



## Photometry with Makali'i

*How to perform photometry using the free image processing software, Makali'i*

Makali'i is an image processing software which is used to analyse FITS file images. These are the files that are produced by the Faulkes Telescopes and which you will be using in your investigation.

**Step 1:** First, open the Makali'i software programme. Go to **Open**, and select all your FITS files of the observations from the Faulkes Telescopes you wish to analyse.

If you do not already have it on your computer, you can download it from the link below:

<https://makalii.mtk.nao.ac.jp/>

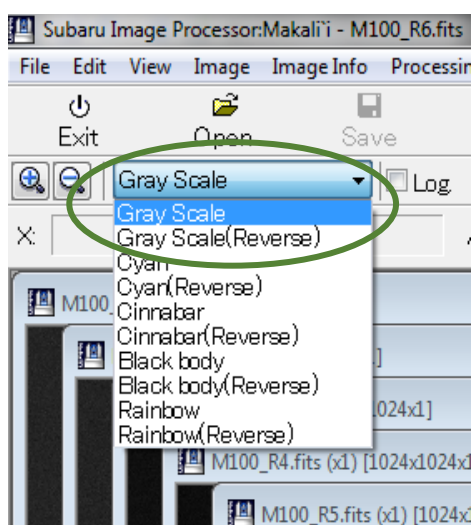
### Viewing your Images

We want to make the images clearer so the objects stand out and are more easily resolved.

**Step 2:** Go to where it says **Gray Scale** at the top left of the page and click on the black arrow. This is circled in green in Figure 1. A drop down menu will appear, select **Gray Scale (Reverse)**.

This is commonly used by astronomers as it inverts the image and shows individual objects more clearly, with a greater contrast to the background.

**Figure 1 – Selecting the reverse gray scale on Makali'i.**



<https://gaia.ac.uk/alerts>

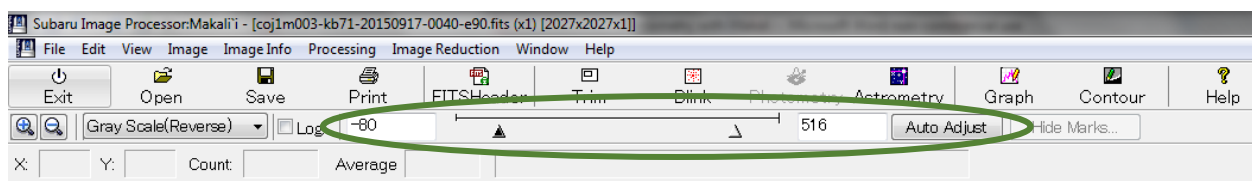


As telescopes use mirrors, the image is the reverse of how it actually appears. Therefore if the image was not automatically flipped, your image may appear upside-down compared with your finder chart.

**Step 3:** To flip your image, go to **Image** → **Flip Vertically**.

If you don't think your image is clear enough you can adjust its brightness and contrast. If you need to do this, you can adjust the sliders shown in Figure 2 or click on the **Auto Adjust** option for the software to adjust the image automatically for you.

**Figure 2 – Adjusting the brightness and contrast of images on Makali'i.**



## Selecting your Comparison stars

If you are performing photometry on multiple images in order to see how the magnitude of an object changes over time, any variability that is measured must be analysed. This is so that we can be sure we are measuring “**true variability**” and not variations caused by other factors.

Even for a star with a constant magnitude, the number of photons that fall onto the pixels within a CCD will vary across images. As a result the counts that are read also vary and the star would appear to change in magnitude.

There are a number of environmental factors that influence the counts of a star. To account for these variations we use **comparison stars**.

**Note:** See worksheet ‘Photometry in Astronomy’ for more information.

Comparison stars are stars that have been measured to establish that they are reliable, non-variable stars. Comparison stars appear in the same field of view as your target object and therefore will be affected in the same way by additional influences unrelated to the stars themselves (see “Photometry in Astronomy” worksheet).

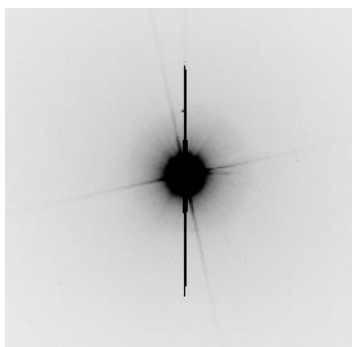
Once you have determined that the comparison stars are not variable stars (See photometry worksheets), and variations that they display can be attributed to environmental factors/seeing effects and their magnitude can be subtracted from the magnitude of your target object. This allows you to obtain the **differential magnitude** of your target and determine its **true variability**.

**Step 5:** Select **3 or 4 stars** to be comparison stars in your image. They should be roughly the **same brightness** as your target object and should not be saturated or close to the edge of the image.



A saturated star will appear similar to Figure 3. There is a limit to how many electrons each pixel can store, so for an exceptionally bright star or a long exposure, the pixel will reach its capacity and additional electrons will have to spread into the surrounding pixels. This is when the CCD becomes saturated and the resulting image will appear similar to Figure 3. When this happens, we are unable to get a reliable measure of how bright the star really is.

Figure 3 – A saturated image of a star.



You will need to use the same comparison stars when measuring all your observations so you may want to check your chosen comparison stars are visible across all your images.

Note: We select 3 or 4 stars as we do not know if they are variable stars (varying magnitude) non-variable stars (constant magnitude), this is in the hope that at least two of them will be non-variable stars.

Refer to your **Finder Chart**. Of your chosen comparison stars, you will need to select **just one** to carry out the remaining steps of this worksheet. You only need to use one star in **one image** as all of your comparison stars should be of similar size and brightness.

### Setting your Aperture Radius

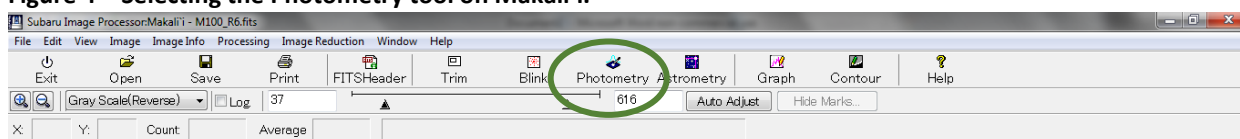
Before we can begin to take measurements of objects in the image, we must first find the most appropriate **aperture radius**.

This describes the **radius** of a circle that surrounds an area on an image in which the **pixel values are counted**.

Note: See **Photometry in Astronomy** for further explanation.

**Step 6:** Go to **Photometry** on the toolbar at the top of the screen, as shown in Figure 4. Then select **Aperture**.

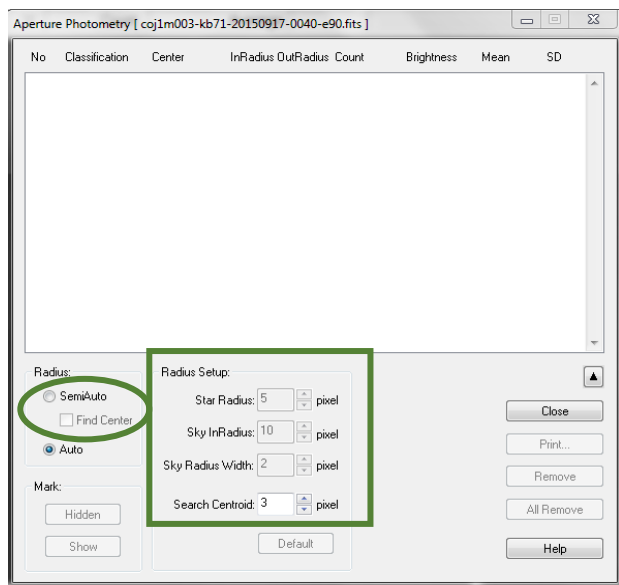
Figure 4 – Selecting the Photometry tool on Makali'i.





An Aperture Photometry box will pop up as seen in Figure 5.

**Figure 5 – Aperture photometry on Makali’i.**



Here you will notice that Radius is already set to Auto. We do not want to use the Auto settings as this will change the aperture radius for each star that is measured, thus not allowing for like-for-like measurements to be performed.

**Step 7:** Instead, under Radius, select the **SemiAuto** option and **Find Center**. You will notice you are now able to adjust the parameters under **Radius Setup**. (See Figure 5).

Select the following options:

- Sky InRadius: 20 pixels**
- Sky Radius Width: 5 pixels**

**Note:** You cannot have a Star Radius that is a larger value than the Sky InRadius, you will therefore need to set the Sky InRadius first.

These parameters measure the background light in the image within the radius that is set. These values are then subtracted from the light from the object you are measuring in order to determine its brightness.

The most important parameter is the **Star Radius**, as this determines the radius within which the counts of the star is measured.

In order to decide on the most appropriate radius and obtain the most accurate results, you will experiment with using different sizes. To do this you will make measurements and record the counts values for each set radius for you to compare. You will only need to use **one of your images** to do this.

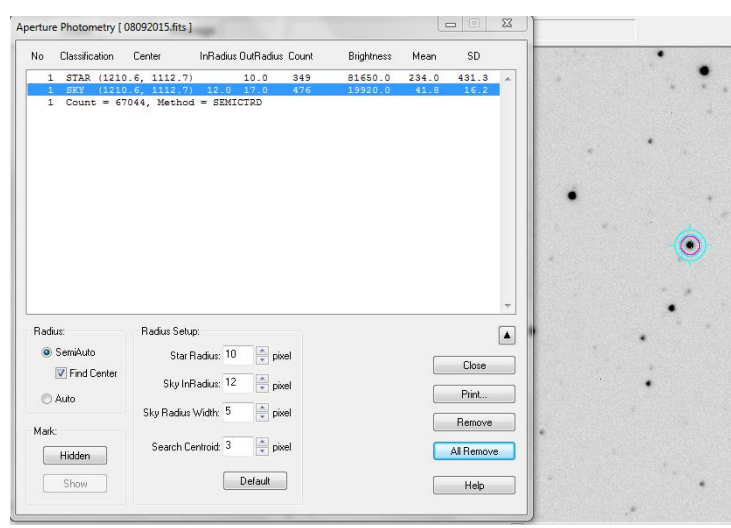
**Step 8:** Begin by selecting a **Star Radius of 2**.

**Step 9:** Click on the centre of one of your comparison stars in the image.



You will see three circles appear on the image and an entry will appear in the Aperture Photometry box as seen in Figure 6.

**Figure 6 – Aperture photometry results on Makali’i.**



**Step 10:** Repeat Steps 8 and 9, **increasing the Star Radius by 2 until you reach 18.** Be sure to always use the **same comparison star** with each measurement.

**Note:** You cannot select a star radius that is larger than the Sky InRadius, therefore you will need to make sure you set the Sky InRadius first.

When you have done this you should have 9 lines of results in your Photometry box.

**Step 11:** When you have done this select **Print** in the Aperture Photometry box and save your data under an appropriate name. This will save the data as a **CSV file** that is compatible with Microsoft Excel and other spreadsheet programmes (See Appendix 1).

### Interpreting your Data

**Step 12:** Now open your saved file into an **Excel Spreadsheet** (or similar software).

The data you will need is under **Obj Radius** and **Result Count** (columns D and Q as shown in the blue squares in Figure 7). The Result Count represents how much light fell onto the pixels within the given aperture radius (star radius), minus the background sky light.

**Figure 7 – Aperture photometry measurements made with Makali’i presented in a Microsoft Excel spreadsheet.**

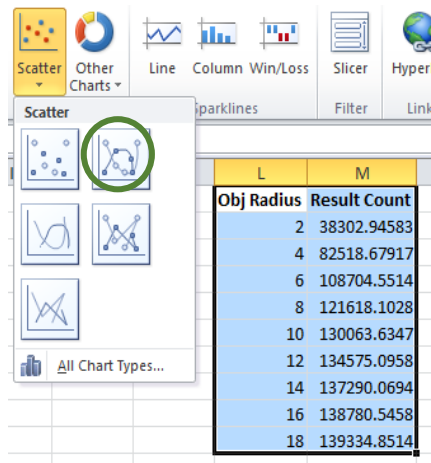
	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1	Number	Obj X	Obj Y	Obj Radius	Obj Pix	Obj Count	Obj Mean	Obj SD	Sky X	Sky Y	Sky InRadius	Sky Width	Sky Pix	Sky Count	Sky Mean	Sky SD	Result Count	Radius
2	1	1170	1081	2	21	40617	1934.143	258.5964	1170	1081	20	5	720	79339	110.1931	22.28291	38302.94583	SEMI
3	2	1170	1081	4	69	90122	1306.116	480.091	1170	1081	20	5	720	79339	110.1931	22.28291	82518.67917	SEMI
4	3	1170	1081	6	137	123801	903.6569	534.5209	1170	1081	20	5	720	79339	110.1931	22.28291	108704.5514	SEMI
5	4	1170	1081	8	221	145844	659.9276	524.5791	1170	1080	20	5	720	78926	109.6194	21.27008	121618.1028	SEMI
6	5	1171	1080	10	349	168331	482.3238	478.8485	1171	1080	20	5	720	78947	109.6486	22.2303	130063.6347	SEMI
7	6	1170	1075	12	489	188052	384.5644	433.2196	1170	1079	20	5	720	78739	109.3597	20.68527	134575.0958	SEMI
8	7	1170	1080	14	665	210187	316.0707	388.7709	1170	1080	20	5	720	78926	109.6194	21.27008	137290.0694	SEMI
9	8	1171	1080	16	861	233188	270.8339	351.8254	1171	1080	20	5	720	78947	109.6486	22.2303	138780.5458	SEMI
10	9	1170	1081	18	1073	257572	240.0485	321.3858	1170	1081	20	5	720	79339	110.1931	22.28291	139334.8514	SEMI



Now we will use the data in these columns to plot an XY Scatter chart with **object radius on the X-axis** and **result count on the Y-axis**.

**Step 13:** To do this, highlight the data in the 2 columns and go to **Insert → Chart → Scatter**

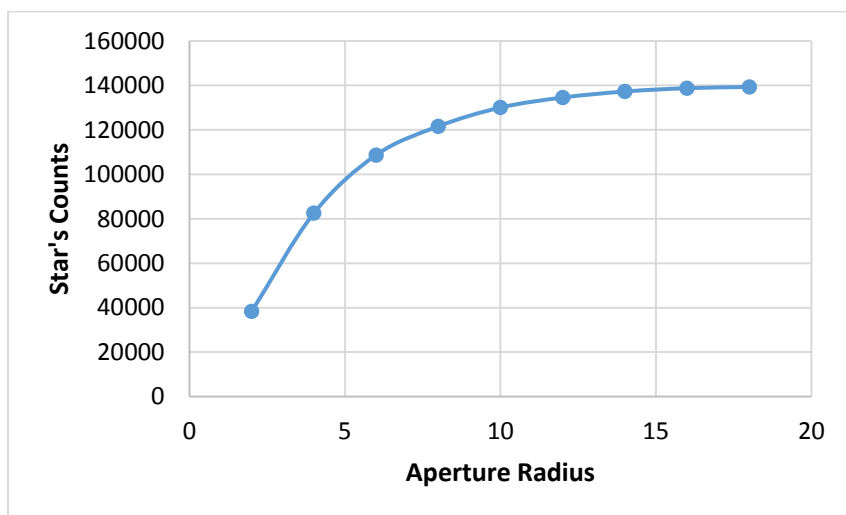
**Figure 8 – Inserting a scatter chart on Microsoft Excel.**



**Step 14:** Adjust the **minimum and maximum values** on the axis to make your graph clearer. Do this by double-clicking on the Y-axis and selecting **Axis Options → Values in Reverse Order**.

You should then have a graph that appears similar to Figure 9.

**Figure 9 – Example of a graph of aperture photometry measurements displaying aperture radius against counts.**



**Step 15:** Can you explain what is happening in the graph and the reason for its shape?



**Step 16:** Use your graph to identify the radius at which the majority of the star's counts is included within the aperture radius, and minimal amounts of background sky.

**Hint:** Look for the area where the graph begins to plateau.

**Step 17:** What part of your eye is comparable with the aperture radius used in photometry?

You are now ready to perform your photometry measurements. Refer to the **Photometry of Supernovae with Makali'i** worksheet to do this.



## Appendix 1 – CSV Files

CSV files are “comma separated values” files. These are used to store data in a table structured format that can be imported into a spreadsheet software for analysis.