

Activity #4: photometry of the galaxy NGC 4826

In this practical activity, we are going to familiarize ourselves with aperture photometry of galaxies using IRAF, aiming to study the surface brightness of the galaxy NGC 4826, also known as the Black Eye Galaxy. For that we utilize various tasks on the package `stdas.analysis.isophote` to perform the automatic analysis of isophotes in the galaxy. We are going to use an image obtained with the 60 cm B&C telescope at Pico dos Dias Observatory, on April 6th, 2016 and exposure times of 1200 s.

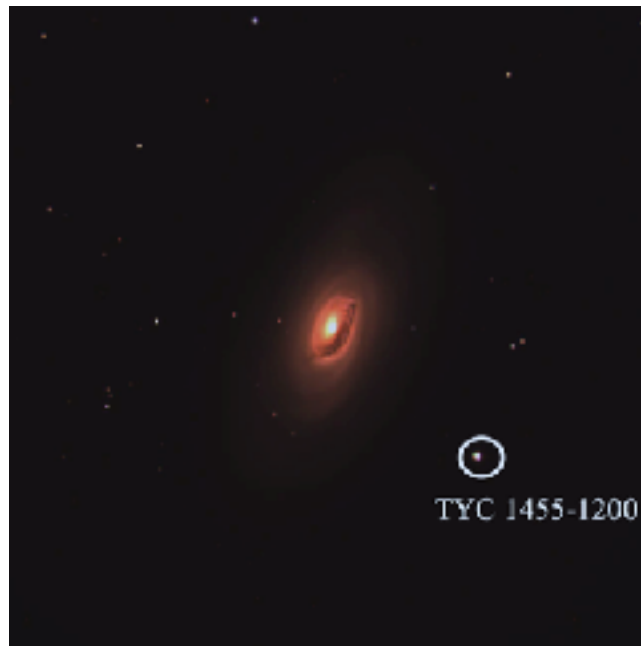


Figure 1: Color image of the galaxy NGC 4826 generate through combination of the OPD images.

The image files can be downloaded here: https://www.dropbox.com/s/yms5coim5fppq4f/NGC4826_processed.zip?dl=0

An important piece of information for this activity is the magnitude of the star TYC 1455-1200: **Bmag = 12.11**. The plate scale of the detector (which relates the number of pixels with the angle in the sky) is **0.68 arcsec per pixel**. In the following steps, I am going to write the values that I obtained when I was setting up this activity. The values that you are going to obtain are probably going to be a little bit different.

In the following items, the words written with *this font* and preceded by \$ are commands that you have to type on IRAF, and in place of "image.fits" you must type the name of the image file. After modifying the the parameters of a given task using the command `epar`, you save the parameters by typing the command `:q` (a colon followed by small Q). You should try to understand what each IRAF task does (type `$ help task_name` to see the documentation of the task). You can also look it up on Google: "iraf task_name" and the first result is normally the manual of the task.

IRAF setup guide:

```
$ cd working_folder
$ mkiraf (choose xgterm for the terminal type)
$ gedit login.cl
```

Change `imt800` (line 26) to `imt2048` (we are working with 2048x2048 pixels images), and `imh` (line 34) to `fits`. On the lines you changed, delete the “#” characters. Save the file and close it.

```
$ ds9 & xgterm &
```

A new terminal, with a white background, is going to open. Click on it and

```
$ cl
```

Guide for performing aperture photometry using isophotes:

1. Measure the FWHM (full-width at half maximum) of the stars in the field. I obtained, in average, 4.5 on filter B.

```
$ imexam image.fits
```

See the observation below. With the cursor pointed to a given star, press R to fit the profile (it will appear in a new window). The FWHM is measure in three different ways, and its values are presented in the lower right part of the new window.

Observation: when using a task that interacts with `ds9`, such as the task `imexam`, the terminal `xgterm` becomes stuck, and `ds9` waits for your commands. These commands are issued on the keyboard, and each task has its own commands. See the documentation to know what each key does. To issue commands to `ds9`, click on its window and point the mouse to the image. To leave this mode, use the command `quit` (press the key Q), which works for many different tasks.

2. Now, let's use the command `phot` (and its various subcommands) to perform the photometry of the star TYC 1455-1200.

```
$ epar fitskypars
```

Change the parameter `annulus` to a value roughly 3 times the measured FWHM.

```
$ epar photpars
```

Change the parameter `aperture` to a value roughly 3 times the FWHM of the stars.

```
$ epar datapars
```

Change the parameters `scale` (the plate scale of the detector) to 0.68 and `fwhmpsf` to the value you measure for the FWHM.

```
$ epar phot
```

Change the parameter `interactive` to `yes`.

```
$ phot image.fits
```

Point to the star that we want to measure, and press C (fit the star center), S (fit the sky) and then O (perform the photometry with an output file). This will create a file with the extension `.mag.X` (where X is a number) with the measurement(s) that you did. Study this output file and find the value measured for the flux of the star. In the B filter, I obtained a value in the order of 10^5 .

3. To produce the isophotes of the galaxy, we use the tasks in the package

```
stsdas.analysis.isophote.
```

```
$ stsdas
```

```
$ isophote
```

```
$ epar geompar
```

Since the isophotes are obtained by an iterative method, it is necessary to provide an initial guess for its parameters. See the documentation of the task (`$ help geompar`) what are the parameters `x0`, `y0`, `ellip0`, `pa0`, and `sma0`, and guess initial values for them. After that, execute the task `ellipse`.

```
$ ellipse image.fits output.out interactive=no
```

The task may ask you to guess the values of `x0` and `y0` again. It will produce a file named `output.tab` which contains the results obtained for the isophotes and the fluxes in each of them.

4. (Optional, but recommended) Visualize the isophotes that you obtained.

```
$ epar isoimap
```

The parameter `table` must contain the name of the file that you generated in the previous step (in the case of this tutorial, it was `output.out`). Mark `fulltable` as `no`. `minsma`, `maxsma`, `nlevels` and `color` are up to you. Execute the task:

```
$ isoimap image.fits
```

5. The file `output.out` generated by the task `ellipse` is in binary format. In order to read the data yourself, you need to transform it into a text file. To do it, we use the task `tdump`:

```
$ tdump table=output.out cdfile=cols.out datafile=ellipse.out
```

This command will produce two files: `ellipse.out`, which contains the table with the results obtained by the task `ellipse`, and `cols.out`, which contains the specifications of what each column of the table is. For instance, the second line of `cols.out` corresponds to the parameters `INTENS`, which, according to the manual, is the average intensity of the isophote. This means that the second column of the table `ellipse.out` corresponds to this parameters. Study these output files and answer the following questions.

- a) What is the magnitude of the galaxy NGC 4826 (in the filter you worked on) inside the **half-light radius**?
- b) What is the surface magnitude ($\text{mag}/\text{arcsec}^2$) of the galaxy NGC 4826 inside the **half-light radius**?
- c) Compare your results with the literature. Discuss what could be the possible sources of uncertainties and disagreements.

* Since it is difficult to define the borders of a galaxy, in astronomy we usually use the half-light radius, which is the radius (or the semi-major axis, in the case of an ellipse) which contains half of the total brightness of the galaxy. You need to compute it and probably perform an interpolation to answer the items *a* and *b*.