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RESEARCH ARTICLE

Investigation of the Gravitational Interaction between the Components of the Galaxy Pairs CPG 165

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Abstract

In this paper the effect of interaction between the components of the galaxy pair CPG 165 on the symmetry of their morphologies and structures is studied by applying the technique of surface photometry. For each component of the pair we present the isophotal contours, profiles of surface brightness (SB), major-axis position angle (PA), and isophotal center-shift. The present analysis is done using the r- and i-band images from the Sloan Digital Sky Survey (SDSS) observation.

It is found that the position angle and the isophotal center shift are strongly affected by the state of interaction between the components of the pair CPG 165.

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1. Introduction

Interactions between galaxies are thought to be a common phenomenon (Donzelli and Pastoriza 1997). Since many galaxies are relatively found close together in groups and clusters, the percentage of collision between galaxies is very high. Even if galaxies did not actually collide, they can affect each other by the mutual gravitational force which can cause both components to slightly change in shape.

Binary galaxies constitute about 10% of the noncluster population (Xu, and Sulentic 1991), and disturbed morphologies are a common property of a large fraction of such pairs (e.g., Arp 1966; Karachentsev 1972). Many catalogs e.g. “The Catalog of Pairs of Galaxies” (CPG, Karachentsev 1972) and “The Atlas of Peculiar Galaxies” (Arp 1966) are an ideal sample for binary galaxy studies (see, e.g.,Sulentic 1989). De Propris et al (2007) found that galaxies in close pairs are generally more asymmetric than isolated galaxies and the degree of asymmetry increases for closer pairs.

In this paper, the photometric analysis of the galaxy pair (GP) CPG 165 was presented to study the effect of interaction between the components of the pair on the symmetry of their morphology and structure. Section 2 explored the observation and the basic parameters of the galaxy pair CPG 165. In section 3, we discussed the technique applied in the present work. Section 4 is a brief discussion on the parameters obtained from surface photometry analysis with respect to the galaxy pair CPG 165. Finally, in section 5, the conclusions are outlined. Throughout the paper we used H_0 = 100 kms^{-1} Mpc^{-1}.

2. The Observation and Data of CPG 165

The data for this study are based on the SDSS Data Release 7 (Abazajian et al. 2009). The SDSS has imaged the sky in the u, g, r, i, and z photometric bands (Fukugita, Shimasaku & Ichikawa 1995, Smith et al. 2002). The reduced images of the galaxy pair CPG 165 in r- and i-bands were retrieved from the SDSS archive (see Table 1).

Basic reductions, including the bias and dark corrections, and flat fielding, had already been carried out at the SDSS archive. A necessary reduction step that had not yet been carried out on the frames was the sky subtraction. The sky background, expressed in adu/pix^2, for each band is extracted from the image header. There is also 1000 adu added to each pixel as a soft-bias value which must be subtracted from each pixel. After subtracting the sky background value and the soft-bias, it is necessary to convert SDSS raw count rate (counts/exposure time) to actual magnitudes via the equation:

$$mag = -2.5 \log[(counts / exptime) \times 10^{0.4(aa + kk * airmass)}], \quad (1)$$

where *aa* represents the photometric zero point, *kk* is the extinction coefficient. The values of these parameters are obtained from the "tsField" files accompanying each field and are presented in Table 2 for each band for each galaxy. A more detailed description of this process is laid out in Lupton et al., 2001; Lupton et al., 2003.

3. Surface photometry and analysis

Surface photometry is an important and powerful tool to study the photometric properties of galaxies. In this technique, the isophotes of the galaxy are fitted to ellipses to derive the radial profiles e.g. surface brightness, ellipticity, position angle, and the x and y center. These profiles provide basic information such as twisting, ellipticity, off-centering, and shape of the isophotes.

The technique of surface photometry is applied to the images of each component of the galaxy pair CPG 165 using the task *ellipse* from IRAF[1].

By using surface photometry we get, for each component, the contour maps, the surface brightness profile, the position angle profile, and the x and y isophotal center-shift.

The contours in both r- and i- bands for each component of the pair are drawn by using IRAF CONTOUR task and then used to describe the pair.

Surface brightness profile is traced out along the line joining the centers of both components. This profile helps us to explore the effect of gravitational interaction on the symmetry of the galaxy by comparing both sides of each component (far-side: the side of the galaxy that is far away from the other component and near-side: the side of the galaxy that is near to the other component). In general, for normal (non-interacting) galaxies the two sides will be nearly symmetric without remarkable deviation. On the other hand, for interacting galaxies (IGs), the behavior of the two sides of each component is expected to be asymmetric.

The position angle profile for each component may help us to study the effect of interaction between galaxies on the outer parts of each component.

The x and y isophotal center-shift of each component are drawn. Generally, for isolated galaxies the isophotes are expected to be nearly centered about a common center. On the other hand, for interacting galaxies, the isophotes of the outer parts show some shift toward the other components due to the mutual attraction.

4. The interacting system CPG165

CPG165 (KPG165a/165b) is a pair of two spiral galaxies and is thought to be in a true interacting stage. The component KPG165a is a barred spiral galaxy (SBb) with heavy disrupted arms, while the component KPG165b is classified as a spiral galaxy (Sab). The basic data of the galaxy pair CPG165 is presented in Table 3.

The images of the system as well as their isophotes in the r- and i-bands are shown in Fig. 1. By carefully inspecting Fig. 1 we notice that, outer contours are unsmoothed and irregular in shape especially in i-band. They are non-co-planarity except in the most inner region of the two components (at the core).

The two components are embedded in a common envelope at levels 23.16mag/arcsec^2 in the r-band, and 21.22mag/arcsec^2 in i-band. Spiral arms structures of the two galaxies, especially the component KPG 165b are clearly observed in both bands (Fig. 1).

4.1 The surface brightness profile of the system CPG165

[1] IRAF is distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.

Starting with the surface brightness profile of KPG165a (Fig. 2a and b in the r- and i-band respectively) we compare between the surface brightness of the two sides of component KPG 165a to show if they are symmetric or not. The surface brightness of the near-side (dotted line) and the surface brightness of the far-side (solid line) look symmetric. It seems that both sides are nearly symmetric in both r- and i-bands.

On the other hand, the comparison between the two sides of surface brightness profile of the component KPG165b is illustrated in Fig. 3a and b in r- and i-band respectively. For this component both sides show a large deviation. The surface brightness of the near-side is decreasing faster than that of the far-side. This means that there is a deviation between the near side and the far one by Δd=0".4 (0.08 kpc) in the r-band, and Δd=0".43 (0.086 kpc) in the i-band. This deviation occurs due to the gravitational force between the two components of the pair.

The deviation between the two sides occurs only in the component KPG 165b in this system, due to the highly different masses of the two components which makes the gravitational attraction affects the less massive component only.

4.2 The position angle profiles of the system CPG165

The position angle profiles in the r- and i-bands for both components of CPG165 are given in Fig. 4a and b respectively. The position angle profiles of the component KPG 165a are nearly consistent in the r- and i-bands (Fig. 4a). Within a=17".4, the position angle fluctuates between 81°.99, and 92°.52. For the outer part (a > 17".4), the position angle of the isophotes decreases steeply from about 86°.78 to about 82°.78, which means that the isophotes in the outer part of this component are twisted toward the N-direction where the component KPG 165b is located. This may reflects the real state of attraction between the two components.

For the component KPG 165b, the position angle profile looks similar in the r- and i-bands (for a > 2".4) (Fig. 4b). Beyond a=2".4 the position angle slowly increases till about a=13".1 and then rapidly increases outwards. This means that the isophotes of the outer part of this component are twisted in the E-direction i.e. toward the other component. This also reflects the fact that the outer part of the component KPG 165b is attracted toward the other component. In general, the behavior of the position angle profile of the outer parts of both components may confirm the state of attraction between them.

4.3 The x and y isophotal center-shifts of the system CPG165

The x and y isophotal center-shift of the component KPG 165a are illustrated in Fig. 5a and b respectively. In the inner part (a < 11".9 and a < 14".1 in the r- and i-bands respectively) of the component KPG 165a, the centers of the isophotes are slightly fluctuating (Fig. 5a and b), while in the outer part, the centers of the isophotes are monotonically shifted in both the N- and E-directions toward the other component. This means that the isophotes in the outer part of the component KPG 165a are shifted in NE direction where the component KPG 165b is located. The amount of the shift in the r-band is estimated to be about 1".59 (0.318 kpc) and 7".83 (1.568 kpc) in the N and E directions respectively where the component KPG 165b is located.

For the component KPG 165b, the x and y isophotal center-shifts are illustrated in Fig. 6a and b respectively. Within the inner part (a < 14".5) the x isophotal center-shift increase gradually, then it rapidly increases till about 18".5 (Fig. 6a), while in the outer part (a > 18".5) the isophotes are monotonically decreasing in the W direction toward the component KPG 165a (see Fig. 1 and 6a). On the other hand, the y isophotal center-shift decreases rapidly for 1".0 < a < 8".7, then slightly fluctuates in the outer part (see Fig. 6b). The amount of the x-shift in the r-band is estimated to be about 1".21 (0.242 kpc) in the S-direction i.e., toward the component KPG 165a.

5. Conclusions

The interacting system CPG 165 is studied in this paper using the SDSS r- and i-band images. The main aim of this paper is to investigate the effect of gravitational interaction between the components of IGs on their morphology, profiles of surface brightness, position angle, and isophotal center shift.
The concluded results are:

For the component KPG 165a, both the near- and far-sides are nearly symmetric and there is no remarkable deviation between them as is clear in both bands. For the component KPG 165b, a remarkable deviation between the surface brightness of both sides is clearly noticed and estimated to be 0".4 (0.08 kpc) in the r-band, and 0".43 (0.086 kpc) in the i-band.

The position angle profile shows that the outer isophotes of the two components are twisted toward each other. This behavior is expected to be due to the fact that the outer isophotes are affected by the gravitational attraction between the two components.

The x and y isophotal center-shift shows a shifted value in the outer isophotes of both components toward each other. For the component KPG 165a, the amount of shift, in the r-band, is estimated to be 1".59 (0.318 kpc) and 7".83 (1.568 kpc) in the N and E directions respectively where the other component is located. For the component KPG 165b, the shift is noticed only in the S-direction and is estimated to be about 1".21 (0.242 kpc). The outer isophotes of each component is twisted and shifted towards the other component which reflects the real state of interaction between the components of the galaxy pair CPG 165.

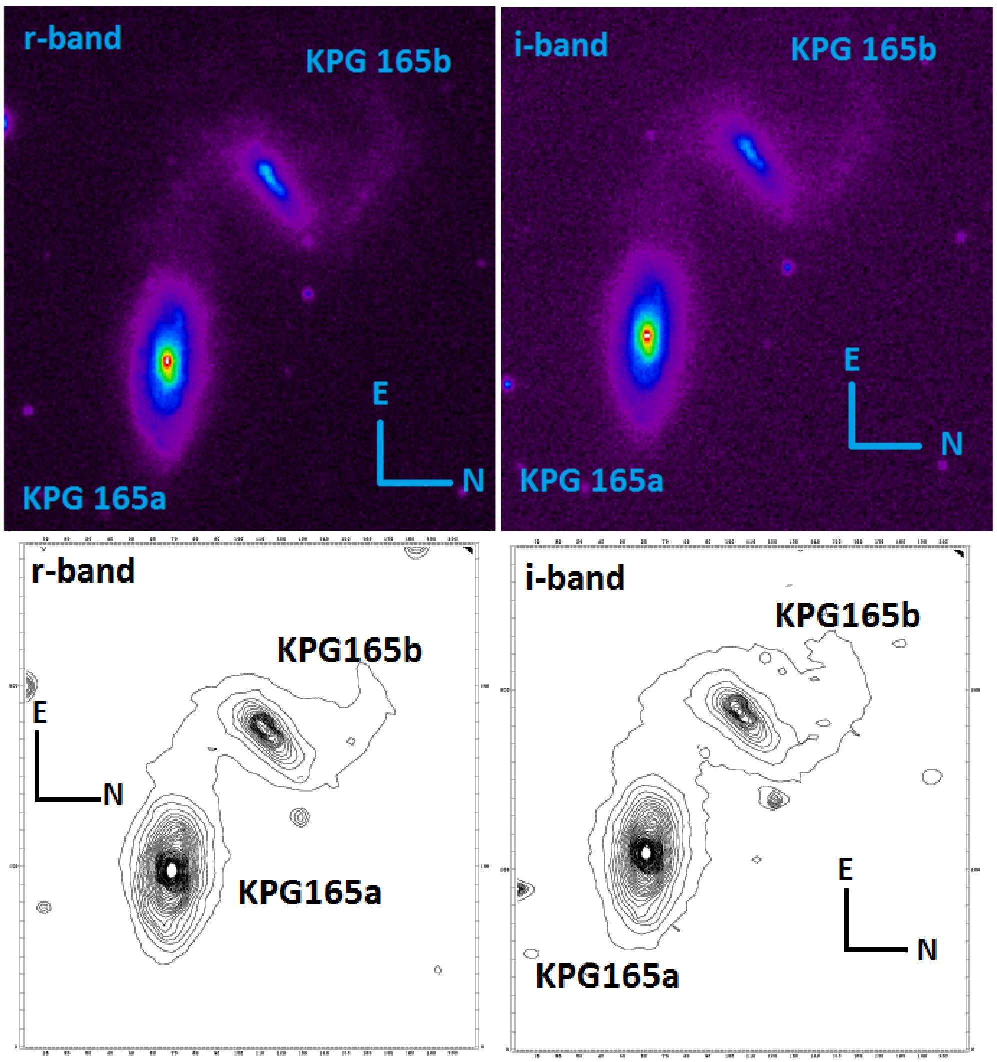


Fig. 1: Images and contour maps of CPG165 in the r-band (left panel) and the i-band (right panel). Each image has a size of about 83"×110". The isophotes start from 23.16 to 19.05 mag/arcsec^2 in r-band, and from 21.22 to 18.9mag/arcsec^2 in i-band.

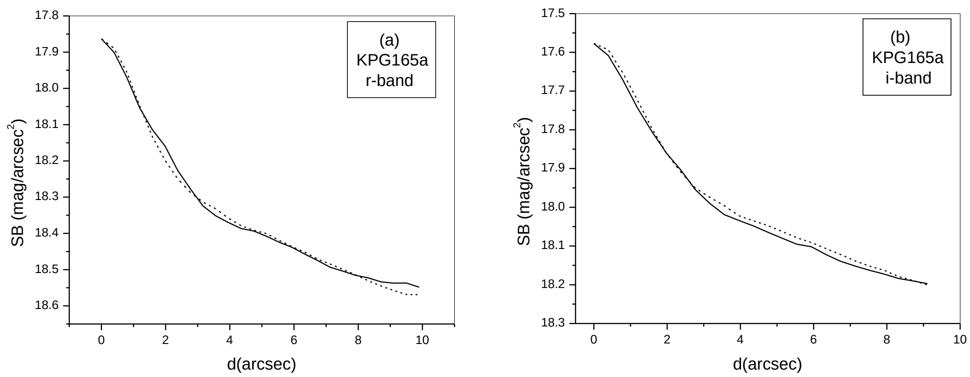


Fig. 2: Comparison between the surface brightness of the near- and far- sides of the component KPG 165a in both bands.

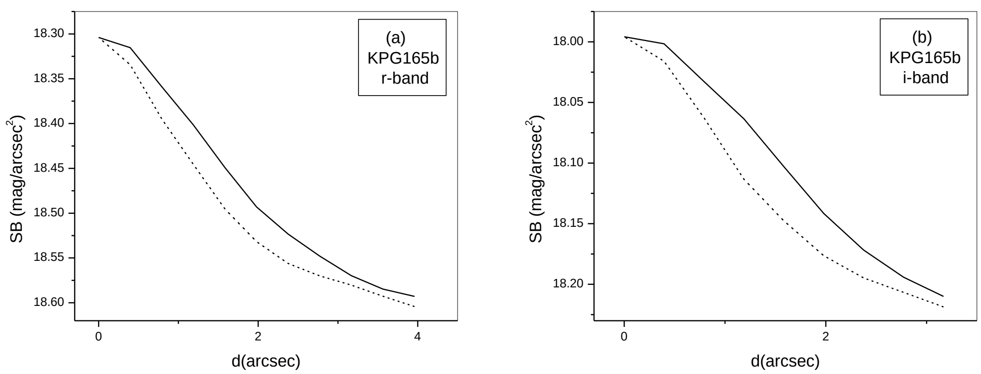
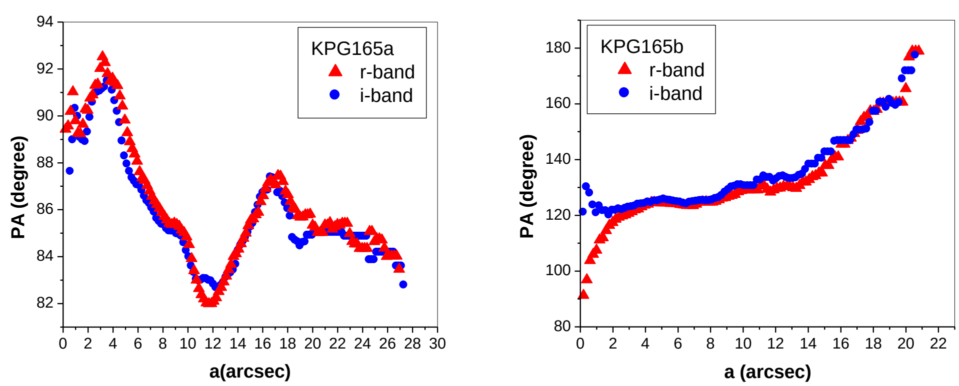
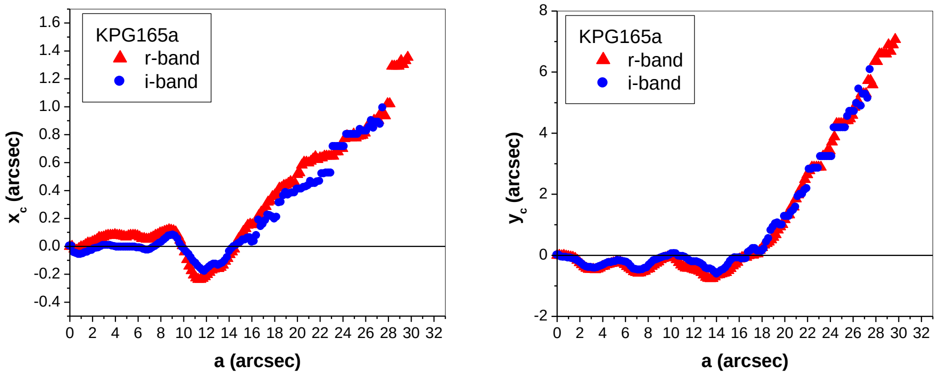


Fig. 3: The same as Fig. 2 but for the component b.



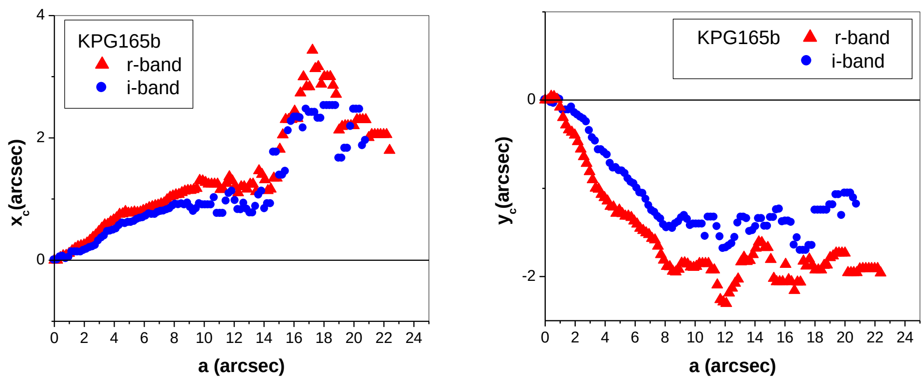
(a) (b)

Fig. 4: Position angle profile of KPG 165a (left) and KPG 165b (right).



(a) (b)

Fig. 5: The isophotal center-shift of KPG165a.



(a) (b)

Fig. 6: The isophotal center-shift of KPG165b.

Table 1: The SDSS retrieved FITS files of the components of the GP CPG 165.

Galaxy pair	Galaxy ID	SDSS Name	Observation Date	FITS File Name
CPG165	KPG165a	SDSS J083431.70+013957.9	30-11-2000	fpC-001907-r4-0040.fit
	KPG165b	SDSS J083433.78+014015.7		fpC-001907-i4-0040.fit

Table 2: The calibration constant of the r- and i-bands in the SDSS Photometric system for the CPG 165.

Galaxy pair	aa	kk	airmass
CPG165 (r-band)	-24.0838	0.07954	1.2331
CPG165 (i-band)	-23.7496	0.03687	1.231

Table 3: The basic data of CPG 165 (NED*).

CPG 165	R.A (2000)*	Dec (2000)*	cz (km/s)*	B_{TC}**	Type**
KPG 165a UGC 4480a	08h34m31.703s	+01d39m57.91s	4131± 2	14.19	SBb
KPG 165b UGC 4480b	08h34m33.73s	+01d40m16.2s	4126± 10	14.70	Sab

∗ NASA Extragalactic Data Base, ** SIMBAD

Table 4: Estimated values of the twist and center shift of the outer isophotes for the components of CPG165 in the r-band.

Parameters	KPG165a	KPG165b
Deviation in the SB profile	No deviation occurs	Δd=0".4 (0.08 Kpc)
Twist in the PA	4° towards N (towards the component b)	49°.3 towards E (towards the component a)
Shifted value of x	Δ x =1".59 (0.318 kpc)	Δx =1".21 (0.242 kpc)
Shifted value of y	Δy =7".83 (1.568 kpc)	No shift

References

Abazajian, K. N., et al. 2009, ApJS, 182, 543.
Arp, H. 1966, Atlas of Peculiar Galaxies , ApJS, 14, 1.
De Propris, R., Conselice, C. J., Liske, J., Driver, S. P., Patton, D. R., Graham, A. W., and Allen, P. D. 2007, AJ, 666, 212.
Donzelli C. J., and Pastoriza M. G., 1997, ApJ, 111, 181.
Fukugita, M., Shimasaku, K., and Ichikawa, T. 1995, PASP, 107, 945.
Karachentsev, I. D. 1972, Comm. Spec. Astrophys. Obs. USSR, 7, 1.
Lupton, R. H., Gunn, J.,E., Ivezic, Z., Knapp, G., Kent, S. and Yasuda N., in ASP Conf. Ser. 238 "ADASS X" ed F.R. Harnden Jr., F.A. Primini, and H.E Payne 2001, ASP Conf Ser 238, 269.
Lupton, R. H., Ivezic, Z., Gunn, J.E., Knapp, G.R., Strauss, M.A., and Yasuda, N. 2003, Proc. SPIE 4836, 350-6.
Smith, J. A., et al. 2002, AJ, 123, 2121.
Sulentic, J. W. 1989, AJ, 98, 2066.
Xu, C., and Sulentic, J. W. 1991, ApJ, 374, 407.