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Comparison of the Structure of Spiral and Lenticular Galaxies, NGC 4305 and NGC 4203 as a Sample

Abdullah K Ahmed
Astronomy and Space Department, College of Sciences, University of Baghdad, Baghdad, Iraq

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Abstract

Photometric techniques are one of the fundamentals and of great importance in the study of astronomical phenomena, including galaxies, and have witnessed a wide development during the last 100 years in equipment, sensitivity and accuracy in data analysis, especially after the direction toward space telescopes and the widespread use of a CCD camera. Therefore, in this research, an analytical study is made to compare two types of galaxies, which are spiral and lenticular galaxies, using photometric techniques and compare the photometric parameters of each type with tables and illustrations. An analysis of the morphological of the two galaxies is done by using the Least Square Fitting Method, and it is fully explained in the research. The results show the clear difference between the structure of spiral and lenticular galaxies.

Keywords: Photometry, Galaxy, Galaxy Classification, Galaxy Morphology, NGC 4305, NGC 4203

مقارنة بين بنية المجرات اللولبية والعدسية، *NGC 4305* و *NGC 4203* كعينة

عبدالله كامل أحمد

قسم الفلك والفضاء, كلية العلوم, جامعة بغداد, بغداد, العراق

الخلاصة

تقنيات القياسات الضوئية هي من الأساسيات وذات أهمية كبيرة في دراسة الظواهر الفلكية ومن ضمنها المجرات وقد شهدت تطورا واسعا خلال ال ١٠٠ سنة الأخيرة في المعدات والحساسية والدقة في تحليل البيانات خصوصا بعد التحول باتجاه التلسكوبات الفضائية وإستخدام الـ CCD كاميرا بشكل واسع.

لذا سيتم في هذا البحث عمل دراسة تحليلية للمقارنة بين نوعين من المجرات وهي المجرات اللولبية والمجرات العدسية باستخدام تقنيات القياس الضوئي حيث تم دراسة علم الهيئة لنموذجين من المجرات وهي NGC 4305 و NGC 4203 كنماذج عن النوعين ومقارنة معلمات القياسات الضوئية لكل نوع مع الجداول والرسوم التوضيحية وكذلك عمل تحليل للتركيب العام للمجرتين من خلال استخدام تقنية الـ Least Square Fitting وتم توضيحها بشكل كامل في البحث. وقد أظهرت النتائج الفرق الواضح بين تركيب المجرات اللولبية والعدسية.

*Email: abdullah.ahmed@sc.uobaghdad.edu.iq

1. Introduction

This work is one of the public studies of the photometric analysis of the galaxies and comparison of the different structures of the galaxies and the different types of them. Hubble (1926, 1936) [1], [2] was the first who used a criteria to classify spiral galaxies which was known as the Hubble Classification. Based on the structural forms of photographic plates images, Hubble's first criterion was the relative size of the nuclear region, and the others were the degree of resolution and the wrap of spiral arms, going from (early-type) Sa to (late-type) Sc. This was the beginning of the galaxy morphological and photometric studies, then studies developed in every branch of galaxies and in all wavebands and spectroscopy and many astronomers and astrophysicists were interested in this topic.

Sandage (1961) [3] noted in the Hubble classification of galaxies that Sa type could exist with both large and small bulges, then Van den Bergh (1997) [4], Simien and de Vaucouleurs (1986) [5] were bold enough to try to place this trend of decreasing bulge-to-galaxy luminosity ratio with increasing galaxy type on a quantitative basis [6] and references there in; as well as at the present time, studies have developed in various fields to study galaxies and their diversity, including, for example: Adnan and Ahmed(2018) studied the overall structure of two galaxies with their photometric parameters [7]; Al-Baqir, Ahmed and Gamal(2019) studied the surface photometry of NGC 3 using griz filter from Sloan Digital Sky Survey (SDSS) [8]. Al Najm (2020) dealt with the molecular gas in extragalactic data selected from the Herschel SPIRE/FTS archive [9]; (2019) made a statistical study for an active galactic nuclei sample of different types of active galaxies [10], Kareem and Rashed(2021) studied the correlation between the supermassive black hole (SMBH) and the star formation rate (SFR) for a sample of Seyfert galaxies types (I and II) [11].

In this research, the photometric analysis examines and analyzes two types of galaxies with detailed surface photometry with IRAF (Image Reduction and Analysis Facility) to show the differences between two galaxies from different types of classification; which is as follows:

1.1 NGC 4305

Is a dwarf spiral galaxy [12] located in the direct of Virgo constellation. The galaxy was discovered by John Herschel 1829 [13]; although considered to be a member of the Virgo Cluster. This galaxy is of type SA(r)a or later. It has a nearby major companion at 40 Mpc and with a large radial velocity, is almost certainly a background galaxy. It has a major tidal companion NGC 4306 and a blue colour for its luminosity, assuming it is indeed far behind Virgo, confirming the tidal origin of its gas deficiency [14]. See also, for more details, Figure 1a &Table 1.

1.2 NGC 4203

Is a lenticular galaxy in the constellation of Coma Berenices. It was discovered in 1787 by William Herschel [15], and is situated 5.5° to the northwest of the star γ Comae Berenices [16]. The morphological classification of NGC 4203 is SAB0− [17], indicating that it has a lenticular form with tightly wound spiral arms and a weak bar structure at the nucleus [18]. See also, for more details, Figure 1b &Table 1.

Table 1: Brief description of the galaxies from NASA/IPAC Extragalactic Database [NED]

Abbreviations	NGC 4305	NGC 4203
Classification	SA(r)a	SAB0-
m_B, mag	12.89	11.65*
M_B ,mag	-20.22*	-19.23
R, Mpc	40.74*	12.90
D_{25}, arcsec	143.50	210
i, deg	64.4*	90*
b/a	0.6	0.93
PA, deg (J2000)	30	10.2*

** HyperLeda, Database for physics of galaxies*

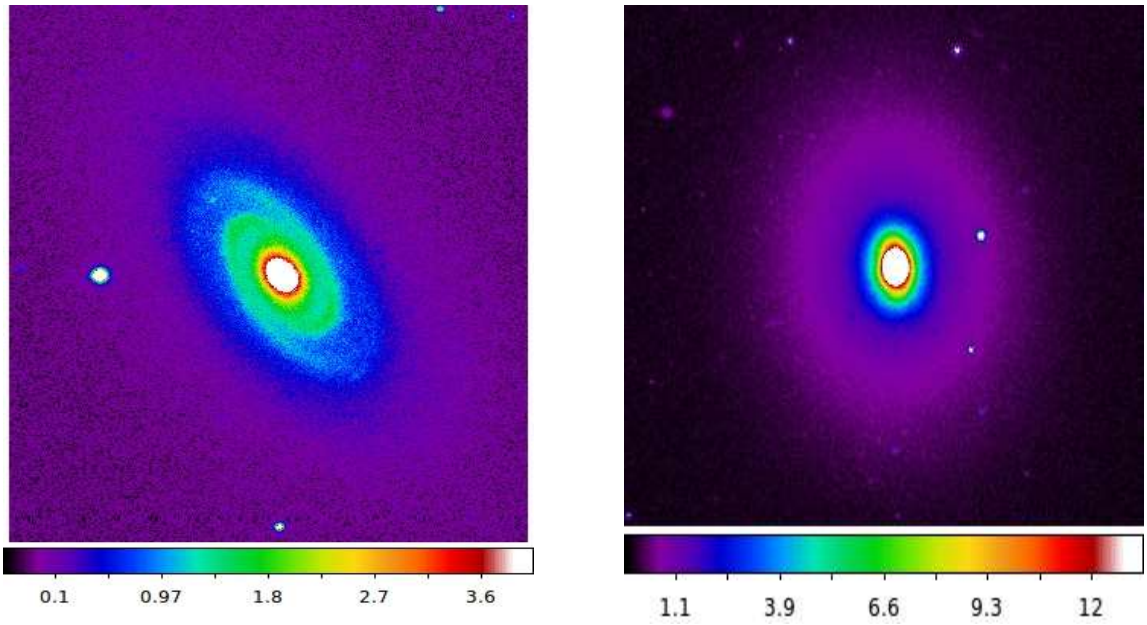

Figure 2: This figure depicts a high-resolution faked color image of galaxies of JPEG file, left NGC 4305, right NGC 4203. North is up and east is at west

2 Observations and Data Reduction

These galaxies were observed by The Sloan Digital Sky Survey (SDSS) which uses a dedicated wide-field 2.5 m telescope, located at Apache Point Observatory (APO) near Sacramento Peak in Southern New Mexico. The telescope uses two instruments. The first is a wide-field imager with 24 2048×2048 CCDs on the focal plane with 0.396" pixels that covers the sky in five filters in the order ugriz. The effective exposure time per filter is 53.9 s, and 18.75 deg^2 are imaged per hour in each of the five filters. The resulting catalogues are stored and distributed via a database accessible on the Catalogue Archive Server(CAS), and the images and flat files are available in bulk through the Data Archive Server(DAS) [19].

The further reduction of the CCD images were carried out at the Astronomy and Space Department, College of Science, University of Baghdad using the standard procedures in the IRAF[1] the Image Reduction and Analysis Facility Package. The main stages of the reduction included the subtracting of the sky background for each image by choosing empty regions in the

image frame far from objects and measures its average intensity value, transforming the counts to a logarithmic scale (magnitudes per square arcsec) based on the results of the photometric calibration, correcting for the air mass, normalized for one second by dividing frames with the exposure time value given in the frame header, and correcting for atmospheric extinction, galactic extinction and transformation to the standard system (using the zeropoint, atmospheric extinction and airmass of the SDSS photometric system at the time of observation) by multiplying the counts by the factor F:

$$F = 10(Z_p + K \times airmass) \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where Z_p and K are the zeropoint magnitude and the atmospheric extinction, respectively. Table 2 lists these values for each galaxy.

Table 2: The zeropoint, Atmospheric Extinction and Airmass from the SDSS photometric system in g-Band

Object	Zeropoint	Atmospheric Extinction	Airmass
NGC 4305	-24.36310	0.2327950	1.24
NGC 4203	-24.4437	0.143135	1.44

3. Results and Discussions

3.1 Morphological and Contoural Results

NGC 4305 represents a spiral galaxy with a bulge to about 3.95" with a faint disk to about 119.2" , the magnitude of surface brightness and apparent magnitude of the outer isophot of NGC 4305 galaxy are 26.12 and 24.11, respectively with 1.56 steps from outer to inner. The arms are highly visible, strongly wrapped up, and extend to the end of the galaxy.

NGC 4203 represents a lenticular galaxy with a bulge to about 4.6" with a bright disk to about 130" , the magnitude of surface brightness and apparent magnitude of the outer isophot of NGC 4203 galaxy are 22.62 and 24.63, respectively with 0.91 steps from outer to inner. There is no evidence for the arms in the galaxy, just a disk extending to the end of the galaxy.

For more details about the galaxies see Figures 1 & 2 and Table 3 which represent the color image and isophotal contour maps of two galaxies.

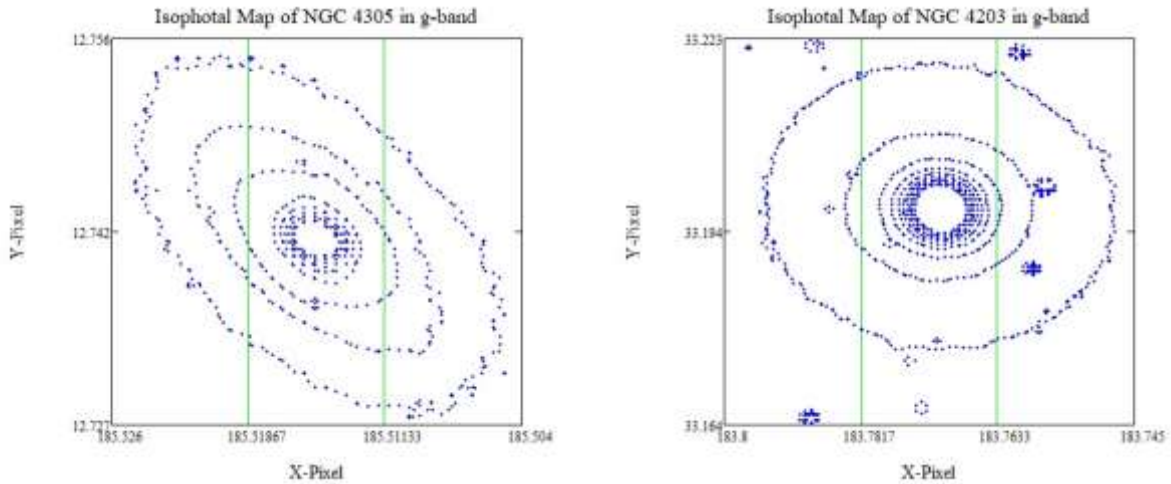

Figure 2: Isophotal contour maps of: Left NGC 4305 Spiral galaxy, Right NGC 4203 lenticular galaxy in g-Band

Table 3: Magnitudes, Surface Brightness, and Intensity for each Isophot of Galaxies from outer to inner

Object		Isophots Numbers								
		1	2	3	4	5	6	7	8	9
NGC 4305	*Magnitude*	26.12	24.57	23.95	23.56	23.28	23.05	22.86	22.70	22.56
	Surface Brightness	24.11	22.56	21.94	21.55	21.27	21.04	20.85	20.69	20.55
	Intensity	0.15	0.64	1.12	1.60	2.09	2.57	3.05	3.54	4.02
NGC 4203	*Magnitude*	24.63	23.72	23.23	22.89	22.64	22.44	22.26	22.11	21.98
	Surface Brightness	22.62	21.71	21.22	20.89	20.63	20.42	20.25	20.1	19.97
	Intensity	0.69	1.61	2.52	3.44	4.35	5.26	6.18	7.09	8.00

3.2 Surface Brightness Profiles Fitting

The surface brightness profiles fitting of the NGC 4305 spiral galaxy and NGC 4203 lenticular galaxy have been decomposed with g-Filter into a bulge which described by de Vaucouleurs law ($r^{1/4}$ law), whereas, the surface brightness distribution in elliptical galaxies and bulge of spiral galaxies essentially depends only on the distance from the center and the orientation of the major and minor axes. If $(\boldsymbol{r})$ is the radius along the major axis, the surface brightness $\boldsymbol{\mu_{bulge}(r)}$ is well described by de Vaucouleurs' law, Equation 2 [20]:

$$\boldsymbol{\mu_{bulge}(r) = \mu_e + 8.3268\left[\left(\frac{r}{r_e}\right)^{1/4} - 1\right]} \quad \text{.....(2)}$$

While the disk follows an exponential brightness profile as in Equation 3 [20]:

$$\boldsymbol{\mu_{disk}(r) = \mu_0 + 1.09\left(\frac{r}{r_0}\right)} \text{.....(3)}$$

Where, $\boldsymbol{\mu_e}$ is the surface brightness at the effective radius $\boldsymbol{r_e}$ which is described by a half of the brightness emitted. The central surface brightness and the scale-length of the disk are denoted by $\boldsymbol{\mu_0}$ and $\boldsymbol{r_0}$, respectively [20].

The results from the decomposition and the residuals values from fitting are shown in Figure 3 for g-Filter, and are also summarized in Table 4, the surface brightness profiles of two galaxies show that the outer disk were of type I Freeman [21]. Through the results of the previous decomposition, it is clear that there is a disky system for both galaxies, but they differ in the degree of brightness and the presence of arms.

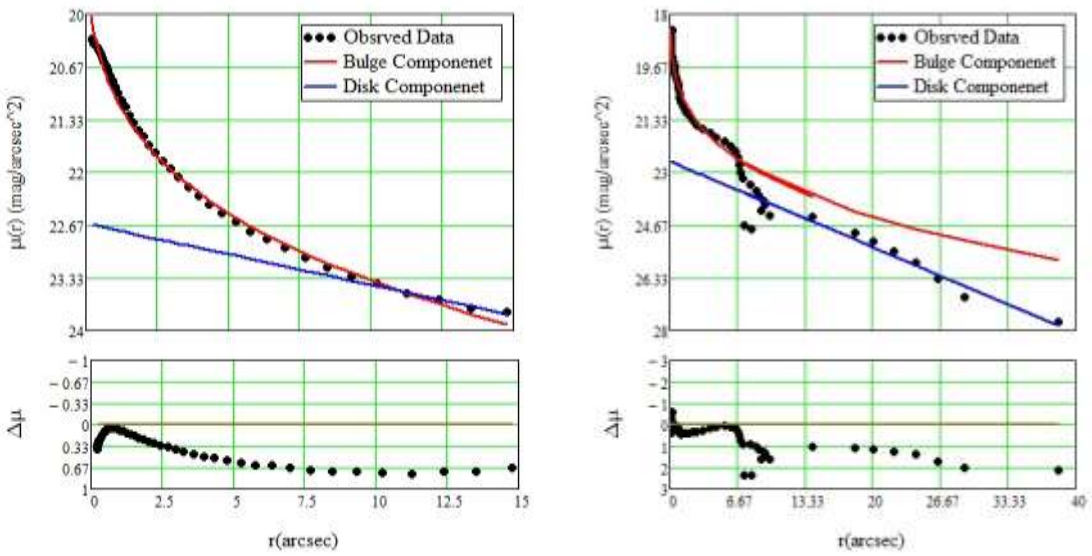

Figure 3: Surface brightness profiles fitting of the components of galaxies left: NGC 4305, right: NGC 4203 in g-Band.

Table 4: Fitting parameters of the galaxies decomposition in g-Band.

Fitting Parameters	NGC 4305	NGC 4203
r start bulge, arcsec	0.22	0.05
r end bulge, arcsec	9.30	6.76
Surface brightness effective(μ_e) ,mag.arcsec^2	26.33	25.10
Effective radius(r_e), arcsec	57.90	28.31
Standard error, arcsec	0.04	0.08
r start disk, arcsec	10.22	6.81
r end disk, arcsec	14.76	38.35
Central surface brightness(μ_0) ,mag.arcsec^2	22.65	22.66
Scale-length of the disk(r_0), arcsec	14.04	8.04
Standard error, arcsec	0.01	0.19
Total magnitude of bulge, mag	14.13	14.45
Bulge to Disk ratio B/D	1.09	2.5

3.3 Photometric Parameters Results

The photometric parameters profiles of semi major-axis of two galaxies were obtained as a function of the distance from the centre of the galaxies r^*, and are illustrated in Figure 4.

As seen from the profiles, the PA were fluctuated from the centre of two galaxies to about 2.2" with 56° for NGC 4305, while for NGC 4203 to about 3.95" with 140.9°; then became more or less steady to about 55.8±11° for NGC 4305 and 146±13° for NGC 4203.

The ellipticity profiles of NGC 4305 were fluctuated too from 0.083 to 0.25 to about 3.26", while the profiles of NGC 4203 were fluctuated from 0.2 to about 0.06, then became more steady to the end of two galaxies with average values 0.24±0.1 and 0.12±0.05 for NGC 4305 and NGC 4203, respectively. The mean values of ellipticity used in Equation 4 [22] to calculate the inclination of the disks which is found to be 78±0.05° and 28±7° for NGC 4305 and NGC 4203 respectively.

$$cos^2 i = \begin{cases} \frac{(1-\varepsilon)^2-0.2^2}{1-0.2^2} \; if & \varepsilon \leq 0.8, \\ 0 & otherwise. \end{cases} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

The fourth harmonic of the Fourier expansion (B4) profiles are illustrated in Figure 4 and presented in Table 5, which shows that the general trend of the two galaxies was a disky system. See Figure 4 and Table 5.

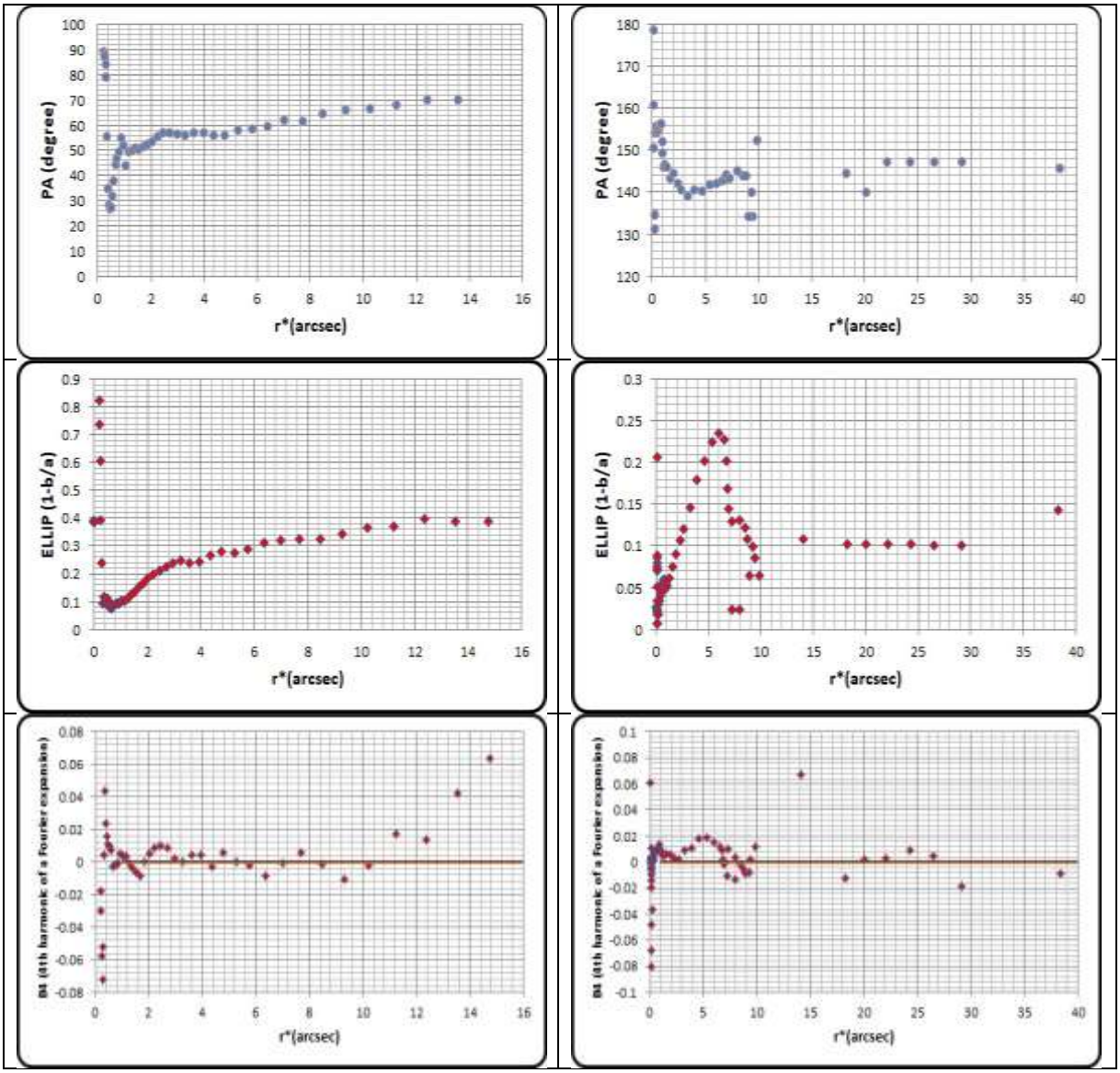

Figure 4: Photometric parameters profiles from up to down position angle, ellipticity, and B4 left: NGC 4305, right: NGC 4203 in g-Band.

Table 5: Photometric parameters of the galaxies: position angle, ellipticity, B4, and inclination in g-Band.

Photometric Parameters	NGC 4305	NGC 4203
Position Angle(PA), deg	55.8±11	146±13
Ellipticity(ε)	0.24±0.1	0.12±0.05
Fourth harmonic of the Fourier expansion(B4)	0.007	0.0009
Inclination(i), deg	78±0.05	28±7

4. Conclusions

Surface photometry with a g-Filter was reported here for spiral and lenticular galaxies to make a comparison between these two types of galaxies, NGC 4305 spiral galaxy and NGC 4203 lenticular galaxy as a sample. The photometric analysis examined and analyzed the two types with detailed surface photometry with IRAF (Image Reduction and Analysis Facility) to show the differences between these samples which represented different types of classification.

The overall structure of the galaxies have been analyzed and performed a bulge/disk decomposition of the galaxy images, and analyzed the structure of the galaxies and refined the model parameters describing the disk and bulge using the Least Square Fitting Method,
The main results of this paper include the following:

1. NGC 4305 represents a spiral galaxy with a bulge to about 3.95" with a faint disk to about 119.2" , the arms are highly visible, strongly wrapped up, and extend to the end of the galaxy, while, NGC 4203 represents a lenticular galaxy with a bulge to about 4.6" with a bright disk to about 130",and there is no evidence for the arms in the galaxy, just a disk extending to the end of the galaxy. The difference was clear between the bulge and disk for each type of galaxies.
2. The surface brightness profiles of two galaxies which are the decomposition values from fitting with g-Filter show that the outer disks for two galaxies were of type I Freeman, and it is clear that there is a disky system for both galaxies, but they differ in the degree of brightness and the presence of arms.
3. Profiles of the PA were fluctuated from the center of two galaxies to about 2.2" with 56° for NGC 4305, while for NGC 4203 to about 3.95" with 140.9°; then became more or less steady to the end of galaxies. The ellipticity profiles of NGC 4305 were fluctuated too from 0.083 to 0.25 to about 3.26", while the profiles of NGC 4203 were fluctuated from 0.2 to about 0.06, then became more steady to the end of two galaxies. The mean values of ellipticity used in Equation 4 and calculate the inclination of the disks which is found to be 78±0.05° and 28±7° for NGC 4305 and NGC 4203 respectively. And from the fourth harmonic of the Fourier expansion (B4) profiles the general trend of the two galaxies were a disky system.

This was a general description of the two galaxies to illustrate the differences and similarities between the two types.

5. Acknowledgments

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