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Identify the differences between ordinary and barred spiral galaxies, NGC 2649 and NGC 4662 for examples

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Abstract

Since the beginning of mankind, the view of the sky was present through observations with the naked eye, then it developed with time, and the sciences and tools of astronomical observations developed, including photometric measurements, which reached a high degree of accuracy in describing various cosmic phenomena, including the study of galaxies, their composition, and the differences between them, and from here the importance of this study emerged, to determine the differences between two distinct types of classification of galaxies, which are normal and barred spiral galaxies, where two galaxies NGC 4662 and NGC 2649 were chosen that represented certain types of galaxies to study the morphological structure of the two galaxies, as well as the photometric study of the composition of the two galaxies, where a contour map was drawn, as well as finding the values of the photometric variables of the two galaxies, including the position angle, the ellipticity and B4. A fitting was made for the two galaxies to show the fundamental difference in composition, through which the basic differences between two known types of galaxies could be identified.

Keywords: Galaxies, Spiral galaxies, Barred spiral galaxies, NGC 2649, NGC 4662, Surface photometry, SDSS.

تحديد الفروق بين المجرات الحلزونية العادية وذات النتوء، NGC 2649 و NGC 4662 مثالاً

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الخلاصة

منذ بداية البشرية كانت رؤية السماء حاضرة من خلال الرصد بالعين المجردة، ثم تطورت مع تطور الزمن، وتطورت كذلك علوم وأدوات الرصد الفلكي، بما في ذلك القياسات الضوئية، التي وصلت إلى درجة عالية من الدقة في وصف مختلف الظواهر الكونية، ومنها دراسة المجرات وتركيبها والاختلافات بينها، ومن هنا ظهرت أهمية هذه الدراسة، لتحديد الفرق بين نوعين متميزين من تصنيف المجرات، وهي المجرات الحلزونية العادية والمجرات الحلزونية ذات النتوء، حيث تم اختيار مجرتين NGC 4662 وNGC 2649 وتمثلان نوعين مختلفين من المجرات وذلك لدراسة البنية التركيبية للمجرتين، وكذلك دراسة التركيب الضوئي للمجرتين، حيث تم رسم خريطة كنتورية، وكذلك دراسة قيم المتغيرات الضوئية للمجرتين، بما في ذلك زاوية

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الموقع وشكل القطع الناقص و4B. وتم عمل ((Fitting curve للمجرتين لإظهار الفرق الأساسي في التركيب، والذي من خلاله يمكن التعرف على الاختلافات الأساسية بين النوعين من المجرات.

1. Introduction

This present research constitutes a single of the public ones that compares the various galaxies' shapes and characteristics using photometric examination of the galaxies. In order to categorised spiral galaxies, Hubble in 1926 and 1936 was the initial scientist to draw on what has since become known as the Hubble Classification[1, 2]. According to the fundamental components of images captured on photographic plates, Within Hubble's categorization of galaxies, De Vaucouleurs in 1959 proposed an expanded version of Hubble's approach through adding a variety scale[3]. Sandage and Van den Bergh in 1961 and 1997 identified how the Sa class might have massive and tiny bulges[4, 5]. Laurikainen in 2007 and 2010 examined the characteristics of bulges and bars in the Hubble series as well as photometric scales relationships for lenticular galaxies and contrasted them to those established for spirals [6, 7]. In 2013 Buta improved the Hubble Categorization along with added extra categories[8]. Furthermore, currently, investigations across different domains have arisen to examine galaxies and their range of characteristics, such as: Rashed and others in 2013 used the information collected from visible and radio wavelengths to estimate the fundamental characteristics of an SDSS galaxies[9]; Mahdi in 2018 studied galaxies' bimodal distributions[10]; also, Rashed et al. in 2019 performed an exploratory statistical examination of an active galaxy nuclei from various kinds of active galaxy[11]; also, Al Najm in 2020 explored the molecular gases based on extragalactic information[12]; Kareem and Rashed in 2021 investigated the associations of supermassive black holes with the stars creation rates for Seyfert galaxies[13]; in 2023 Zamal and Al Najm employed broad band analytics to examine the physical characteristics of starburst galaxies[14]; and Ahmed in 2023 analysed the photometric patterns of a couple categories of galaxies spiral and lenticular[15]; Al-baqir and Ahmed in 2023 studied the spectroscopic and photometric characteristics of the SIP-39 galaxy pair[16].

1.1 NGC 2649 and NGC 4662

NGC 2649 is an -SAc- ordinary spiral-shaped galaxy[17] that lies within the Lynx constellation. The galaxy was first identified in 1788 as a result of John Herschel observation[18], at a distance of 65Mpc[19] and a diameter of 35 Kpc[20]. It was categorised as SAB (rs) bc by de Vaucouleurs et al.[21].

NGC 4662 was -SBc- Barred spiral-like galaxy [17], found within the Canes Venatici constellation. The galaxy was noticed in 1787 due to a John Herschel survey[22], at an approximate distance of 106 Mpc[19] and a diameter of 51 Kpc[23]. It was described as SB (rs) bc by de Vaucouleurs et al.[21]. In the present research, photometric analysis was utilized to compare these two types of galaxies which present ordinary and barred spiral galaxies; by applying Image Reduction & Analysis Facilities (IRAF).

2. Observations and, Data Reduction

2.1 Observations

Data for the galaxies NGC 2649 and NGC 4662 used in this research were taken from the Sloan Digital Sky Survey (SDSS) Data Release 7 [24]. The bias frame and flat field frame were corrected for all fits image using the SDSS pipeline.

2.2 Data reduction procedures

Data reduction was performed using the procedures in the IRAF-Package. The main reduction steps are as follows:

1. Sky background values are subtracted by the imarith task by choosing empty regions in the image far from objects and measuring their average value.
2- The Isophote ellipse-task is applied to obtain the structural profile parameters.
3. Transform from pixel units to arcsec^2: by dividing the scale (1 pixel = 0.396 arcsec for Apache Point Observatory (APO)).
5- Dividing frames by exposure time to convert to one second.
6- Correct image frames by using Zeropoint, Atmospheric extinction and Airmass of the SDSS photometric system at the time of observation.

3. Results and Discussion

3.1 Morphological Descriptions

The classification of the two galaxies is clear and beyond doubt that the galaxy NGC 2649 is an ordinary spiral galaxy devoid of any manifestations of the presence of the bar, unlike the NGC 4662 galaxy, which is a galaxy containing a bar that extends from the end of the bulge at 4.05" to about 7.05", and through the descriptive analysis of the shape of the two galaxies, have been noticed a clear effect of the bar on the general structure of the galaxy and the distribution of intensity, as well as the effect on the size and beginning of the wrapping of the spiral arms, which shows the clear relative difference in size between the bulge of the galaxy that contains bar and the other, and this can be clearly seen in Figures 1, 2 and 3, which shows the division of the two galaxies into a number of isophots and how the intensity, apparent magnitude, opening angle of the spiral arms, and surface brightness distribution change. See Table 1.

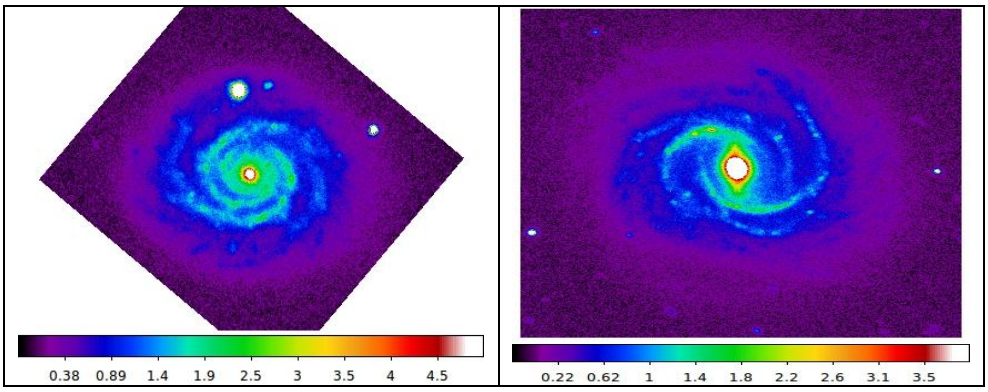

Figure 1: Fuzzy color images in g-band for NGC 2649 Left and NGC 4662 Right. North direction is up and East direction is at west**.**

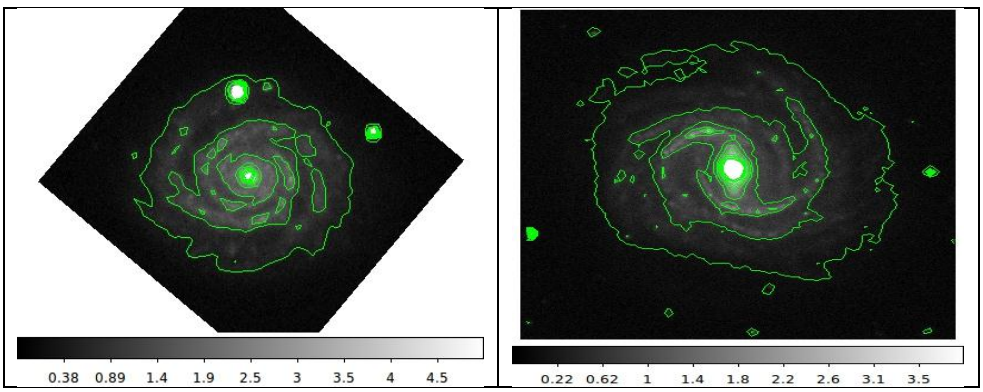

Figure 2: NGC 2649 Left and NGC 4662 Right contour maps with image background and gray level bar in g-band. North direction is up and East direction is at west.

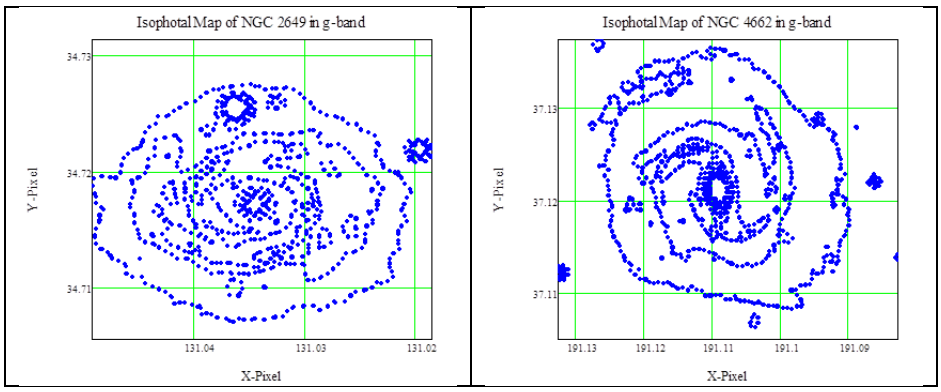

Figure 3: NGC 2649 Left and NGC 4662 Right contour maps in g-band with pixel positions. North direction is up and East direction is at west.

Table 1: Variations of photometric parameters with isophot number

Galaxy	Parameters	Isophot No.									
		0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
NGC 2649	Intensity	0.3	0.71	1.12	1.53	1.94	2.36	2.77	3.18	3.59	4
	Magnitude	25.29	24.35	23.86	23.52	23.26	23.05	22.88	22.73	22.59	22.48
	Surface Brightness	22.71	21.77	21.28	20.94	20.68	20.47	20.30	20.15	20.02	19.90
NGC 4662	Intensity	0.1	0.52	0.94	1.35	1.77	2.20	2.61	3.02	3.44	3.86
	Magnitude	26.76	24.97	24.33	23.93	23.64	23.41	23.22	23.06	22.91	22.79
	Surface Brightness	24.18	22.39	21.75	21.35	21.06	20.83	20.64	20.48	20.34	20.21

3.2 Surface Brightness Decomposition

The g-band equivalent surface brightness profiles were decomposed into the spheroidal (r^{14}) and disk (exponential) components using the least square fitting technique, equations 1 and, 2 respectively[25]:

$$log\ \mu_{Bulge}(r)/\mu_e = -3.33\left[\left(\frac{r}{r_e}\right)^{\frac{1}{4}} - 1\right] \quad (1)$$

$$\mu_{Disk}(r) = \mu_0\ exp\ exp\ (-r/\ r_0) \quad (2)$$

Where, r_e is the effective radius which represents half of the total luminosity of the bulge and μ_e is the effective surface brightness at that radius, where μ_0 and r_0 are the central surface brightness and the scale-length of the disk. The results of the decomposition are given in Figure 4 and Table 2, where the observed profiles (dots), and the bulge and disk components (red and blue lines) are shown. the decomposition profiles of the two galaxies show that the disks of these galaxies are of type II Freeman[26]. Through the results of the previous decompositions it is clear that there are a disky systems with a fundamental and clear difference in the size of the bulges and the beginning and size of the spiral arms, and they differ in the degree of brightness of bulges and disks, and the apparent magnitude of the bulges as well as the B/D ratios of the two galaxies which are determined and presented in Table 2 show that NGC 2649 galaxy is bulge dominant and NGC 4662 galaxy is disk dominant.

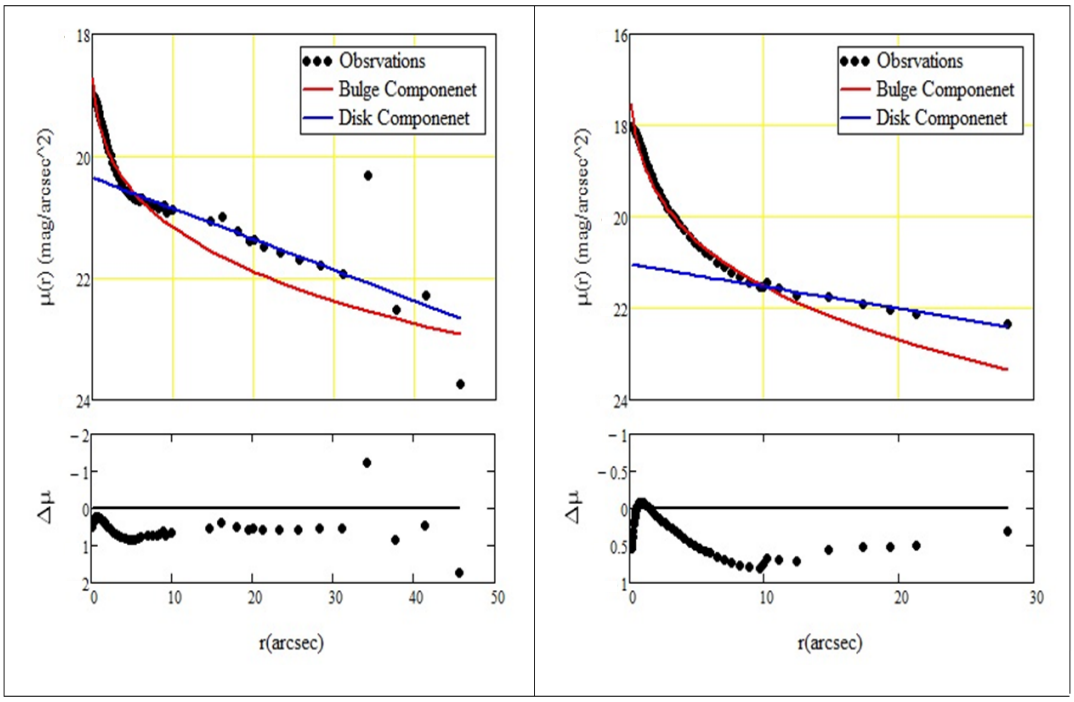

Figure 4: Surface brightness decomposition of two galaxies; NGC 2649 Left and NGC 4662 Right.

Table 2: Surface brightness decomposition parameter values.

	Parameters									
Galaxy	r_s Bulge	r_{end} Bulge	μ_e	$r_{effec.}$	r_s Disk	r_{end} Disk	μ_0	r_0	m_{Bulge}(mag)	B/D
NGC 2649	0.168	5.43	25.7	232.8	5.89	45.5	20.36	21.5	10.5	1.6
NGC 4662	0.19	9.7	23.6	31.6	9.97	28.1	21.05	22.56	12.7	0.36

3.3 Elliptical isophote analysis parameters

The g-band of NGC 2649 and NGC 4662 were analyzed by using fits a set of elliptical isophotes over an image of galaxies by ellipse task in the STSDAS isophote package (The Space Telescope Science Data Analysis System) in IRAF. The isophotal parameters of the best fit ellipses are listed in Table 3 and illustrated graphically in Figures 5, 6, and 7. The three curves clearly show that these two galaxies have a fundamental difference in their structure due to the presence of the bar; the galaxy NGC 2649 shows a clear behavior of a spiral galaxy, and through the photometric parameters, it appears clear that the position angle (PA) and ellipticity have a normal behavior, and from the fourth harmonics of a fourier exparsion profile (B4) is a disky system, however, NGC 4662 behaves close to the behavior of elliptical galaxies because of the presence of the bar, where we see very little change in the values of PA and ellipticity, and the galaxy shows behavior of a boxy system.

Table 3: Isophotal parameters of the best fit ellipses values

	Parameters				
Galaxy	r_{start}	r_{end}	*Average PA*	*Average Ellipticity*	*Average B4*
NGC 2649	8.26	45.5	85.7±20	0.22±0.13	0.017
NGC 4662	30.6	60.05	37.4±16.4	0.15±0.07	-0.0005

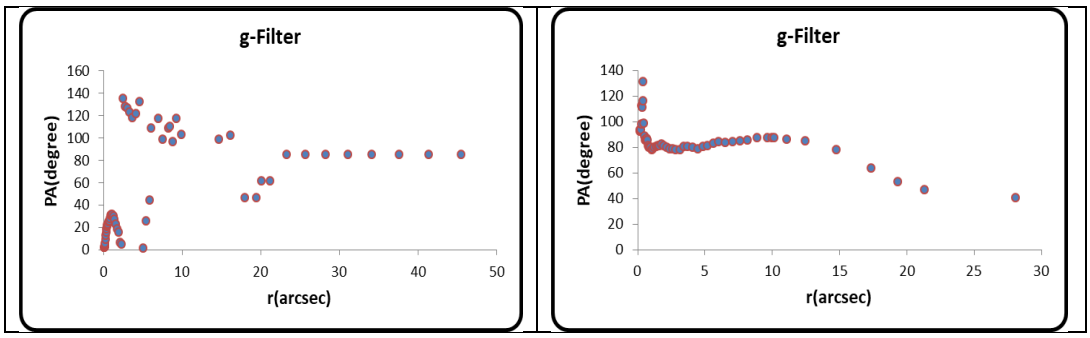

Figure 5: Position angle profiles; NGC 2649 Left and NGC 4662 Right.

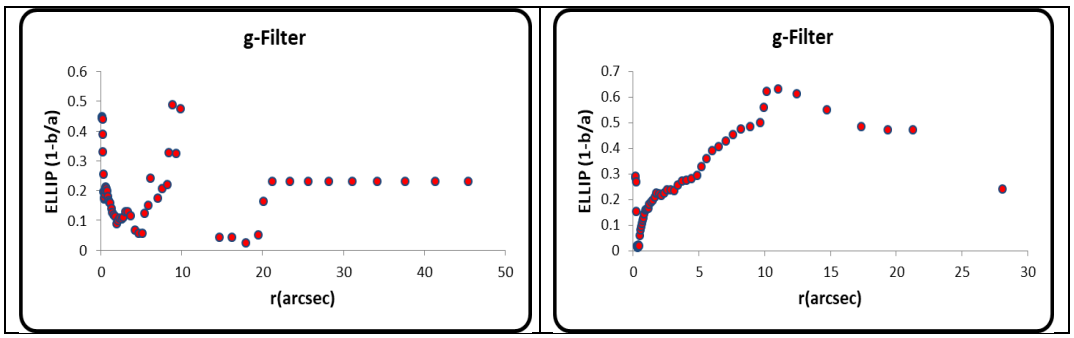

Figure 6: Ellipticity profiles; NGC 2649 Left and NGC 4662 Right.

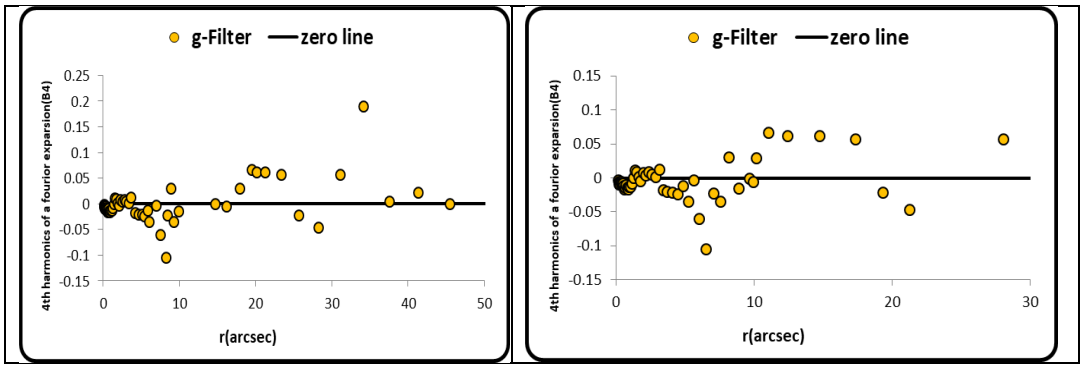

Figure 7: The fourth harmonics of a fourior exparsion profiles; NGC 2649 Left and NGC 4662 Right.

4. Conclusion

Surface photometry is a powerful tool to study the structure of galaxies, likewise, comparative studies have a major role in explaining the difference between different types of galaxies. For this investigation, we used a sample of two spiral galaxies; NGC 2649 which represents a normal spiral galaxy and NGC 4662 which is a barred galaxy. For each galaxy, the isophotal maps, the profile decomposition of the surface brightness, PA, ellipticity, and B4 are obtained and discussed; and from the descriptive analysis of the shape of the two galaxies, have been noticed a clear effect of the bar on the general structure of the galaxy and the distribution of intensity, as well as the effect on the size and beginning of the wrapping of the spiral arms. From the apparent magnitude of the bulges as well as the B/D ratios of the two galaxies show that the NGC 2649 galaxy is bulge dominant and the NGC 4662 galaxy is disk dominant. Through the photometric parameters, it appears clear that the position angle (PA) and Ellipticity have a normal behavior for NGC 2649, and from 4th Harmonics of a Fourier Expansion Profiles (B4) it is a disky system, however, NGC 4662 because of the presence of the bar, it behaves close to the behavior of elliptical galaxies, where we see very little change in the values of PA and Ellipticity, and from (B4) the galaxy shows behavior of a boxy system.

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