


## Photometry of Supernovae with SalsaJ

How to perform photometry on supernovae targets using the free image processing software, SalsaJ



This worksheet describes how to use photometry to investigate the changing brightness of the supernova target Gaia16agf. The data files (in .fits format) for this object are provided in the .zip file called 'Data - Gaia16agf'.

When you have carried out your measurements and obtained your data, you will present your results onto a graph to display the light curve of the target. The method you will use can then be replicated for other supernovae targets.

Where you see the  symbol, there is a corresponding screencast to go with the written section of the document. The filename of the screencast corresponds to the number shown on the symbol.

## Identifying your Targets

Before we can begin the photometry, we must identify the targets we want to measure in the images.

1. Look at Appendix 1 where you will see a Finder Chart. It shows a field of view containing the supernova target Gaia16agf. The supernova target is circled blue and the three check stars (circled orange) which you will be measuring are highlighted.

## Photometric Analysis of your Supernova Target



From completing the 'Photometry with SalsaJ' worksheet, you should have now decided on the most appropriate aperture for your analysis. In doing so we can begin to investigate the supernova target to see how it changes in brightness over time.

2. Open your images and go to Analyse > Photometry Settings.

3. Next to the Star Radius and Sky option, change the settings from Auto to Forced Star Radius and Forced Sky Radius. Then input the suitable Star Radius you identified in the Photometry with SalsaJ worksheet and apply a Sky Radius of 12.

Note: If you have not completed the Photometry with SalsaJ worksheet, a Star Radius value of 10 would be suitable.

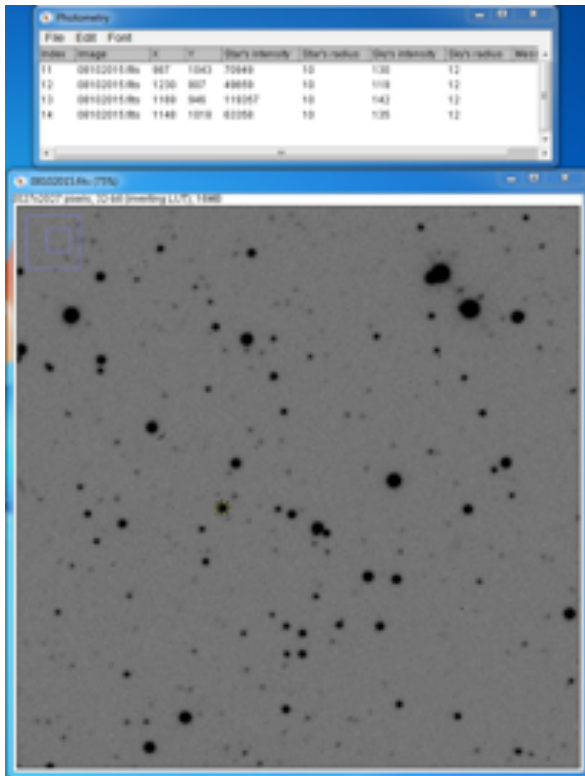


Figure 1 – Photometry measurements for supernova target and check stars in Salsa].

4. Click on the centre of your supernova target and each of your individual check stars in order. Your measurements should appear in the 'Photometry Results' box similar to as seen in Figure 1.

You may need to zoom in two or three times to get a better view of your target. To zoom in, select the magnifying glass button and then click on the region of your image you wish to magnify.

5. Repeat Step 4 for each of your images, making sure you measure the objects in the same order for each image. You may find it easier to close each image once you have taken your measurements. If prompted, you will not need to save the changes you have made.

6. When you have performed your photometry measurements on each of your images, go to your Photometry results box and select File > Save As, and save your data under a suitable filename.

## Presenting your Data

7. When you have completed Steps 4 to 6, open your data into an Excel Spreadsheet (or similar software).

Your results should look similar to those seen in Figure 2. Here the supernova target and three check stars have been recorded, where the numbers under the Index column represents the following objects:

- 1 – Supernova Target
- 2 – Check Star 1
- 3 – Check Star 2
- 4 – Check Star 3

This order is then repeated afterwards for each of the images. Therefore each corresponding object is separated by three rows.

8. In the 'Message' column, you can identify the SN, check star 1, 2 and 3 to avoid confusion later.

	A	B	C	D	E	F	G	H	I
1	Index	Image	X	Y	Star's intensi	Star's radius	Sky's intensi	Sky's radius	Message
2	1	9 - 20160316	187	154	21194	10	471	12	SN
3	2	9 - 20160316	506	115	110127	10	485	12	1
4	3	9 - 20160316	55	191	23626	10	471	12	2
5	4	9 - 20160316	257	174	5813	10	471	12	3
6	5	8 - 20160314	197	172	21409	10	212	12	SN
7	6	8 - 20160314	516	133	101330	10	230	12	1
8	7	8 - 20160314	66	210	21823	10	211	12	2
9	8	8 - 20160314	268	193	5608	10	207	12	3
10	9	7 - 20160313	199	151	24753	10	184	12	SN
11	10	7 - 20160313	518	112	111014	10	193	12	1
12	11	7 - 20160313	67	188	23923	10	184	12	2
13	12	7 - 20160313	269	171	5887	10	184	12	3

Figure 2 – Photometry results obtained from SalsaJ presented in an Excel spreadsheet.

9. By highlighting on the first 4 rows of the message column and dragging the blue box downwards, each SN and check star will be labelled accordingly. Choose 'copy cells' to ensure it labels the stars 1, 2 and 3.

You can now sort the data on column I so that all the SN data and each check star data is together:

10. Highlight column I and go to Data > Sort > Expand selection and sort on column 'Message'.

We now need to separate each of the objects by selecting their corresponding information and inserting it into their own spreadsheet or spreadsheet tab.

11. Highlight all the rows that correspond to your supernova target, then Copy and Paste these values into a separate spreadsheet.

12. Repeat step 11 for each of your check stars.

You should now have four separate spreadsheets, one for your supernova target and one for each check star.

## Calculating Magnitudes

We now need to calculate the magnitude of the objects from their intensity values.

The star's intensity value refers to the number of photons that fell onto the CCD in a given area. The area for the star's intensity is the aperture radius that you set.

We convert this value into a magnitude using the equation:

$$\text{magnitude} = -2.5 \times \log^{10} \text{star's intensity}$$

In Microsoft Excel this formula is typed as:

$$=-2.5*LOG10(\text{Star's intensity})$$

where (Star's intensity) is the value corresponding to each image.

13. For each of your four data sets add a new column titled Magnitude and input this equation to calculate the instrumental magnitude for the supernova target and three check stars in each image.

Hint: You can input the equation in the first box and drag the bottom right corner of this box down the column so that it automatically fills the remaining boxes with the corresponding equation.

14. When you have calculated the magnitudes, open a new spreadsheet and Copy and Paste the Magnitude values for your four objects into this new sheet. Be sure to note the order in which these values are pasted in – i.e. which image number corresponds to each set of magnitude values – you will need to know this later when obtaining the date/time information for your lightcurve plot. It is recommended that you add a column here and input the image number. Also, make sure the values are pasted in the same order for each object e.g. paste the supernovae value in first, then check star 1, then check star 2, then check star 3.

Note: As you have used a formula to calculate these values, when you paste them into a new spreadsheet you will need to select 'Paste Values'.

Your new spreadsheet should appear similar to Figure 3:

	B	C	D	E
SN	Check 1	Check 2	Check 3	
-12.0033	-11.0807	-12.0531	-11.4009	
-11.9095	-11.012	-11.9921	-11.323	
-12.2258	-11.3498	-12.2705	-11.6541	
-11.9495	-11.1071	-12.0817	-11.3867	
-12.06	-11.3061	-12.2773	-11.6477	
-11.9667	-11.3043	-12.2772	-11.6543	
-12.4291	-11.9628	-12.9489	-12.3006	
-12.6621	-12.0383	-13.0278	-12.3592	
-12.4818	-11.9989	-12.9753	-12.3763	
-12.1594	-11.751	-12.7158	-12.0504	
-12.1416	-11.775	-12.7476	-12.0855	
-11.9775	-11.6613	-12.6471	-11.9867	
-12.0676	-11.8834	-12.8408	-12.154	
-12.1796	-11.991	-12.9583	-12.3085	
-12.0056	-11.9016	-12.8417	-12.1782	

Figure 3 – The magnitude values for the four objects, copied and pasted into a separate spreadsheet, Here, SN is the supernova target.

## Ordering the Timescale of your Observations

As our intention is to produce a light curve to see how the brightness of the object changes with time, we need to input the observation dates.

15: Open up the Observation Information file into Excel (or similar software). Your screen should appear similar to Figure 5.

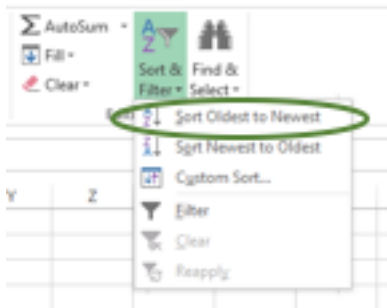


Figure 5 – The information for the observations dataset

	A	B	C	D	E	F	G	H	I	J
1	Image number		Basename	Time	Proposal	Object	Filter	Type	Exp. Time	R.level
2	1		ogg2m001-f02-20160302-0128-e90	03/03/2016 07:44	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
3	2		ogg2m001-f02-20160303-0091-e90	04/03/2016 06:42	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
4	3		ogg2m001-f02-20160304-0105-e90	05/03/2016 08:10	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
5	4		ogg2m001-f02-20160305-0064-e90	06/03/2016 06:38	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
6	5		ogg2m001-f02-20160307-0084-e90	08/03/2016 07:26	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
7	6		ogg2m001-f02-20160310-0102-e90	11/03/2016 07:20	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
8	7		ogg2m001-f02-20160311-0113-e90	12/03/2016 06:15	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
9	8		ogg2m001-f02-20160313-0090-e90	14/03/2016 05:35	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
10	9		ogg2m001-f02-20160314-0011-e90	15/03/2016 06:56	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
11	10		ogg2m001-f02-20160316-0073-e90	17/03/2016 07:43	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
12	11		ogg2m001-f02-20160318-0097-e90	19/03/2016 06:41	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
13	12		ogg2m001-f02-20160320-0097-e90	21/03/2016 07:14	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
14	13		ogg2m001-f02-20160321-0060-e90	22/03/2016 06:56	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
15	14		ogg2m001-f02-20160322-0093-e90	23/03/2016 06:44	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
16	15		ogg2m001-f02-20160327-0091-e90	28/03/2016 05:40	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
17	16		ogg2m001-f02-20160328-0086-e90	29/03/2016 06:01	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
18	17		ogg2m001-f02-20160402-0056-e90	03/04/2016 05:44	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
19	18		ogg2m002-f01-20160405-0067-e90	05/04/2016 10:06	FTPEPO2014A-003	Gaia16agf	R	EXPOSE	200	Reduced (DRAC)
20										

Figure 4 – Ordering observations in time order on Microsoft Excel.

The information we are interested in is under column time (column D). This column corresponds to the observation date and time for each file.

16. Create a new column in your magnitudes spreadsheet to match the dates to the corresponding data. You may need to expand the width of the column to see the dates and times. You should have already inputted in an 'Image Number' column in your magnitudes spreadsheet, so matching each row with the correct time/date should be easier.

Hint: Insert the time column to the left of your magnitude columns.

You may realise that the observations are not in order.

17. To list the data from the earliest observation to most recent observation, highlight all of your data, starting with the time/date column. Then go to the Home toolbar > Editing > Sort & Filter, and select Sort Oldest to Newest, as seen in Figure 4.

### Accounting for Instrumental Variability

The magnitude values you have calculated are Instrumental Magnitudes.

Instrumental magnitude is different from apparent magnitude and absolute magnitude. Apparent magnitude is how bright a star appears to us on Earth. Absolute magnitude describes how bright a star would appear if it were located at a distance 10 parsecs away from Earth.

Instrumental magnitude however, as the name indicates, is dependent on the instruments that are used to measure the object.

This is where we apply our measurements of the check stars in order to see if the supernova target varies in brightness respectively.

First we need to make sure none of our check stars are variable stars.

18. To do this, create three more columns and calculate the following subtractions for each image:

Check 1 Magnitude minus Check 2 Magnitude (i.e. mag 1 – mag2)

Check 1 Magnitude minus Check 3 Magnitude (i.e. mag 1 – mag 3)

Check 2 Magnitude minus Check 3 Magnitude (i.e. mag 2 – mag 3)

19. Now plot each of these the columns against their corresponding dates of the observation in an XY Scatter Chart.

You should have the date on the X axis and change in magnitude on the Y axis.

As seen in Figure 5, all three lines should appear relatively flat (or within around 0.03-0.05 magnitudes).

This means they are all standard stars, with no variability. If they appear much more variable then they are not suitable as check stars.

Now you know your check stars are not variable, we can compare the variability of the supernova target with the average instrumental magnitude of the three check stars.



Figure 5 – Ensuring that the check stars are not variable stars

20. Create a new column in your magnitude sheet and calculate the average magnitude of the three check stars in each image.

To do this in Excel input the following formula:

$$=(\text{check star 1 magnitude} + \text{check star 2 magnitude} + \text{check star 3 magnitude})/3$$

21. You now need to subtract the average magnitude values of the check stars from the instrumental magnitude of the supernova target for each image. Add another column and input this calculation.

You now have the difference in magnitude of the supernova target in each image.

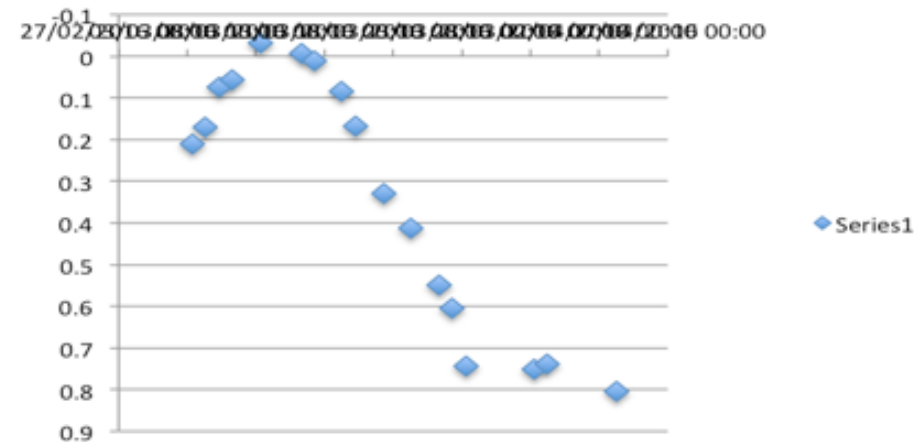
### Plotting your Light Curve

22. Plot the magnitude values you have just calculated against the time of their observation in each image, again in an XY Scatter Chart. You should have date on the X axis and change in magnitude on the Y axis.

23. You will need to reverse the values of your Y axis. This is because lower magnitude values represent brighter objects than higher magnitude values.

To do this, double click on your values on the Y axis of the graph. A pop up window should appear (or a toolbar on the right-hand side of the document. Tick the box that says 'Display values in reverse order'.

You now have a light curve of the supernova Gaia16agf. It should appear similar to the figure below:



## Appendix 1 – Finder Chart

A finder chart to identify the supernova target and check stars in the images.

