filters, measured very carefully by astronomers. By comparing the magnitude of your object with the magnitude of a standard star that you have observed, and knowing its real magnitude, you can calculate the '*calibrated magnitude*' of your object. Comparisons of different people's data with calibrated magnitudes is then perfectly valid because you are definitely comparing like with like.

In this activity you have not been asked to observe a standard star, so the magnitudes you are calculating are **not** calibrated magnitudes - they are instrumental magnitudes. This does not affect the shape of your CMD however - the only difference that you would see if you were using calibrated magnitudes is that the points on the plot would all be shifted by the same amount in the same direction.