Practical No : 1
Galaxy Surface Brightness Profile through Photometric Analysis
MSc - II Practical

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Abstract

This report documents the analysis of galaxy surface brightness profiles using photometric analysis techniques. The Sérsic profile is employed to model the galaxy's brightness distribution, utilizing Python and the photutils package for data analysis and visualization.

1 Introduction

The surface brightness of galaxies can be modeled by the Sérsic profile, which describes how the brightness changes as a function of distance from the galaxy's center. This practical exercise aims to determine the geometric parameters of galaxies from their FITS images, fit ellipses to obtain surface brightness profiles, and analyze additional parameters such as ellipticity and position angle.

2 Practical Exercise

- **Tools and Packages**: Python is utilized alongside the `astropy` and `photutils` packages, supplemented by `numpy` and `matplotlib`.
- **Procedure**:
  1. **import the necessary libraries**:

```python
from numpy import *
from matplotlib.pyplot import *
import os
from astropy.io import fits
from astropy.modeling.models import Gaussian2D
from photutils.datasets import make_noise_image
from photutils.isophote import EllipseGeometry
from photutils.aperture import EllipticalAperture
from photutils.isophote import Ellipse
from photutils.isophote import build_ellipse_model
```

  2. Read the FITS image of the galaxy.

```python
NGC = os.path.join('/home/gauravbhoir147/Practicals/Galaxy/NGC_1199.fits')
HDUList = fits.open(NGC)
HDUList.info()

data = HDUList[0].data
#mean, median, std = sigma_clipped_stats(data) # get some image statistics
figure(figsize=(10,10))                        # set up the plot panel
imshow(data,origin='lower')#, vmin = median - 2*std, vmax = median + 20*std,
    origin='lower')
colorbar()
show()
```

3. Use `EllipseGeometry` and `EllipticalAperture` functions from `photutils` to determine the galaxy's geometric shape.

```
geometry = EllipseGeometry(x0=123, y0=123, sma=20, eps=0.5,pa=35.0* pi/180.0)
aper = EllipticalAperture((geometry.x0, geometry.y0), geometry.sma,geometry.sma * (1
    - geometry.eps),geometry.pa)
figure(figsize=(10,10))
imshow(data,origin='lower')
colorbar()
aper.plot(color='white')
```

4. Fit ellipses using the `Ellipse` function in `photutils.isophote` to obtain isophotes.

```
ellipse = Ellipse(data, geometry)
isolist = ellipse.fit_image()
print(isolist.pa)
```

5. Save isophote data into an external file for analysis.

```
iso_table = isolist.to_table()
print(iso_table)
# Convert the Astropy table to a pandas DataFrame
df = iso_table.to_pandas()
# Define the path for the output Excel file
excel_path = '/home/gauravbhoir147/Practicals/Galaxy/NGCdata.xlsx'
# Save the DataFrame to an Excel file
df.to_excel(excel_path, index=False)
print(f'Table saved to {excel_path}')
```

6. Plot the surface brightness profile (normalized intensity versus semi-major axis length), ellipticity, and position angle as functions of distance from the galaxy center.

```
ny = nx = 247
y, x = mgrid[0:ny, 0:nx]
#noise = make_noise_image((ny, nx), distribution='gaussian', mean=0.0,stddev=2.0,
    seed=1234)
#data = data + noise

figure(figsize=(8, 8))
title('Parameters Vs Semimajor axis')
subplots_adjust(hspace=0.15, wspace=0.15)

subplot(2, 2, 1)
scatter(isolist.sma, isolist.eps)
xlabel('Semimajor Axis Length (pix)')
ylabel('Ellipticity')

subplot(2, 2, 2)
scatter(isolist.sma, isolist.pa / pi * 180.0)
xlabel('Semimajor Axis Length (pix)')
ylabel('PA (deg)')

subplot(2, 2, 3)
scatter(isolist.sma, isolist.x0)
xlabel('Semimajor Axis Length (pix)')
ylabel('x0')


show()
```

3 Results and Analysis

The galaxy given to us was a elliptical galaxy1 and the ellipse fitting the galaxy is shown in 2

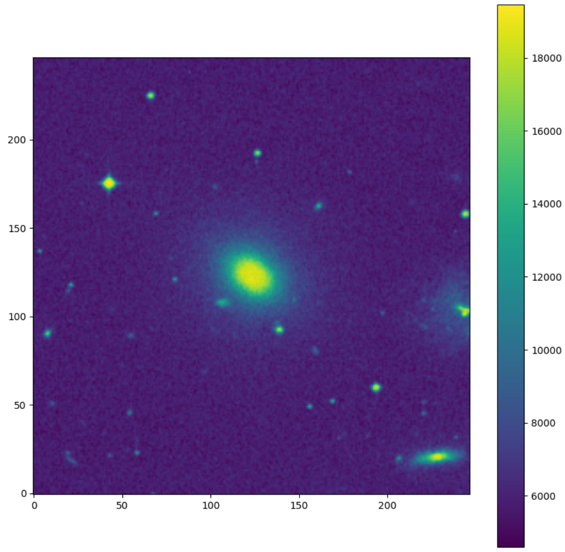

Figure 1: Elliptical galaxy

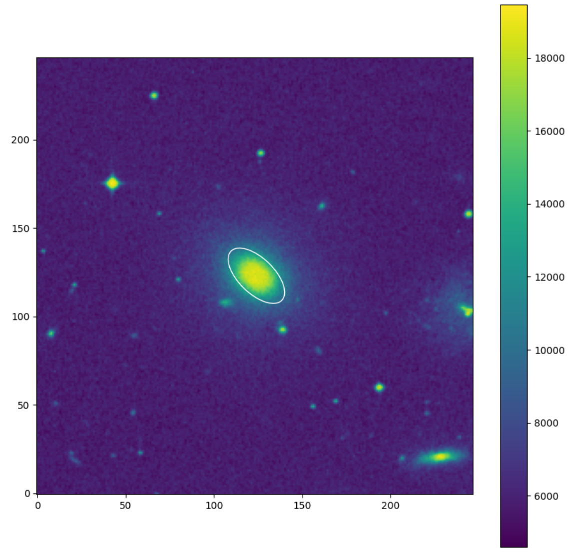

Figure 2: Fitted ellipse on the galaxy

- **Geometric Parameters**: The following parameters were used for fitting:
  - Central coordinates: $(x_{\text{center}} = 123, y_{\text{center}} = 123)$
  - Semi-major axis length: $a = 20$
  - Ellipticity: $\epsilon = 0.5$
  - Position angle: $\theta \approx 110^o$

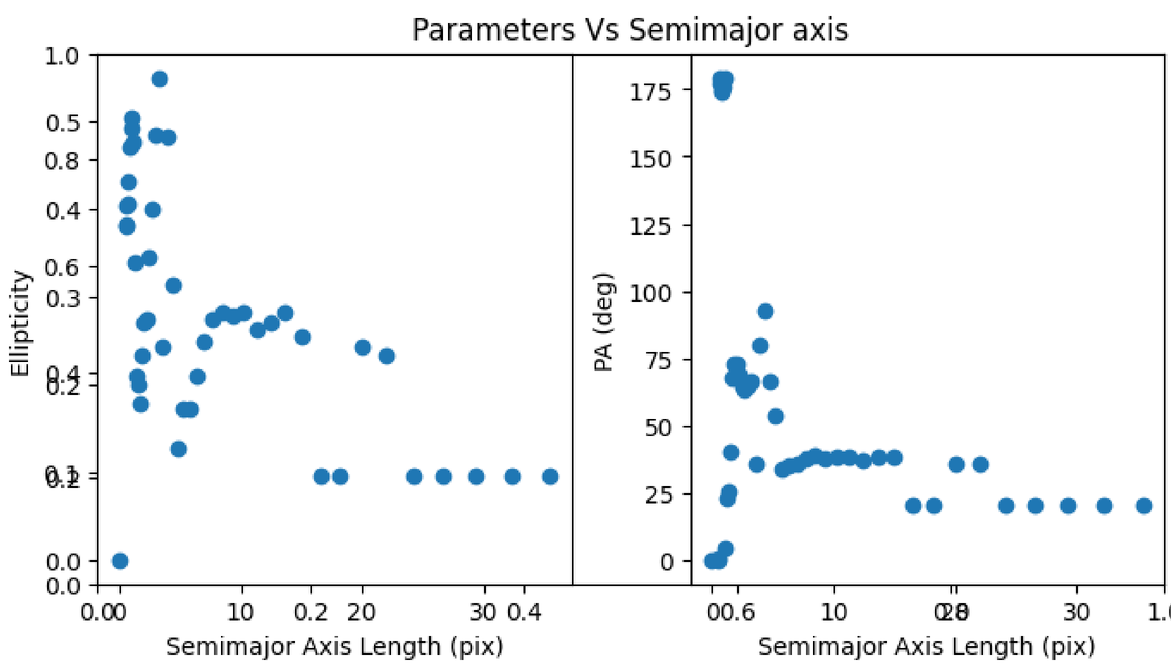

Figure 3: Graphs for ellipticity, Position angle and

- **Surface Brightness Profiles**: Figure **??** shows the surface brightness profiles, ellipticity and Position Angles of the galaxy: Plots illustrating how ellipticity and position angle vary with distance from the galaxy center provide additional insights into the galaxy's structure.

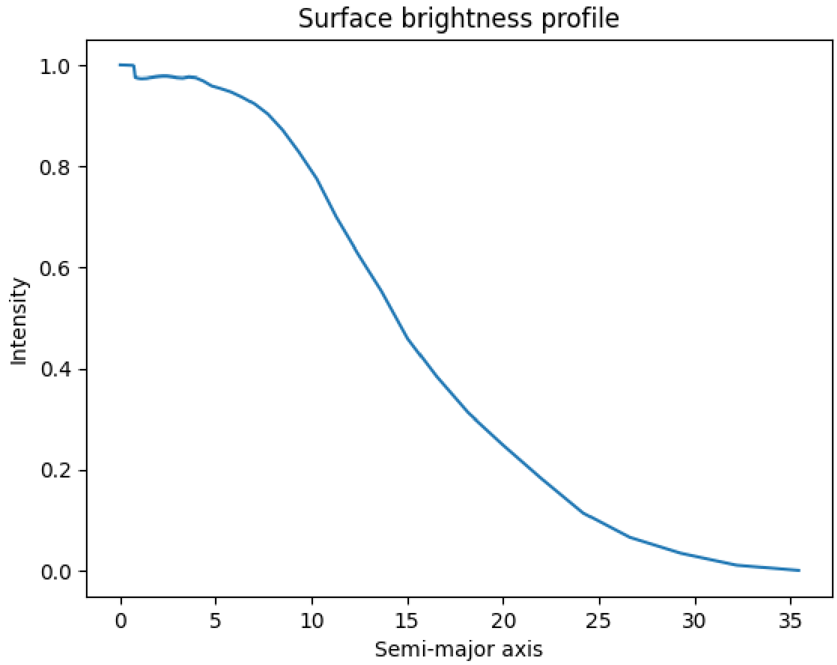

Figure 4: Graphs for ellipticity, Position angle and

As we can see in the graph 1 the surface brightness is falling as we move away from the centre(The deviation is due to not aligning the ellipse at proper centre).

4 Conclusion

This practical exercise demonstrates the application of photometric analysis techniques to study galaxy surface brightness profiles. By fitting ellipses and analyzing isophotes, valuable geometric and intensity data are obtained, enhancing our understanding of galaxy structure.

5 References

References

[1] Photutils Documentation: `https://photutils.readthedocs.io/en/stable/isophote.html`