A Face-On Perspective: Exploring Sersic Indices in Galaxies NGC3982, NGC7773, NGC3865

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Abstract
The project aims to study the morphology and properties of different face-on galaxies NGC3982, NGC7773, and NGC2865. The Sersic index serves as a crucial parameter characterizing the light distribution in galaxies, providing insights into their structural properties and formation histories. This research paper presents a methodology for calculating the Sersic indices of these galaxies using observational data acquired from the Las Cumbres Observatory. Efficient Python techniques has been used for the curve fitting algorithms to model the surface brightness profiles obtained from the observational data. Sersic indices are calculated for the selected galaxies and compared with the theoretical models which explains morphological properties of the galaxies. The results shows the efficiency of the computational performed on these galaxies which gives more insights into the galaxy formation and evolution.
Keywords: galaxy, sersic index, NGC3982, NGC7773, NGC2865

I. Introduction:

Galaxy is a collection of stars, star remnants, dust, gas particles which are bound together by gravity. Galaxy come with many sizes and shapes like elliptical, spiral or regular shape. To further characterise the galaxies based on their shapes, a classification system is used namely Hubble's tuning fork diagram 1.

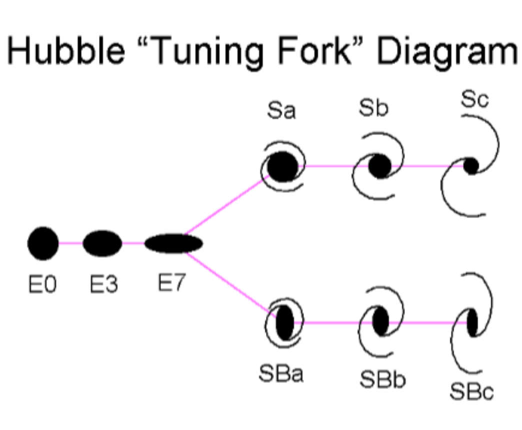

Figure 1: Tuning fork diagram

I.1. Sersic Function

In classifying the galaxies, the structural parameters play an important role in explaining their morphology and properties of the galaxy. One such parameter is Sersic index, which describes the radial distribution of light intensity in galaxies. It contains crucial information about the galaxy;s morphology which provides insights into its dynamical and evolutionary state[13].

The sersic function which gives an index value n which tells us about the edge and shape of the galaxy2. It corresponds to morphology of galaxy whether it is elliptical, spiral or dwarf galaxy.

The below equation describes the surface brightness of the galaxy with varying radius as a function, [5]

$$I(R) = I_e exp(-b_n[(\frac{R}{Re})^{1/n} - 1])$$

where
I_e is an Intensity value at effective radius
R_e is the effective radius
b_n is a proportionality constant
n is the sersic index
b_n is given by $b_n = 1.9992$n - 0.3271 for $0.5 < n < 10$ and $b_n = 2n - \frac{1}{3}$ for larger values of n [8].

The other properties like the simulated dark matter halo and the mass of the black hole present in the center of the galaxies are also linked with the sersic index [6].The sersic index values can be range from n = 1 to n = 10 [14] with increasing indices as shown in the figure 2

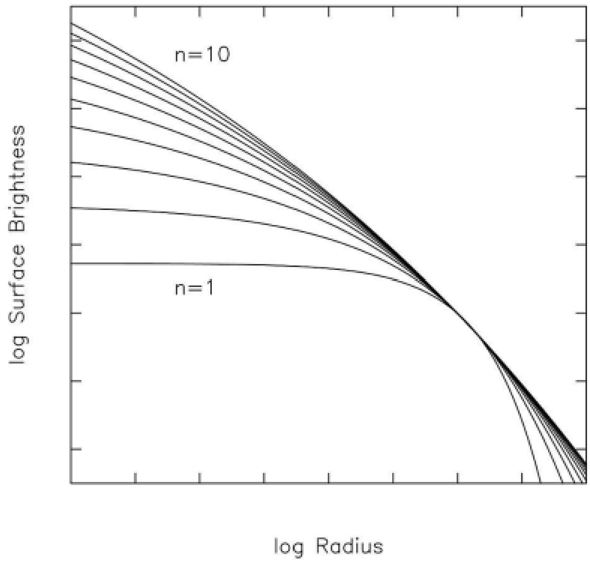

Figure 2: Sersic index

The structure of the galactic core can be described using the sersic index of the galactic core of the spiral galaxies. The values of $n > 2$ and $n < 2$ [9]are associated with the classical and pseudobulges and the bars are described using n = 1 [11].

So, the above equation is modified to two 1D sersic profiles known as double sersic which is used to describe the bulge and the outer disk of the galaxy, is shown in the equation below [5]

$$I(R) = I_{e,bulge} exp(-b_{n,bulge}[(\frac{R}{R_{e,bulge}})^{1/n,bulge} - 1$$

$$+ I_{e,disk} exp(-b_{n,disk}[(\frac{R}{R_{e,disk}})^{1/n,disk} - 1])$$

where

$I_{e,bulge}$ is an Intensity value at effective radius of bulge
$R_{e,bulge}$ is the effective radius of bulge
$b_{n,bulge}$ is a proportionality constant of bulge
$_{n,bulge}$ is the sersic index of bulge
$I_{e,disc}$ is an Intensity value at effective radius of disc
$R_{e,disc}$ is the effective radius of disc
$b_{n,disc}$ is a proportionality constant of disc
$_{n,disc}$ is the sersic index of disc
b_n is given by b_n = 1.9992n - 0.3271 for $0.5 < n < 10$ and $b_n = 2n - \frac{1}{3}$ for larger values of n [8].

The double sersic profiles are used to describe more about the shape of the galaxy like the bulge and disk of the galaxy. The values of the sersic index is estimated for each such that it explains the shape and edges of the galaxy in detail.

In this study, we explore the field of galactic morphology by focusing on sersic indices of three face-on galaxies: NGC3982, NGC7773, and NGC2865. The observational data of the targeted galaxies is obtained using the 2-meter MuSCAT telescope at Haleakala from the Las Cumbres Observatory (LCO)[1]. By analysing and comparing with the theoretical models, we aim to calculate precise sersic indices for the selected galaxies, thereby unraveling the structural properties of the galaxies.

II. Methodology:

II.1. Aperture Photometry

As previously discussed, in order to obtain the surface brightness profile, aperture photometry technique is applied to the targeted galaxies. Concentric apertures are placed on each galaxy and the observed flux is calculated inside the apertures. Software like AstroImageJ[4] and APT[12] can be used to do the aperture photometry on the galaxy.

JS9[7] can be used to obtain radial profile of the galaxy automatically using its online version. Upon uploading the galaxy FITS file into the JS9, the aperture can be placed on the galaxy which will calculate the brightness value within the aperture. Multiple apertures can be placed by defining the positions of the apertures such that the brightness values can be calculated from the center of the galaxy to the edge of the galaxy. The radius values can be converted into arc-seconds by multiplying with the value 0.26, since one pixel value is 0.26 arc-seconds for the MuSCAT telescope at LCO[1]. The radial profile can be generated using JS9 using the analysis option. But the profile is not accurate since the line width of the aperture is constant.

The key to solve this problem, Photutils[3], a python package can be used. Using this python package, Photutils, the customized apertures can be placed on the galaxy image to obtain accurate data points. After converting the data points into $countsperarc-seconds^2$ and radius values into arc-seconds, the radial profile of the galaxy can be generated using matplotlib python package as shown in the figures 3 8 9.

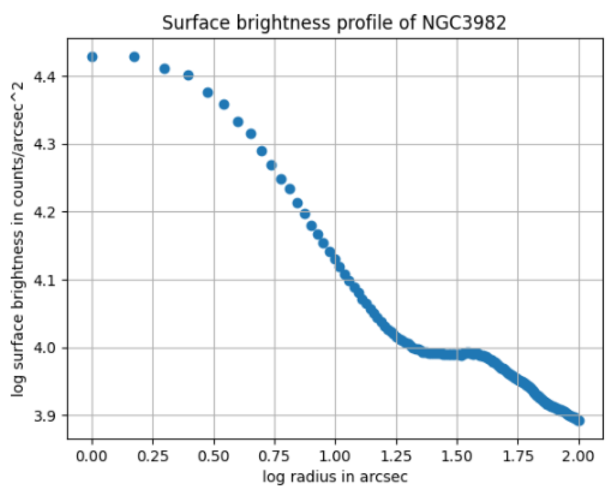

Figure 3: Surface-brightness profile of NGC2865

To model the surface brightness profile with the appropriate sersic index, curve fitting techniques from the python can be used. The in-built one-dimensional sersic function from the astropy [2] modelling and the curve fitting from the scipy [15] optimization package is ideal for the curve fitting. Using the appropriate bounds single sersic fit is obtained for the galaxy NGC3982 as shown in the figures 4 10 11.

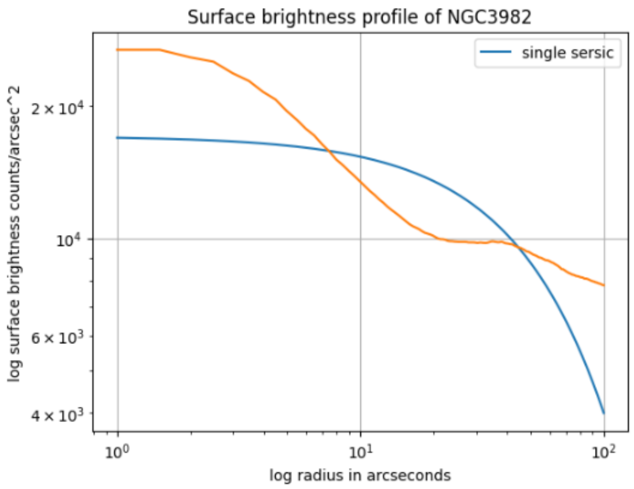

Figure 4: Sersic1D profile of NGC3982

The Sersic1D function can be modified to use it as double sersic function which includes the sersic function of bulge and disc of the galaxy. Using this double sersic function and appropriate bounds, double sersic profile can be generated and sersic indices of bulge and disc of the galaxy can be obtained as shown in the figures 5 6 7.

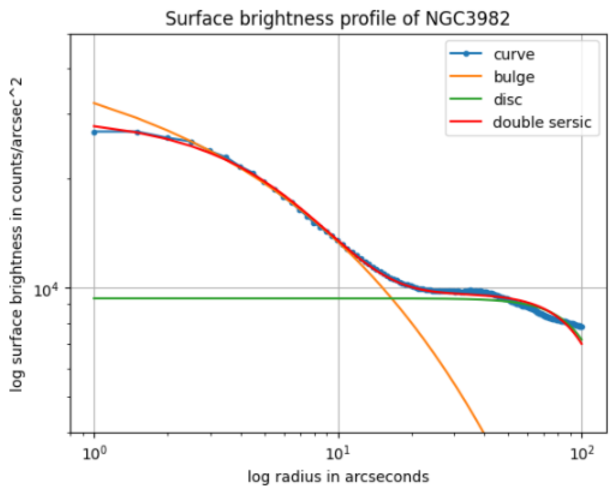

Figure 5: Double Sersic fit of NGC3982

III. Results:

The single sersic and double sersic profiles were calculated and the sersic indices were computed using the methodology above for the targeted galaxies NGC3982, NGC2865,

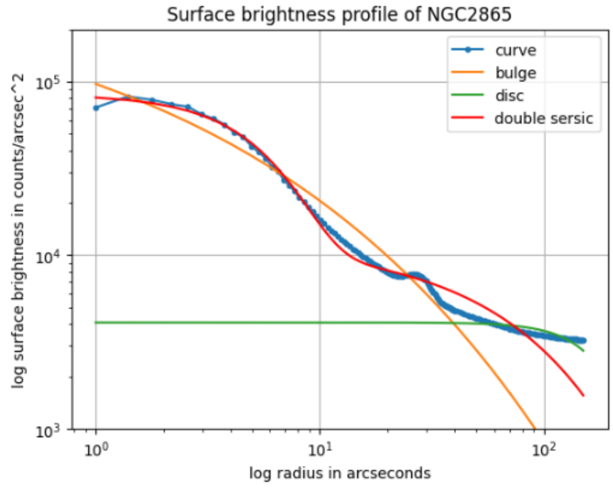

Figure 6: Double Sersic fit of NGC2865

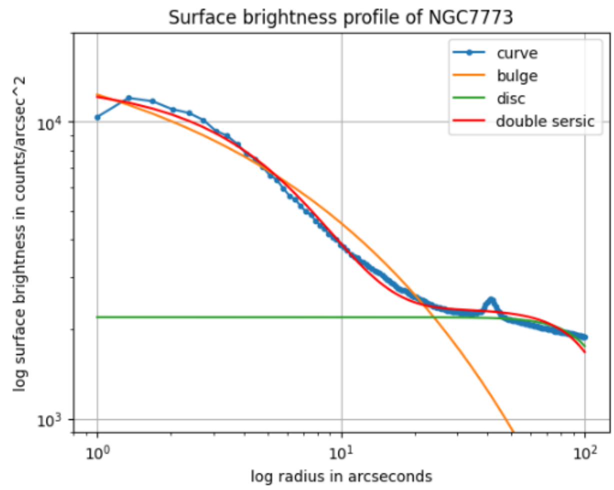

Figure 7: Double Sersic fit of NGC7773

and NGC7773. The obtained sersic indices of the galaxies provide various insights about the structural properties such as the edge of the galaxies and the edge of the bulge and disc. The sersic indices values of the targeted galaxies are given in the table below.

Galaxy	Type	Single Sersic	Bulge	Disc
NGC3982	spiral	0.8	2.1	0.2
NGC2865	elliptical	2.4	3.1	0.3
NGC7773	barred-spiral	1.9	2.3	0.2

IV. Discussion and Conclusion:

The Sersic index typically ranges from 0.5 to 10 for galaxies. The galaxies with higher value indicates that light is more concentrated at the center of the galaxy.

For NGC3982, an intermediate spiral galaxy, the sersic index falls in the range 1 to 4, and the sersic index of bulge is 1.9 according to the fisher [8] which is close to the sersic index that was calculated using the observational data from the LCO.

For NGC2865, an elliptical galaxy, typically has higher sersic index since the light is more concentrated at the center of the galaxy[10]. The higher values of the sersic indices from the table shows that the value is closely approximated.

For NGC7773, a barred-spiral galaxy, which exhibits a higher level of light concentration at the center of the galaxy since the sersic index value is higher than the NGC3982.

Finally, we can conclude that the results are promising but the values can be approximated precisely with more data points taken from the bulge than the disc of the galaxies. Different approximating and curve-fitting techniques can be implemented to get more accurate sersic index values.

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V. Appendices

V.1. Surface brightness profiles

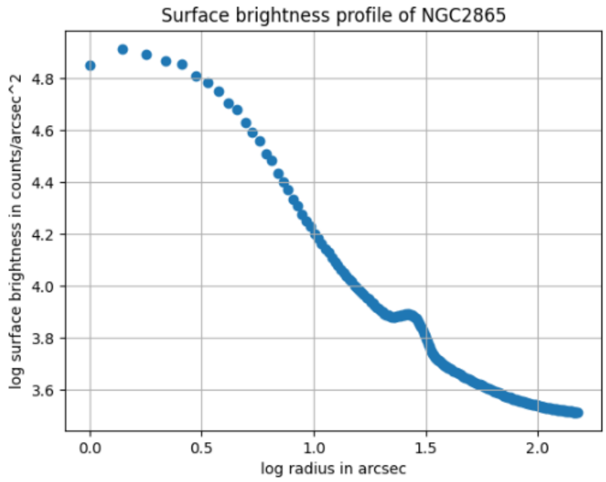

Figure 8: Surface-brightness profile of NGC2865

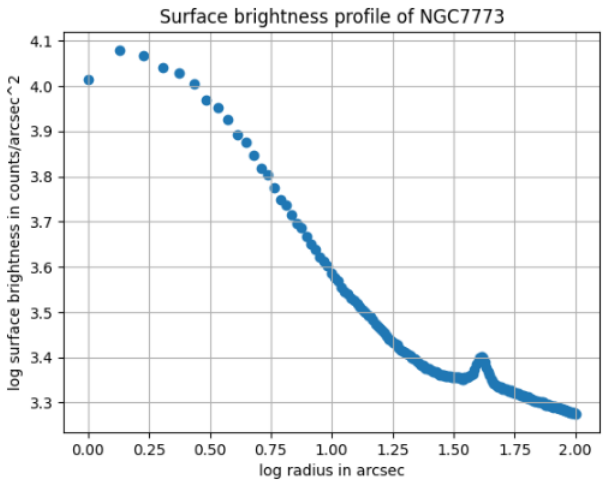

Figure 9: Surface-brightness profile of NGC7773

V.2. Sersic 1D profiles

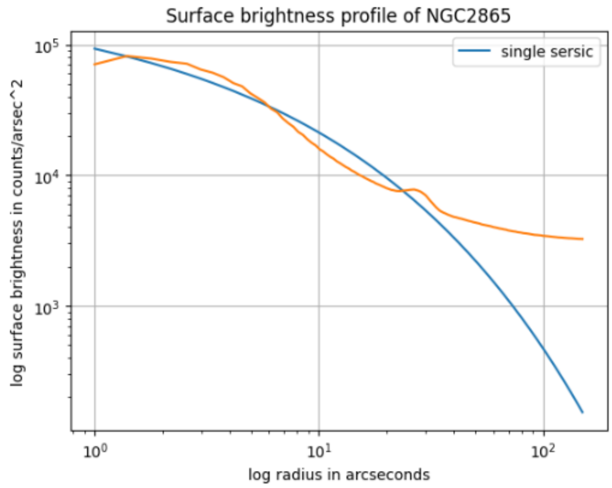

Figure 10: Sersic1D profile of NGC2865

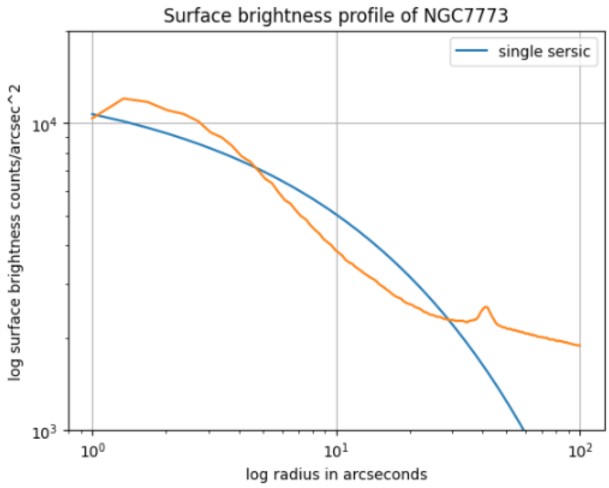

Figure 11: Sersic1D profile of NGC7773