

Morphological analysis of the galaxy NGC4686

Andrea Bavari, Gaetano Borgese, Francesco Cannarsa, Carlo Damiano Maria Spedicato

Scuola Navale Militare “F. Morosini”, Venezia

ABSTRACT

In this work we determined the morphology of the galaxy NGC 4686 by means of the photometric analysis of images extracted from the Sloan Digital Sky Survey public archive.

I. INTRODUCTION

Hubble’s morphologic classification, introduced by the american astrophysicist Edwin Powell Hubble in 1925, divides galaxies in four main groups: elliptical galaxies (E), normal (S0) and barred (SB0) lenticular galaxies, normal (S) and barred (SB) spiral galaxies, and irregular galaxies (Irr). The projection of a galaxy onto the sky plane produces a bi-dimensional image, the study of which let us recognize the morphological type of the galaxy considered. To succeed in this process the geometric components of the galaxy are fundamental: bulge, disk, and possible bars or spiral arms. In this report we analyze the images of the galaxy NGC 4686. A method to study the morphology of a galaxy is to analyze its isophotes. The isophotes are ideal lines linking points of a source with the same intensity. Each ellipse is defined by the following parameters: mean intensity (concerning photon counts), centre (x_0, y_0), semi-major axis (SMA), ellipticity and position angle (the angle between the North direction and the semi-major axis, calculated from North to East). By putting this information in a graph, considering these parameters as a function of the distance from the galactic centre, we can infer the galaxy morphological type. The photon counts collected by the CCD (**Charge Coupled Device**) have to be converted in apparent magnitudes by subtracting the average sky intensity multiplied by the area of the galaxy in pixels and dividing the result by the exposure time.

II. OBSERVATIONAL DATA

In our morphological study of the galaxy NGC 4686 we used images taken from the Sloan Digital Sky Survey public archive in the u, g, r, i, z bands, covering the visible spectral range.

Here are listed some properties of NGC 4686:

Right Ascension	12h 46m 39.7sec
Declination	+54° 32' 03"
Major Diameter	2.3 arcmin
Apparent Magnitude	13
Constellation	UMa

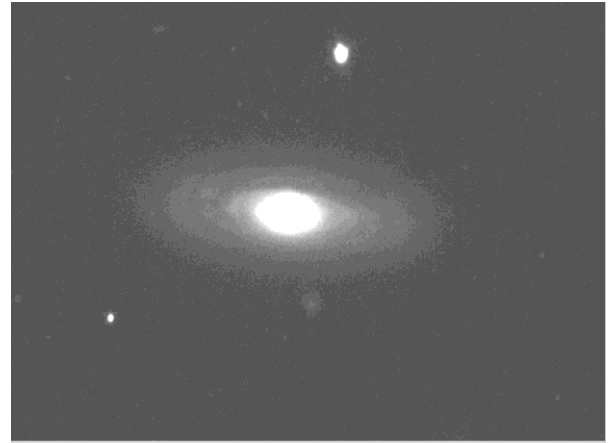


Fig 1: Image of NGC 4686.

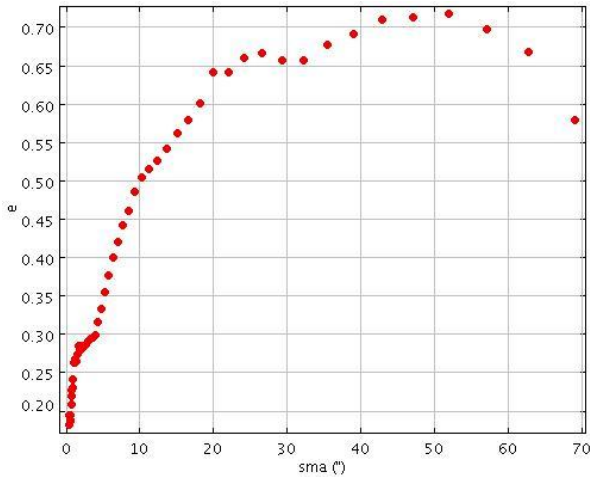
III. WORK DESCRIPTION

The images were analyzed with the IRAF and DS9 softwares. DS9 is the displayer we used to view our images. The IRAF task ELLIPSE was used to reproduce the galaxy’s isophotes fitting them with ellipses. In this way, we obtained the morphological parameters of the galaxy, like the ellipticity and the position angle, and also their trend with the distance from the galaxy centre.

The image below shows the trend for the ellipticity defined as:

$$e = 1 - \frac{b}{a}$$

where a is the semi-major axis and b is the semi-minor axis.



In this graph, the SMA is given in arcseconds and it is shown how the ellipticity grows continuously from the centre to the end of the galaxy.

Since for each ellipse we had the mean intensity of the correspondent isophote of the galaxy, this analysis gave us the light intensity as a function of the distance from the centre. With the ellipses we were able to build a model of the galaxy light distribution and subtract it from the original image. The result was an image containing the residuals, which are the deviations from the model (such as bars, spiral arms, etc).

In the two following images are shown the outputs of this procedure.

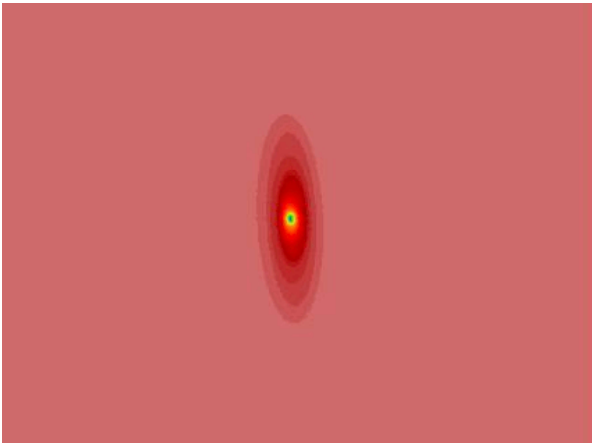


Fig 3: Model given by the interpolation of the ellipses.

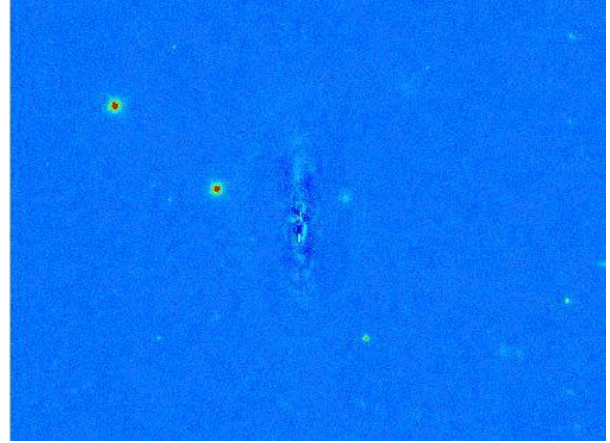


Fig 4: Residuals of the galaxy after the subtraction of the model.

Running again the task ELLIPSE, this time keeping fixed the centre of the ellipses, we recreated the galaxy's brightness profile, which is the surface brightness as a function of the SMA. To do this, we calculated the intensity of the galaxy light contained in every ring between two consecutive ellipses. Then we subtracted the sky intensity multiplied by the number of pixels contained in each ring and divide everything by the exposure time multiplied by the angular area of a pixel, which is in this case $0.4'' \times 0.4''$. The surface brightness μ is then given in (mag/arcsec²) by:

$$\mu = -2.5 \log \left(\frac{I_{gal} - I_{sky} \cdot N_{px}}{T_{exp} \cdot Area_{px}} \right)$$

After plotting on a graph the brightness profile, we applied experimental laws and determined their best fit parameters.

In order to find the bulge intensity, we used the effective radius and intensity we had found fitting the previous graph with an exponential law:

$$\Sigma_b = 5.36 \Sigma_e e^{-1.68 r/r_e}$$

With:

$$r_e = 3.3$$

$$\Sigma_e = 165$$

Therefore the bulge intensity is:

$$I_b = 11.93 \cdot I_e \cdot r_e^2 = 21436$$

In order to find the disk intensity, we used the scale length and the central intensity we had found fitting the previous graph with the Freeman's law:

$$\Sigma_d = \Sigma_0 e^{-r/h}$$

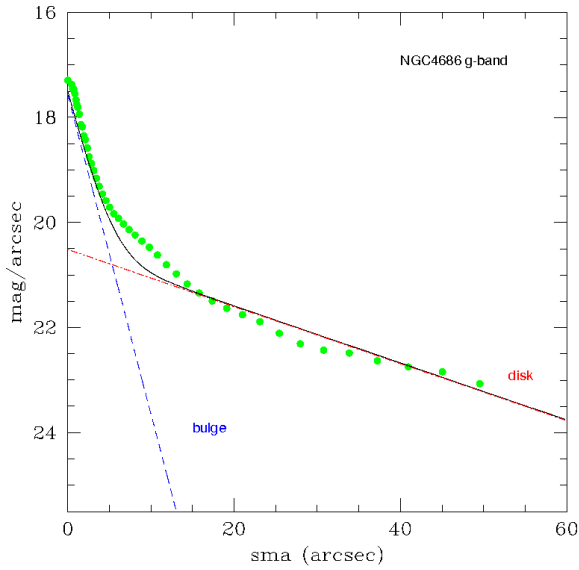
$$h = 20$$

$$\Sigma_0 = 45$$

Therefore the disk intensity is:

$$I_d = 2\pi \cdot I_0 \cdot h^2 = 113097$$

The following graph shows the brightness profile reproduced with an exponential law for the bulge and the Freeman's law for the disk.



We then calculated the intensity of the bulge related to the total intensity. This ratio shows the importance of the bulge component, therefore it gives an idea of the shape and classification of the examined galaxy:

$$\frac{I_{bulge}}{I_{bulge} + I_{disk}} = \frac{21436}{134533} = 0.16$$

Another method to see the importance of each component is to make a colour map by applying the following formula to the r and g fluxes:

$$g - r = 2.5 \log \frac{I_r}{I_g}$$

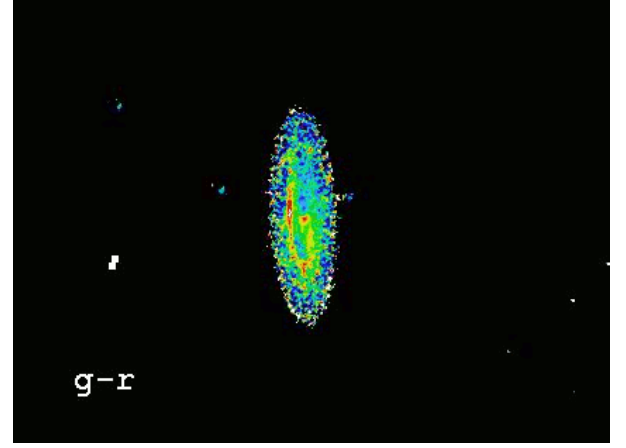


Fig 6: NGC 4686 colour map (g-r).

In order to have a more precise classification, we transformed the previous intensities into instrumental magnitudes through the formula:

$$m = -2.5 \log(I)$$

Therefore:

$$m_b = -10.83$$

$$m_d = -12.63$$

$$m_{tot} = -12.82$$

We then passed from instrumental (in photon counts) to calibrated (in physical units) magnitudes by correcting for atmospheric extinction, photometric zero point and airmass:

$$m_{cal} = m_0 + m_{inst} - K \cdot X$$

where:

K is the atmospheric extinction coefficient that depends on λ and therefore changes for every photometric band; X is the airmass given by:

$$X = \frac{1}{\cos(\frac{\pi}{2} - h)}$$

where h is the height of the object on the horizon.

The calculations gave us:

$$m_{b,cal} = 13.37$$

$$m_{d,cal} = 11.57$$

$$m_{tot,cal} = 11.38$$

$$\Delta m = m_{b,cal} - m_{tot,cal} = 1.99$$

From the difference between the bulge and the total magnitudes and the figure in Simien & DeVaucouleurs (1986) we got a morphological T-type 4 corresponding to a Sbc galaxy.

IV. RESULTS

We studied the morphology of NGC 4686 analyzing the radial trend of ellipticity and position angle. This analysis showed that this object does not have a bar.

By fitting the brightness profile with various laws, we can infer that the galaxy has two components: a bulge and a disk.

The small ratio between the bulge intensity and the total intensity is typical of a non prominent bulge.

Based on these results we can classify NGC 4686 as a Sbc galaxy.

Our results do not agree with those in literature, being the galaxy is classified as Sa.

