Galaxy photometry v2

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1 Introduction: Isophotal analysis

The GPv2 is based on the "photutils.isophote"[1] package and it attempts a 4 step ellipse fitting method which returns the final physical parameters of the galaxies. The 4 step refers to the 4 repetitions of the isophotal analysis, defining more constrains for the different parameters in each step. In the first step, the script generates an estimation for the isophotal ellipses using predefined parameters without fixing the central coordinates, ellipticity or position angle (PA). Based on those results, more accurate initial parameters will be defined and the isophotal ellipses will be recalculated by fixing the central coordinates of the galaxy. This steps are repeated when attempting to find a constant value for the ellipticity and PA.

This document summarise some basic information for using the GP_v2, for future information of the input parameters check the help option of the script.

2 Input parameters

Different input parameters can be adjusted for the different galaxies. The most typical modified variables during the execution : a.)The GPv2 use "photutils.background"[2] package for background estimation, this requires a "box_size" parameter for defining the sampling step size, this parameter is important to be adjusted properly to the size of galaxy to avoid artificial effects or to correct the problematic image reduction see Figure 1. b.) In cases when the galaxies were larger than 0.2' diameter, the semi-major axis of the first ellipse is needed to be increased. c.) In a few cases, the center of the galaxy can be shifted relative to the image due to incorrect header information during cropping step. In these cases the x0 and y0 central coordinates need to be adjusted slightly, before the execution.

[1]Developed by [1]:https://photutils.readthedocs.io/en/stable/isophote.html
[2]https://photutils.readthedocs.io/en/stable/background.html

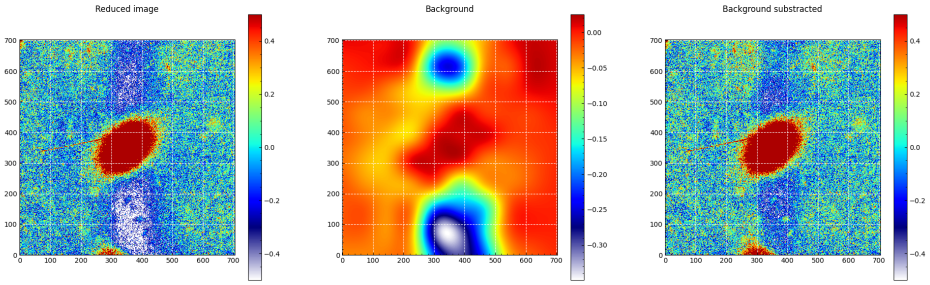

Figure 1: Background model of the galaxy VCC523. The impurities appeared during the data reduction can be adjusted.The first image is our data plotted between the certain limits, second image is the calculated background model, the third represents the background subtracted data between the same limits as our original data.

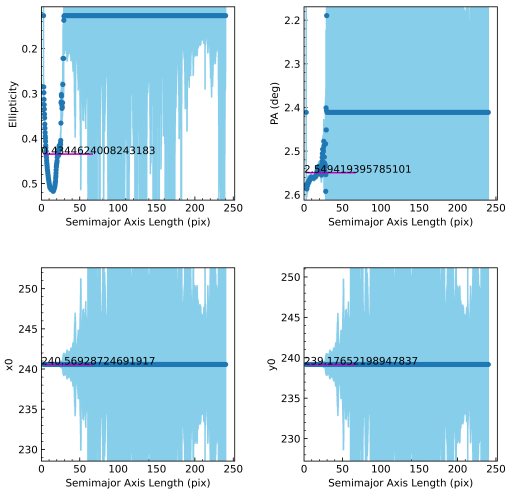

Figure 2: Example of the GPv2 output, LEDA 126848. The coordinates of the center(x0, y0) are fixed while ellipticity and PA fluctuates. Blue dots are parameters of the individual isophotal ellipses, magenta line marks the adopted size of the galaxy and the values contributing into the median for an initial approximation. The skyblue vertical lines are the error bars.

3 Automatically defined parameters

During the script execution some parameters are automatically calculated.

The new central coordinates, ellipticity, PA values are the weighted average of the individual isophotal ellipses inside the galaxy size limit, see Figure 2. In case of the PA the circular mean formula was used: $\overline{PA} = arctan\frac{\overline{sinPA}}{\overline{cosPA}}$. The weight values are the inverse values of the respective parameter's error for the individual isophot measurements. Using the weighted average instead of the median the ellipse parameters closer to the central part of the galaxy gets more importance.

The size of the galaxy (a_T) was determined based on the flux inside consecutive isophotal ellipses. When this value reaches the background level and starts to fluctuate around it, we consider that we reached the maximum size for the galaxy, given the available deepness. The background level is the maximum background value calculated during the background modelling.

4 Intensity to magnitude conversion

Using the "photutils.isophote" we can obtain the total intensity and the isophotal intensity values. Converting intensity to magnitude we used the $m = zp + m_{surf} - 2.5 * log_{10}I$ formula where $m_{surf} = 2.5 * log_{10}ps^2$ (ps=pixel scale). Converting the intensity error (σ_I) values to magnitude error (σ_m) values we used the error propagation formula:

$$\sigma(m(I)) = \frac{\delta(c - 2.5log_{10}I)}{\delta I} * \sigma_I \tag{1}$$

$$\sigma_m = -\frac{1.086}{I} * \sigma_I \tag{2}$$

4.1 Verification

To incorporate the results returned by GPv2, we used 3 criteria: 1.) The central coordinates (x0, y0) always need to be fixed. Fixing the ellipticity or PA is not requested but at least one of them is preferred. 2.) The calculated allowed difference of the galaxy size to the starting point of the noise level (indicated also in the Figure 3 through the errors in the isophotal magnitudes) is less than 10%. 3.)

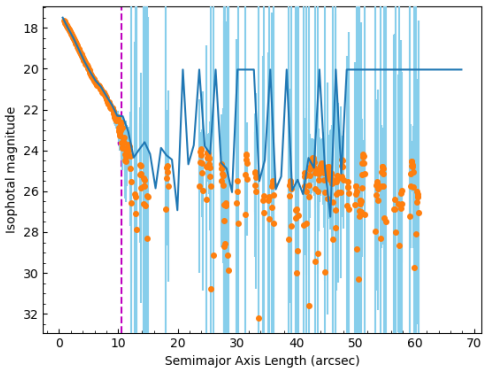

Figure 3: IRAF versus GPv2 comparison, LEDA 126848. Orange dots are the GPv2 results, the dark blue line is the IRAF result, the vertical dashed magenta line marks the adopted size of the galaxy. The skyblue vertical lines are marking the error bars.

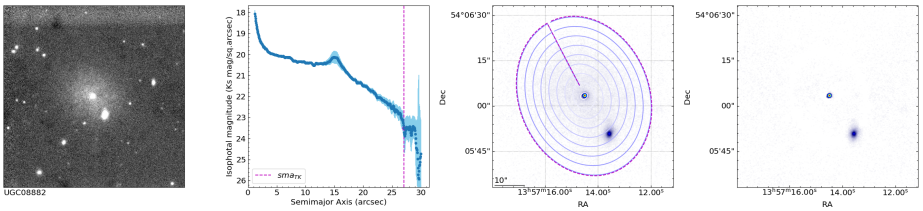

Figure 4: Example UGC08882. The first image shows the cropped galaxy picture after data reduction, before masking. The second plot shows the SBP of the galaxy, the third and fourth plots are used for verification. The third image shows an example set of isophotal ellipses plotted on the galaxy, the last image is the reconstructed model subtracted from the image used for the analysis.

The residuals of the galaxy after model subtraction from the image is comparable to the background noise. Where we were not satisfied with the results the input parameters were modified.

The results were cross checked with the IRAF ELLIPSE task. A comparison of the results is shown in Figure 3.

An example of the final plot is presented in Figure 4. We used Iraf IMEDIT task to remove the foreground objects, except the close bright galaxy, for obtaining a smoother profile.

References

[1] Larry Bradley, Brigitta Sipőcz, Thomas Robitaille, Erik Tollerud, Zè Vinícius, Christoph Deil, Kyle Barbary, Tom J Wilson, Ivo Busko, Hans Moritz Günther, Mihai Cara, Simon Conseil, Azalee Bostroem, Michael Droettboom, E. M. Bray, Lars Andersen Bratholm, P. L. Lim, Geert Barentsen, Matt Craig, Sergio Pascual, Gabriel Perren, Johnny Greco, Axel Donath, Miguel de Val-Borro, Wolfgang Kerzendorf, Yoonsoo P. Bach, Benjamin Alan Weaver, Francesco D'Eugenio, Harrison Souchereau, and Leonardo Ferreira. astropy/photutils: 1.0.0. September 2020.