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Surface Photometry of Spiral Galaxy NGC 5005 and Elliptical Galaxy NGC 4278

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Abstract:

Two galaxies have been chosen, spiral galaxy NGC 5005 and elliptical galaxy NGC 4278 to study their photometric properties by using surface photometric techniques with **griz**-Filters. Observations are obtained from the Sloan Digital Sky Survey (SDSS). The data reduction of all images have done, like bias and flat field, by SDSS pipeline. The overall structure of the two galaxies (a bulge, a disk), together with isophotal contour maps, surface brightness profiles and a bulge/disk decomposition of the galaxy images were performed, although the disk position angle, ellipticity and inclination of the galaxies have been estimated.

Keywords: *CCD Photometry, Elliptical galaxy, NGC 4278, NGC 5005, Spiral Galaxy.*

Introduction:

Spiral barred galaxy ***NGC 5005*** is an inclined ***SAB(rs)bc*** Seyfert, at a distance of D = 16.9±6.7 Mpc, with a broad-line LINER (low-ionization nuclear emission line regions) nucleus(1, 2), this system is clearly inclined, bright, elliptical bulge with a flattened nuclear region. Bulge is threaded by a bar with a P.A. incline approximately 30º from that of the bulge. The outer bulge isophotes are boxy. There are two ansae near the ends of the bar, two very narrow spiral arms. However, the outer arms tighten and appear to wrap several times around the system. The outer disk shows an occasional knot, but there is no coherent star-forming pattern associated with the outer arms(3). The nucleus has a very broad dust lane obscuring the north part of the image. A spiral arm is visible to the south, with several isolated star clusters and richer star-forming regions(4) as shown in Fig. 1.

Elliptical galaxy ***NGC 4278*** is the brightest of a member that includes elliptical galaxy NGC 4283 and spiral galaxy NGC 4286, which may form a physical group. The Digitized Sky Survey image (DSS) shows that the galaxy has a round, bright core with an extensive, fainter outer envelope, the many bright knots in and around the outer halo are the system's globular clusters(5).

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From the SLUGGS (SAGES Legacy Unifying Globulars and GalaxieS) survey, the galaxy was noted to have declining spin profiles at a large radii by Bellstedt et al. (2017)(6). This galaxy is classified as elliptical galaxies, with circularised effective radii (R_e) of 28.3"(7), as demonstrated in Fig. 2.

Some basic properties of two galaxies are shown in Table 1.

Table 1. Some Basic parameters of the studied galaxies.

Characteristics	NGC 5005	NGC 4278
type	*SAB(rs)bc*	*E1-2*
B_T^o**, mag**	*10.19*	*10.97*
M_{BT}^o**,mag**	-	-
	21.96±0.102[a]	*20.43±0.174*[a]
V_{hel}**, km/sec**	*946±5 km/s*	*620±5 km/s*
D, M_{Pc}**(**H_0 **=73±5 km s**$^{-1}$ **Mpc**$^{-1}$**)**	*13.6±1.0*	*8.48±0.60*
d_{25}**,arcmin minor**	*2.8*	*3.8*
d_{25}**,arcmin major**	*5.8*	*4.1*
i, deg	*61*	*21*
Axis Ratio (b/a)	*0.48*	*0.93*
P.A., deg[J2000]	*65*	*28*
RA(2000)	*13h10m56.2s*	*12h20m06.8s*
DEC(2000)	*+37d03m33s*	*+29d16m51s*

[a] HyperLEDA(Makarov et al. 2014)(8).

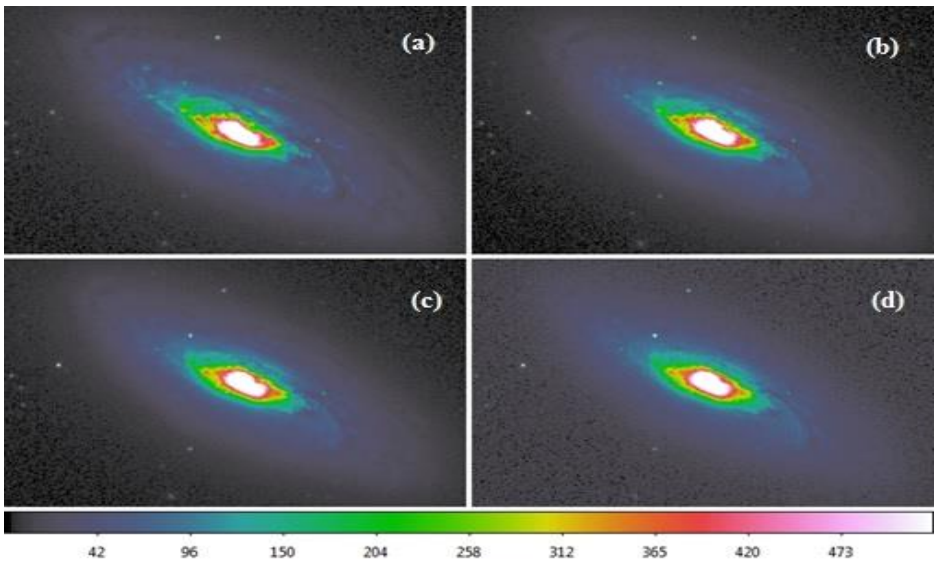

Figure 1. Fuzzy Color images of Spiral galaxy NGC 5005 with griz-Filters, from (a to d) respectively. North is up and East is at left, with Color bar in intensity unit from low amount to high.

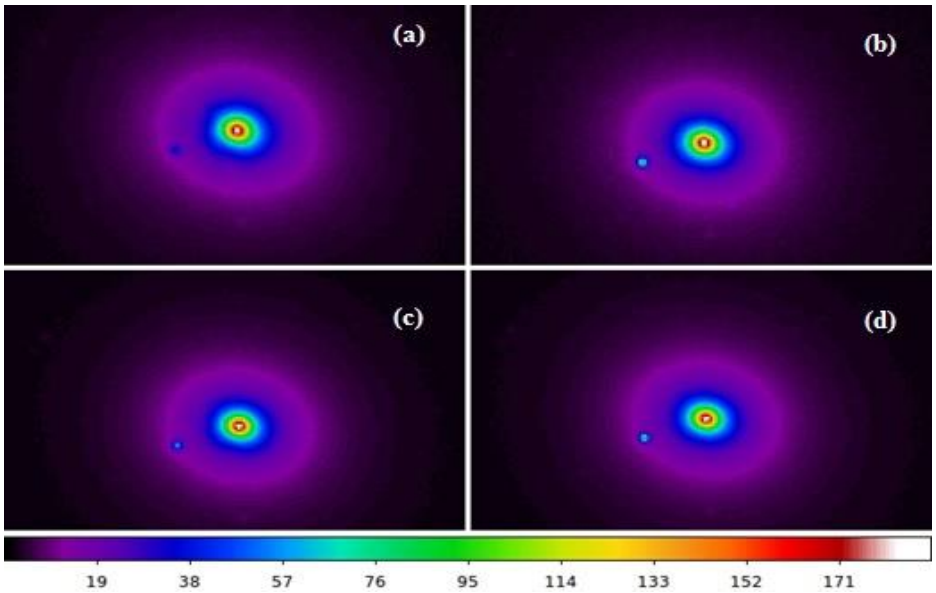

Figure 2. Fuzzy Color images of Elliptical galaxy NGC 4278 with griz-Filters, from (a to d) respectively. North is up and East is at left, with Color bar in intensity unit from low amount to high.

Observations and Data Reduction

The galaxy images are obtained from the Sloan Digital Sky Survey (SDSS) Data Release(9). All the images are corrected for bias and flat field by SDSS pipeline. Table 2 shows the Data observations.

Table 2. Data observations

Galaxy name	SDSS Name	Observation Date	Fits File Name
NGC 5005	J131056.27+370332.3	2004-03-16	fpC-004504-*x*4-0239.fit
NGC 4278	J122006.82+291650.5	2004-05-23	fpC-004649-*x*2-0026.fit

** x is the filter name which may be u, g, r, i, or z.*

The subsequent reduction of the data was carried out using the standard procedures in the IRAF image-reduction Package. The main reduction steps are:

1. The contribution of the sky background signals is subtracted by choosing empty regions in the image frame far from objects and measures its average intensity value.
2. Masking is done for the superimposed and nearby objects, stars or galaxies as shown in Fig. 3 and 4. The IRAF ISOPHOTE ELLIPSE task is applied to obtain the intensity and structural profiles.
3. For each intensity profile, the following steps are done before fitting:

a- Conversion from pixel units to arcsec^2: by dividing the scale (1 pixel = 0.396" for Apache Point 2.5m Observatory in the Sacramento Mountains in Sunspot, New Mexico, United States (APO)).

b- Normalization for exposure: by dividing frames by the exposure time value given in the header (the value is the same for all filters, it equals 53.907456 seconds).

c- Correction 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 where:

$$f = 10^{(z_p + k*airmass)} \quad \ldots\ldots(1)$$

Where zp and k are the zeropoint magnitude and the atmospheric extinction, respectively. Table 3 lists these values for the galaxy in each filter.

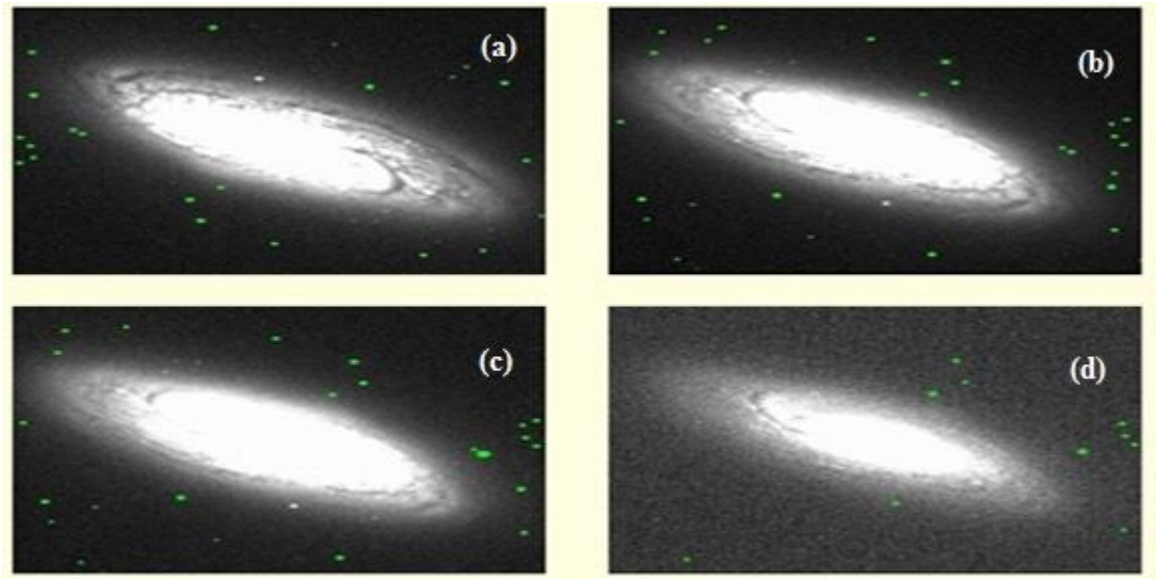

Figure 3. Spiral galaxy NGC 5005 images with masking in griz-Filters, from (a to d) respectively. North is up and East is at left.

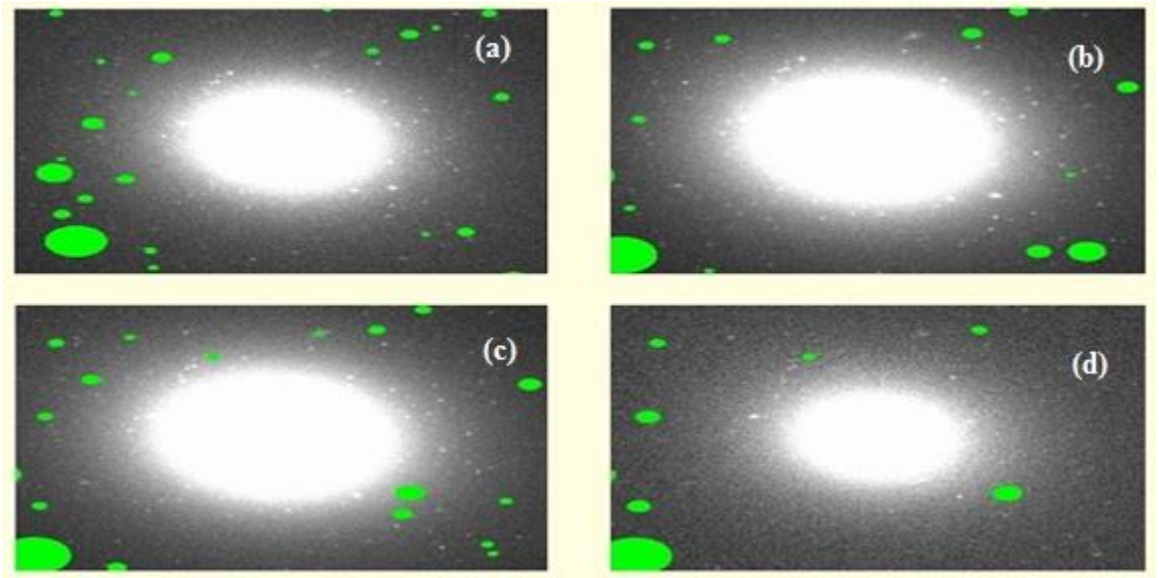

Figure 4. Elliptical galaxy NGC 4278 images with masking in griz-Filters, from (a to d) respectively. North is up and East is at left.

Table 3. The Data of Corrections.

Galaxy	Band	Airmass	Zeropoint	Atmospheric Extinction
NGC5005	***g***	1.138	-24.47	0.188
	r	1.128	-24.00	0.1076
	i	1.131	-23.74	0.061
	z	1.136	-21.84	0.068
NGC 4278	***g***	1.194	-24.35	0.186
	r	1.181	-23.95	0.1015
	i	1.184	-23.55	0.061
	z	1.191	-21.88	0.054

d- Conversion to magnitude units by the well known formula(10):

$$\boldsymbol{m} = -2.5\log(I) \quad \ldots(2)$$

Where I is the intensity.

e- We corrected all the data for Galactic extinction based on NASA/IPAC EXTRAGALACTIC DATABASE (NED).

We assume throughout this work a Hubble constant of H0 = 74±4 kms^{-1} Mpc^{-1}. Given the adopted distance to NGC 5005 galaxy from Tully et al. (2013)(11), which is about 18 Mpc, and 15.4 Mpc from surface brightness fluctuation (SBF) for NGC 4278, the image scales are 87.27 pc/arcsec and 74.66 pc/arcsec respectively.

Results and Discussion:

Morphologies and Contour maps

Fig. 5 represents the isophotal contour maps of spiral galaxy NGC 5005. From this figure, we obtained that the galaxy has a disky system with a 5.5" nucleus with a bulge to about 51", the bulge is surrounded by an ellipsoidal disk with two components first, a bar to about 76"; second, a tightly wrapped spiral arms extended to about 134" from the center of galaxy.

Figure 6 represents the isophotal contour maps of elliptical galaxy NGC 4278. From this figure, we obtained that The galaxy has a nucleus component to about 4" and a boxy bulge component of diameter about 11.5" with an fainter envelopes extended to the end of galaxy to about 87". The contour maps reveal the presence fainter envelopes in the outer parts of the galaxy. The surface brightness levels are listed in Table 4.

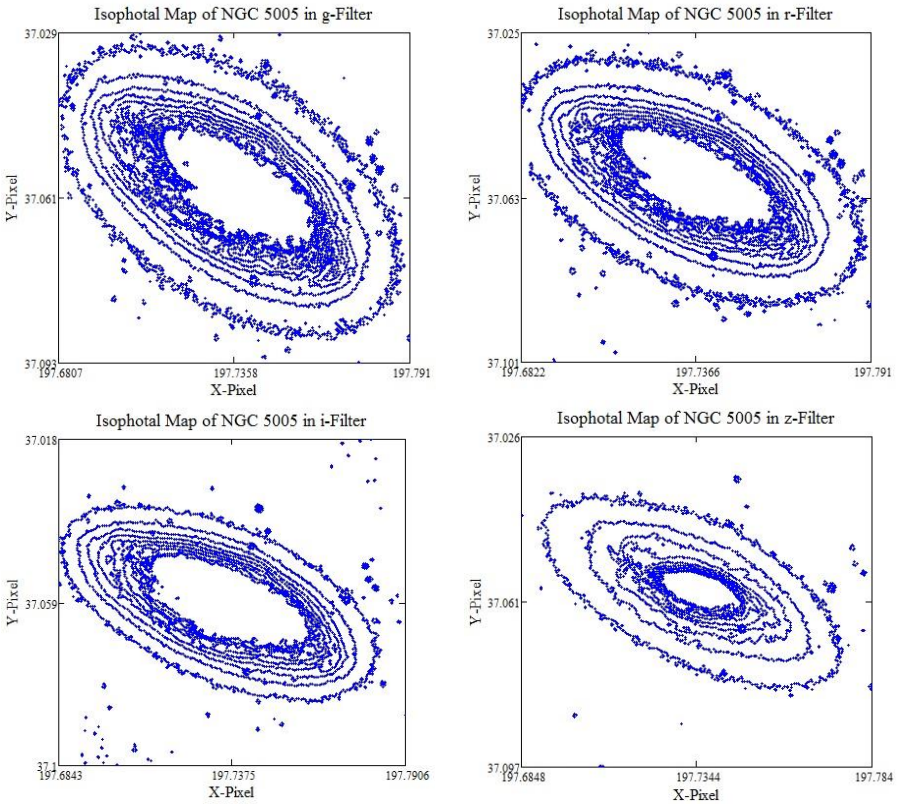

Figure 5. Isophotal Contour Maps of NGC 5005 Galaxy in griz-Filters, North is up and East is at left.

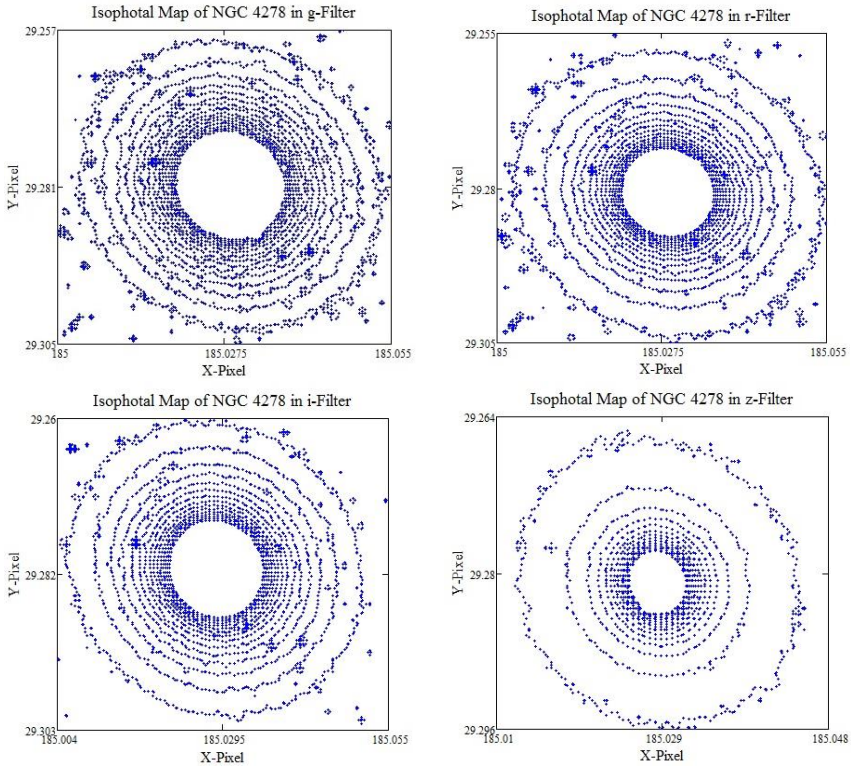

Figure 6. Isophotal Contour Maps of NGC 4278 Galaxy in griz-Filters, North is up and East is at left.

Table 4. Surface Brightness Levels.

Galaxy	Band	Apparent magnitude of Outer isophot (mag)	Surface brightness of Outer isophot (mag/arcsec^2)	Steps (mag, mag/ arcsec^2)
NGC 5005	*g*	18.1	16.1	1.3
	r	23.5	21.5	1.6
	i	21.5	19.5	1.7
	z	27.1	20.7	1.02
NGC 4278	*g*	21.6	19.6	0.54
	r	23.3	21.3	0.93
	i	29.5	27.5	0.82
	z	25.2	18.9	0.93

Position Angle, Ellipticity and B4 Profiles

Figures 7, 8, and 9 represent the relation between the radius (r) of the galaxies NGC 5005 and NGC 4278 with the position angle (P.A.), ellipticity ($\varepsilon \equiv 1-b/a$) and B4 (4th harmonic of a Fourier expansion) respectively. It is noticed that the profiles show more or less similar behavior and consistency in the different bands.

For ***NGC 5005*** from the **griz**-Filters and because the behavior is approximately the same in all filters, the PA is almost fluctuate from 25±0.1°, in the inner region of the galaxy to about 30±0.1°, at about 34", then be almost constant at the outer region about 31±0.1°. The ellipticity profiles of NGC 5005 increase from 0.34 to 0.64 at 12.4". In the disk region (r > 16"), the ellipticity almost is constant with a mean value 0.52±0.1, used Eq. 3(12) to calculate the inclination of the disk which is found to be 70°±4.

$$\cos^2 i = \begin{cases} \frac{(1-\varepsilon)^2-0.2^2}{1-0.2^2} & \text{if } \varepsilon \le 0.8, \\ 0 & \text{otherwise.} \end{cases} \quad \ldots\ldots(3)$$

The B4 (4th harmonic of a Fourier expansion) profile illustrated in Fig. 9a and presented in Table 5 shows that the general trend of the galaxy is disky.

For ***NGC 4278,*** also from **griz**-Filters within the inside of the Bulge to about 40.8", the PA fluctuate between 69° to about 54.6°, then from 40.8" to the end of galaxy PA is almost constant at about 53±3°. Inside the Bulge to about 28.13" region the ellipticity profiles of NGC 4278 decreases from 0.156 to 0.095, at the outer region of the galaxy. The ellipticity has a mean value of 0.092. The mean value of ellipticity profile is (0.09±0.01) used in Eq. 3 (12) to calculate the inclination of the disk which is found to be 25.4°±1.5.

The mean value of the B4 profiles is 0.0017, and illustrated in Fig. 9b and presented in Table 5 which shows that the general trend of the galaxy is a boxy.

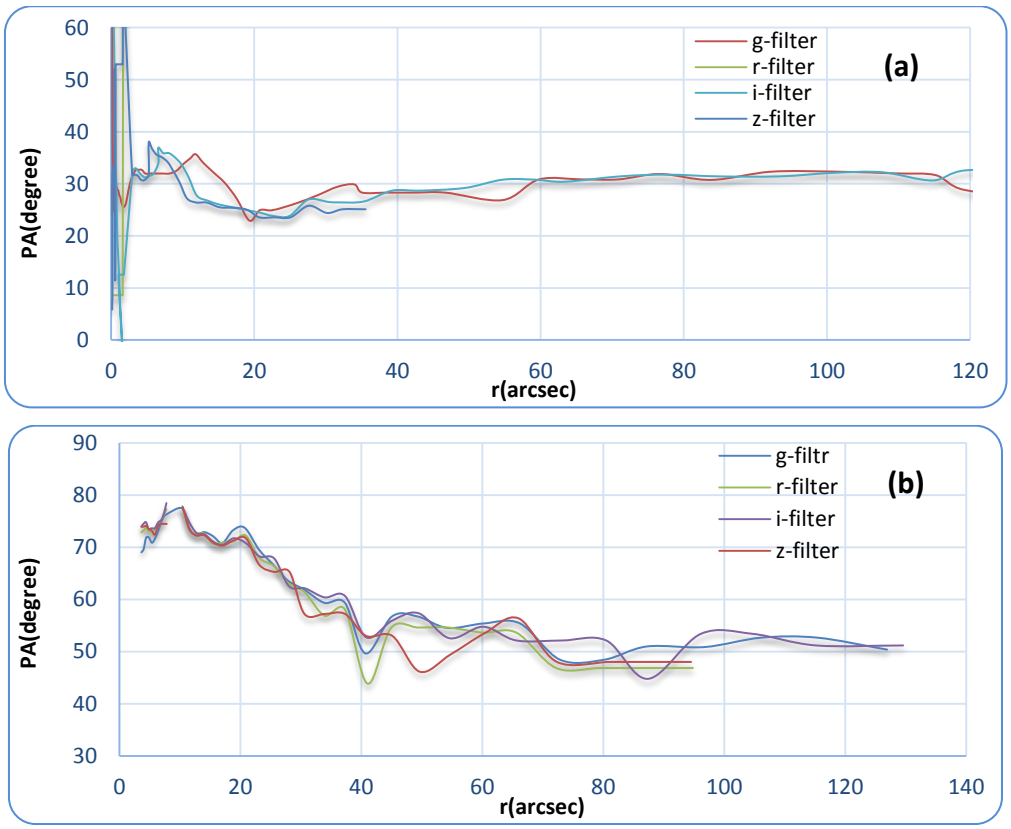

Figure 7. The relation between position angle (PA) with the radius of the galaxy (r) in griz-Filters for a-(spiral galaxy NGC 5005) and b-(elliptical galaxy NGC 4278).

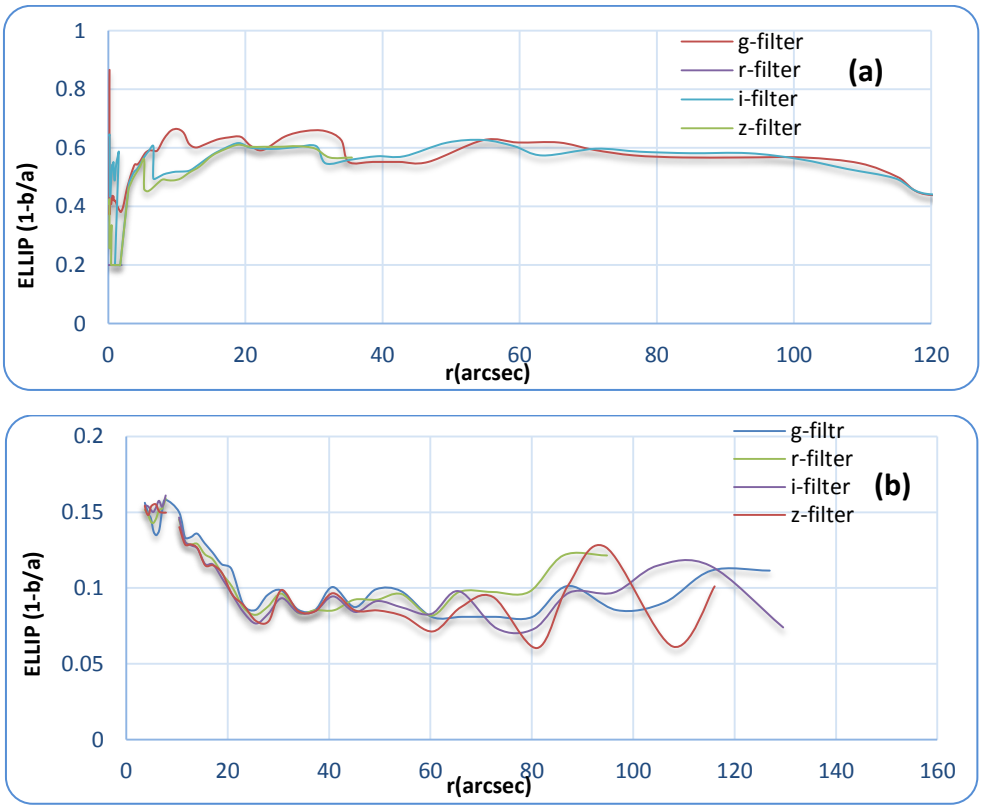

Figure 8. The relation between ellipticity (ε) with the radius of the galaxy (r) in griz-Filters for a-(spiral galaxy NGC 5005) and b-(elliptical galaxy NGC 4278).

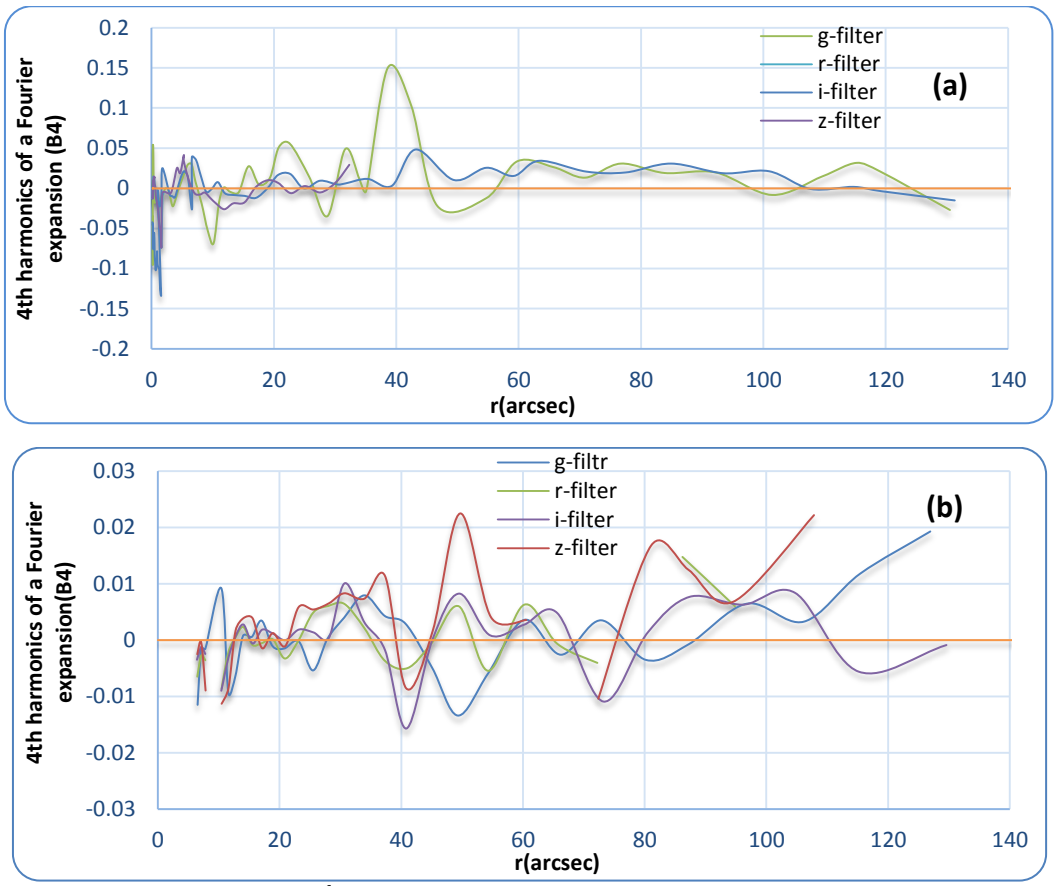

Figure 9. The relation between 4th harmonics of a Fourier expansion (B4) with the radius of the galaxy (r) in griz-Filters for a-(spiral galaxy NGC 5005) and b-(elliptical galaxy NGC 4278).

Table 5. The photometric parameters.

Galaxy	Band	PA(°)	Ellipticity(ε)	Inclination(°)	B4
NGC 5005	***g***	30.6±0.1	0.52±0.1	70±3.5	0.0
	r	42.3?	0.2?	-	-0.01
	i	33.5±0.1?	0.53±0.2?	-	0.007
	z	40.6±0.15?	0.38±0.15?	-	-0.007
NGC 4278	***g***	63.5±9.8	0.11±0.03	25.4±1.5	0.001255
	r	63.8±10.9	0.11±0.025	28.1±3.2	0.000639
	i	63.8±10	0.109±0.029	27.5±3.7	0.000895
	z	63.5±10	0.108±0.03	26.5±6	0.003956
	global value	63.65±10	0.109±0.029	26.9±3.6	0.001686

? Uncertain Values

Surface Brightness Profiles Decomposition

The composition of surface brightness profiles of the spiral galaxy NGC 5005 in ***giz***-filters (results of ***r***-filter are inaccurate and have been neglected) and the surface brightness profiles of elliptical galaxy NGC 4278 in **griz**-Filters are a bulge which described by a de Vaucouleurs profile (the most commonly used is the "$r^{1/4}$ law " proposed by de Vaucouleurs (1948)(13) to a good approximation (Eq.4) and the disk follows an exponential brightness profile (Eq.5), using the least square fitting method.

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

$$\mu_{disk}(r) = \mu_0 + 1.09\left(\frac{r}{r_0}\right) \ldots.(5)$$

Here, μ_e is the surface brightness at the effective radius r_e which is defined such that half of the brightness is emitted within r_e. The central surface brightness and the scale-length of the disk are denoted by μ_e and r_0 , respectively. It has to be noted that μ_0 is not directly measurable since μ_0 is not the central surface brightness of the galaxy, only that of its disk component.

Figure (10) demonstrates the relation between fitting surface brightness of the composition (Bulge+Disk) of spiral galaxy NGC 5005 with radius of galaxy r in ***giz***-Filters while Fig. 11

illustrates the relation between fitting surface brightness of the composition (Bulge) of elliptical galaxy NGC 4278 with the radius of galaxy r in **griz**-Filters.

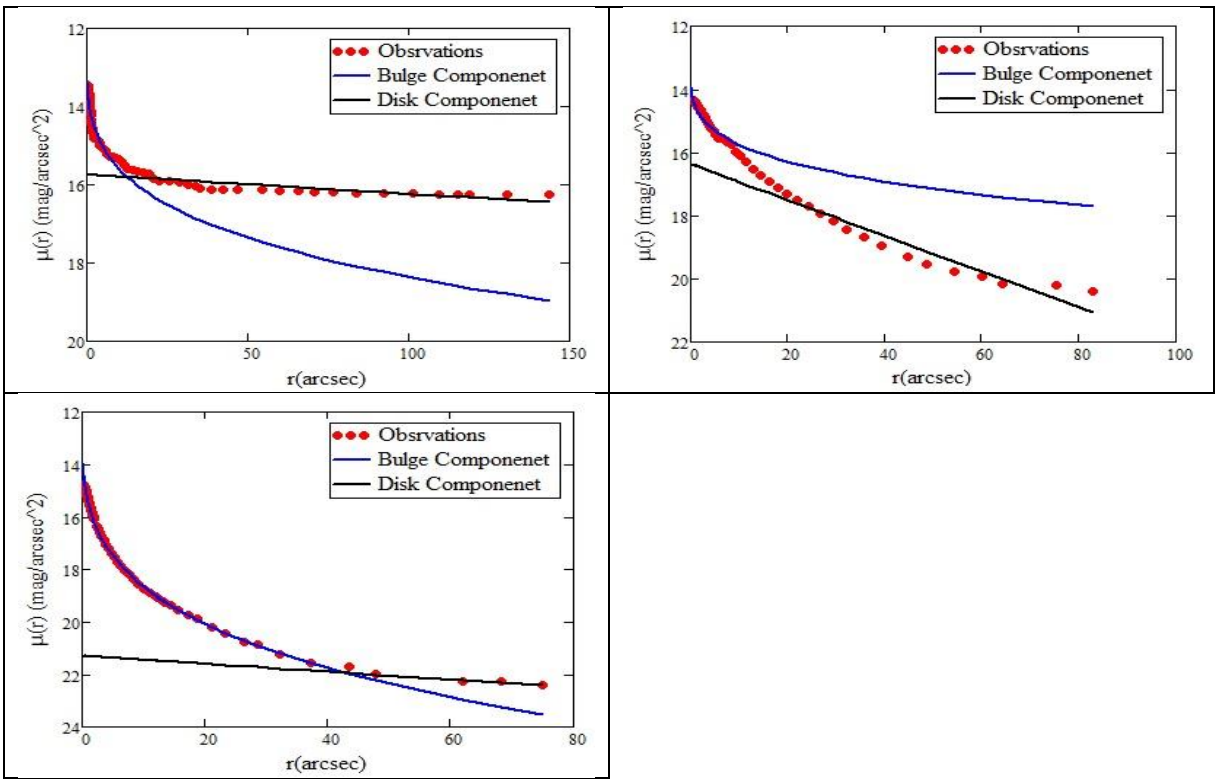

Figure 10. Fitting surface brightness of the components (Bulge+Disk) of spiral galaxy NGC 5005 with the radius of the galaxy r in *giz*-Filters. From upper left to right.

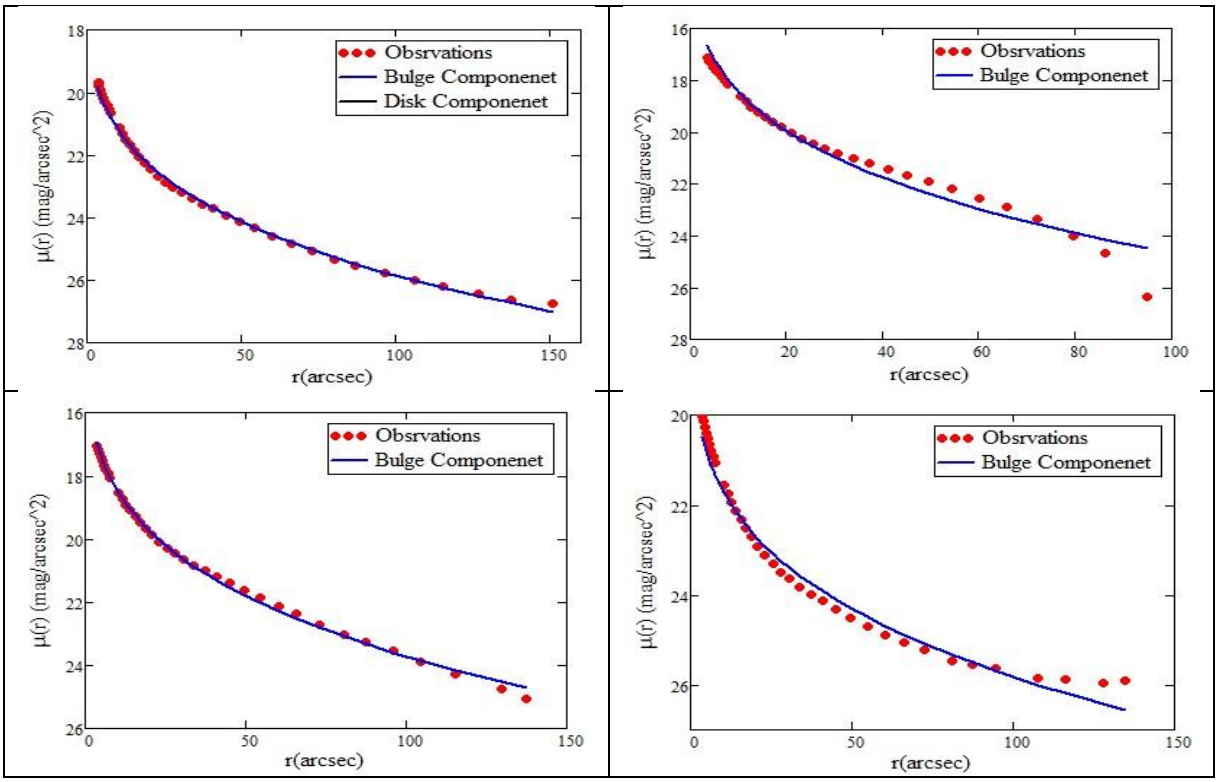

Figure 11. Fitting surface brightness of the component (Bulge) of elliptical galaxy NGC 4278 with the radius of the galaxy r in griz-Filters. From upper left to right.

Tables 6 and 7 represent the results that we obtained from Fig 10 and 11.

Table 6. Fitting surface brightness decomposition parameters of spiral galaxy NGC 5005.

	Bulge				Disk				
Band	**range (arcsec)**	**μ_e (mag/arcsec^2)**	**r_e (arcsec)**	**Standared error**	**μ_o (mag/arcsec^2)**	**r_o (arcsec)**	**Standared error**	**LB_T (mag)**	**B/D**
g	0.3-11	20.4	299	0.07	15.8	226	0.05	4.6	0.05
i	0.3-8.4	21.3	762	0.05	16.4	19.15	0.14	3.5	33.2
z	0.5-12.2	19.5	15.4	0.03	21.3	72.9	0.02	10.2	0.4

Table 7 Fitting surface brightness decomposition parameters of elliptical galaxy NGC 4278.

	Bulge			
Band	**range (arcsec)**	**μ_e (mag/arcsec^2)**	**r_e (arcsec)**	**Standared error**
g	5.9-151	27.2	36.6	0.04
r	5.9-95	18.8	11.7	0.18
i	5.9-137.5	20.02	23	0.04
z	5.9-128	24.7	59.3	0.1

Conclusion:

We have carried out **griz** photometric studies of the spiral galaxy NGC 5005 and elliptical galaxy NGC 4278 and we have concluded that:

Every arcsecond in the images of the spiral galaxy NGC 5005 is 87.27 parsec and in elliptical galaxy NGC 4278 is 74.66 parsec, in the real scale where we can imagine the size of the two galaxies.

From the contour maps of the spiral galaxy, NGC 5005 is a disky system with a bulge surround by an ellipsoidal disk with two components, bar and tightly wrapped spiral arms. And the elliptical galaxy NGC 4278 is a boxy bulge component with a fainter envelopes extended to the end of galaxy.

From the photometric properties of the spiral galaxy NGC 5005 is a disky system, tilted at an angle 30º from the North, with an average ellipsoidal shape, inclined with 70º with the line of the sight. And the elliptical galaxy NGC 4278 is a boxy system, tilted at an angle 53º from the North, with an almost oval shape, inclined with 25º with the line of the sight.

The fitting of surface brightness of the compositions of the spiral galaxy NGC 5005 with the radius of the galaxy r was given uncertain values in ***riz***-filters but the ***g***-filter gives a good approximation to the de Vaucouleurs and exponential brightness profiles. And the elliptical galaxy NGC 4278 can be described by the de Vaucouleurs equation as a bulge.

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Conflicts of Interest: None.

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قياس اللمعان السطحي للمجرة الحلزونية NGC 5005 والمجرة الإهليليجية NGC 4278

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قسم الفلك والفضاء، كلية العلوم، جامعة بغداد، بغداد، العراق.

الخلاصة:

لقد تم اختيار مجرتين أحدهما حلزونية **NGC 5005** و إهليليجية **NGC 4278** لدراسة خصائصهما الضوئية بإستخدام المرشحات الضوئية **griz**-Filters. الأرصاد المستخدمة في هذا البحث تم الحصول عليها من خلال بيانات Sloan Digital Sky Survey (SDSS). حيث تم معالجة البيانات لصور المجرتين بإستخدام برنامج IRAF، مثل bias و flat field عن طريق SDSS pipeline. وقد تم دراسة التركيب العام للمجرتين (الإنتفاخ، القرص)، جنبا إلى جنب مع الخرائط الآيزوفوتومترية الكونتورية، وكذلك المقطع العرضي للسطوعية السطحية وتحليل قيمة الإنتفاخ / القرص. بالإضافة الى ذلك فقد تم تخمين قيم زاوية موقع القرص والتفلطح وميل المجرتين.

الكلمات المفتاحية: مجرة لولبية، مجرة إهليليجية، قياس الشدة الضوئية.