NRIAG Journal of Astronomy and Geophysics 7 (2018) 4–9

Contents lists available at ScienceDirect

NRIAG Journal of Astronomy and Geophysics

journal homepage: www.elsevier.com/locate/nrjag

Full length article

BVR photometric investigation of galaxy pair KPG 562

Y.H.M. Hendy

National Research Institute of Astronomy and Geophysics (NRIAG), Astronomy Department, 11421 Helwan, Cairo, Egypt

ARTICLE INFO

Keywords:
Galaxies
Galaxy pairs
Individuals: KPG 562

ABSTRACT

This work presents BVR photometric observations and analyses for galaxy pair KPG 562 selected from the Karachentsev Catalog of Isolated Pairs of Galaxies. The observations were obtained using the 1.88-m Telescope of the Kottamia Astronomical Observatory (KAO), Egypt. There is no interaction signs assigned for this pair as reported by Karachentsev Catalog.

We used the surface photometry technique to obtain photometric parameters for each galaxy of the pair. The isophotal contours, the luminosity profiles, color profiles (B-V, V-R), ellipticity profiles, position angle (PA) profiles and isophotal center-shift (xc, yc) profiles have been presented. The total and absolute magnitude, ellipticity and position angle (PA) were also obtained from the studied galaxy pair.

The studied galaxy pair is clearly showing signs of interaction opposed to that found by Karachentsev. We found that the galaxy KPG 562b contains one tidal tail. The length and thickness of tidal tail were obtained and presented in this study.

1. Introduction

The study of Isolated Galaxy Pairs (IGP) provides us with important information about the conditions of formation and the properties of evolution of galaxies. Studying close and wide galaxy pairs are very important to know interactions effect on galaxy morphology and its connection to galaxy formation and the Hubble sequence (Sulentic, 1992). Close galaxy pairs show strong signs of interaction and mergers. They have high Star Formation Rate (SFR) (e.g. Patton et al., 2000; Carlberg et al., 2000; Le F'evre et al., 2000; Patton et al., 2002; Lin et al., 2004; Bundy et al., 2004; Bell et al., 2006).

Mohamed and Reshetnikov (2011) established catalog of interacting galaxies using several deep fields of Hubble Space Telescope (HST: HDF-N, HDF-S, HUDF, GOODS and GEMS). This catalog contains nearly 900 interacting galaxies with tidal tails, tidal bridges and M51 interacting galaxies. Mohamed et al. (2011) measured the geometrical parameters of tidal tails. They found that there is a relation between galaxy luminosity and tidal tails length in kpc. Reshetnikov and Mohamed (2011) estimated the evolution of the space density of M51 galaxies nearly at $z = 0.7$.

We selected KPG 562 from Karachentsev Catalog of Isolated Pairs of Galaxies (Karachentsev, 1972: KPG). This galaxy pair has no interaction signs in KPG catalog. It has been classified as isolated galaxy pair. The studied sample was suitable for observations with Kottamia Astronomical Observatory.

The main goal of this paper is to re-investigate the studied galaxy pair KPG 562 for the presence of interaction signs. The basic data of galaxy pair KPG 562 were taken from NED and HyperLeda database (Table 1). The presence of interaction signs (Tidal Tails and/or Bridges) is examined by determining their dimensions (length and thickness) following the same way described by Mohamed et al. (2011) and Ali (1993). The length of the tidal tail is measured from its start at the galaxies disk to its end and the thickness of the tidal tail is measured at the half length width along the tail.

The cosmological model with $H_o = 70\,km\,s^{-1}\ Mpc^{-1}$, $\Omega_m = 0.3$ and $\Omega_\Lambda = 0.7$ is used to obtain all numerical values in this study. The paper was organized as follows: observations, data reduction and photometric calibration are presented in Section 2. The surface photometry analysis is presented in Section 3, while the results are described in Section 4. Finally, discussions and conclusions are presented in Section 5.

2. Observations, data reduction and photometric calibration

The observations were carried out using CCD camera EEV 42-40 (2048 × 2048 pixels) mounted at the Newtonian focus of the 1.88-m telescope, KAO, of National Research Institute of Astronomy and Geophysics (NRIAG), Egypt. The scale and FoV of the imaging system are 0.304″/pixel and 10 square arc-minutes respectively. The filters used in this study are closely matched with the Johnson-Cousins system.

Table 2 presents the journal of observations. Column 1 gives the

Peer review under responsibility of National Research Institute of Astronomy and Geophysics.
E-mail address: y_hendy_yasser@yahoo.com.

https://doi.org/10.1016/j.nrjag.2018.05.001
Received 18 March 2018; Received in revised form 29 April 2018; Accepted 3 May 2018
Available online 07 May 2018

Table 1
Basic data for galaxies in the studied sample.

Pair ID	z[a]	Type[b]	PA[b] (degree)	B_T[b] (mag)	d25[b] (arcmin)
KPG 562a	0.045558	Sc	79.0	15.15 ± 0.32	0.59
KPG 562b	0.045078	Sbc	10.0	15.05 ± 0.41	0.66

[a] NED.
[b] HyperLeda.

Table 2
Journal of the observational data of the sample on 2014 June 25.

Pair ID	Filter	Exp. (s)	FWHM (arcsec)	Airmass	UT
KPG 562	B	6 × 300	2.03	1.026	01:10:13
	V	2 × 300	2.30	1.183	01:01:14
	R	2 × 300	1.95	1.240	01:25:57

identification number in the KPG catalog, column 2 gives the filter, column 3 represents the exposure time in seconds, columns 4 and 5 give the mean seeing FWHM in arcsec and airmass respectively, column 6 represent the time of observations.

All raw images are observed with two amplifiers, overscan, bias and flat-field. We constructed a code for data reduction using IRAF package. Cosmic-ray events were subtracted using the Pych's algorithm (Pych, 2004).

The instrumental magnitudes of the standard stars were measured using the aperture photometry package QPHOT/IRAF. The total magnitudes were measured at different circular apertures from small aperture radius to large radius. We applied the curve-of-growth technique (Stetson, 1990) of the package MKAPFILE/IRAF to compute the best aperture from different circular apertures taken for each standard star. We used the standard stars in the Landolt's catalogue (Landolt, 2009) to calibrate the instrumental magnitude using the package PHOTCAL/IRAF to transform the instrumental magnitude (bvr) to the standard magnitude (BVR) using the following equations:

$$B= b-K_b X_b + CT_b(b-v) + ZP_b \quad (1)$$

$$V = v - K_v X_v + CT_v(b - v) + ZP_v \quad (2)$$

$$R= r-K_r X_r + CT_r(v-r) + ZP_r \quad (3)$$

where B, V, and R are the standard magnitudes from Landolt (2009) and b, v, and r are the instrumental magnitudes. The K_b, K_v, and K_r are the extinction coefficients for the atmosphere in the B, V and R bands respectively, X_b, X_v and X_r are the air masses in the B, V and R bands respectively, CT_b, CT_v, CT_r are the color terms in the B, V, and R bands respectively and ZP_b, ZP_v, ZP_r are the photometric zero points in the B, V, and R bands respectively.

Table 3 shows the results of the photometric calibration in the B, V, and R bands (using Eqs. (1)–(3)), the zero points, the extinction coefficients, color terms and the RMS error in the B, V, and R bands.

3. Surface photometry and analysis

Surface photometry is an important and powerful tool to obtain the photometric properties of galaxies. We used The ELLIPSE task from the IRAF to obtain the isophotes of the galaxies which are then fitted to ellipses to derive the radial profiles e.g. luminosity, color, position angle, x and y center and the ellipticity. These profiles provide the basic information such as isophote twisting, color, total magnitudes, and off-centering of the isophote. The technique of surface photometry was applied to the images of each component of the galaxy pairs.

The contour maps in the R band for each component were drawn using SAOimage DS9 version 7.2 to describe the pair. The position angle profile and the x and y isophotal center shifts for each component may help us to study the effect of interaction between galaxies on the outer parts of each component. Generally, the x and y isophotal center-shift for the isolated galaxies are expected to be nearly centered about a common center. But the isophotes of the outer parts for the interacting galaxies show some shift toward the other components in case of mutual attraction or away the other components in the case of collision (Ali, 1993).

The obtained magnitudes were corrected for internal extinction from Schlafly and Finkbeiner (2011), k-correction from Chilingarian et al. (2010) and cosmological dimming by subtracting 10 log (1 + z). The photometric characteristics of galaxy pair KPG 562 was summarized in Table 4. The total magnitudes were measured within isophote with a semimajor axis of 0.22 arcmin and 0.19 arcmin of component KPG 562a and KPG562b respectively.

Table 3
The values of Zero point, ZP, extinction coefficients, K, color term, CT, and the root mean square error for each band.

Filter	ZP	K	CT	RMS
B	19.934 ± 0.224	0.528 ± 0.153	0.331 ± 0.027	0.064
V	21.726 ± 0.081	0.272 ± 0.053	-0.027 ± 0.013	0.032
R	22.063 ± 0.039	0.130 ± 0.027	-0.097 ± 0.012	0.024

Table 4
Measured photometric parameters for the studied sample.

Parameters	KPG 562a	KPG 562b
SMA (arcmin)	0.22	0.19
Ellipticity	0.421 ± 0.027	0.160 ± 0.019
PA (deg)	72.578 ± 2.374	23.042 ± 4.032
B	16.007 ± 0.016	15.729 ± 0.014
V	15.629 ± 0.009	15.281 ± 0.009
R	14.301 ± 0.006	14.025 ± 0.006
Mv	−20.85	−21.18

4. The galaxy pair KPG 562

The KPG 562 system is a pair of the two normal spiral galaxies (Fig. 1). The component a (PGC 068144) is classified as Sc, the component b (PGC 068143) is classified as Sbc. We measured the angular separation between the two components to be 1.07 arcmin (60.9 kpc) Table 6. A saturated star is superposed, south east of the component b at 0.15 arcmin (Miyauchi-Isobe and Maehara, 1998). This pair is interacting system, north direction of the component b contains the curved line of the tidal tail with length = 8.7 kpc and thickness = 1.4 kpc in R-band (see Fig. 1 and Table 6). We downloaded the FITS image of this system from SDSS survey in *r*-band. The contour maps of the *r*-band in SDSS survey confirmed that the tidal tail is in the north direction of the component b (Fig. 1).

4.1. Morphologies and contour maps of the KPG 562

We investigated the component of the galaxy pair KPG 562 by visual inspection of their images and contour maps to recognize the presence of interaction signs e.g. tidal tails and/or tidal bridges. The galaxy pair KPG 562 contains only one tidal tail of the component KPG 562b as shown in Fig. 1 for our observation in R-band and SDSS data in *r*-band. The surface brightness of the outer isophotes and the interval between two successive isophotes of the system KPG 562 in present study and SDSS data survey are listed in Table 5. The isophotal contour of component KPG 562a is shown nearly symmetric and concentric isophotes, while the component KPG 562b is shown asymmetric and nonconcentric isophotes. This confirms that the component b has signature of the interaction.

The dimensions (the length and the thickness) of the tidal tails are extracted following the method described by Mohamed et al. (2011).

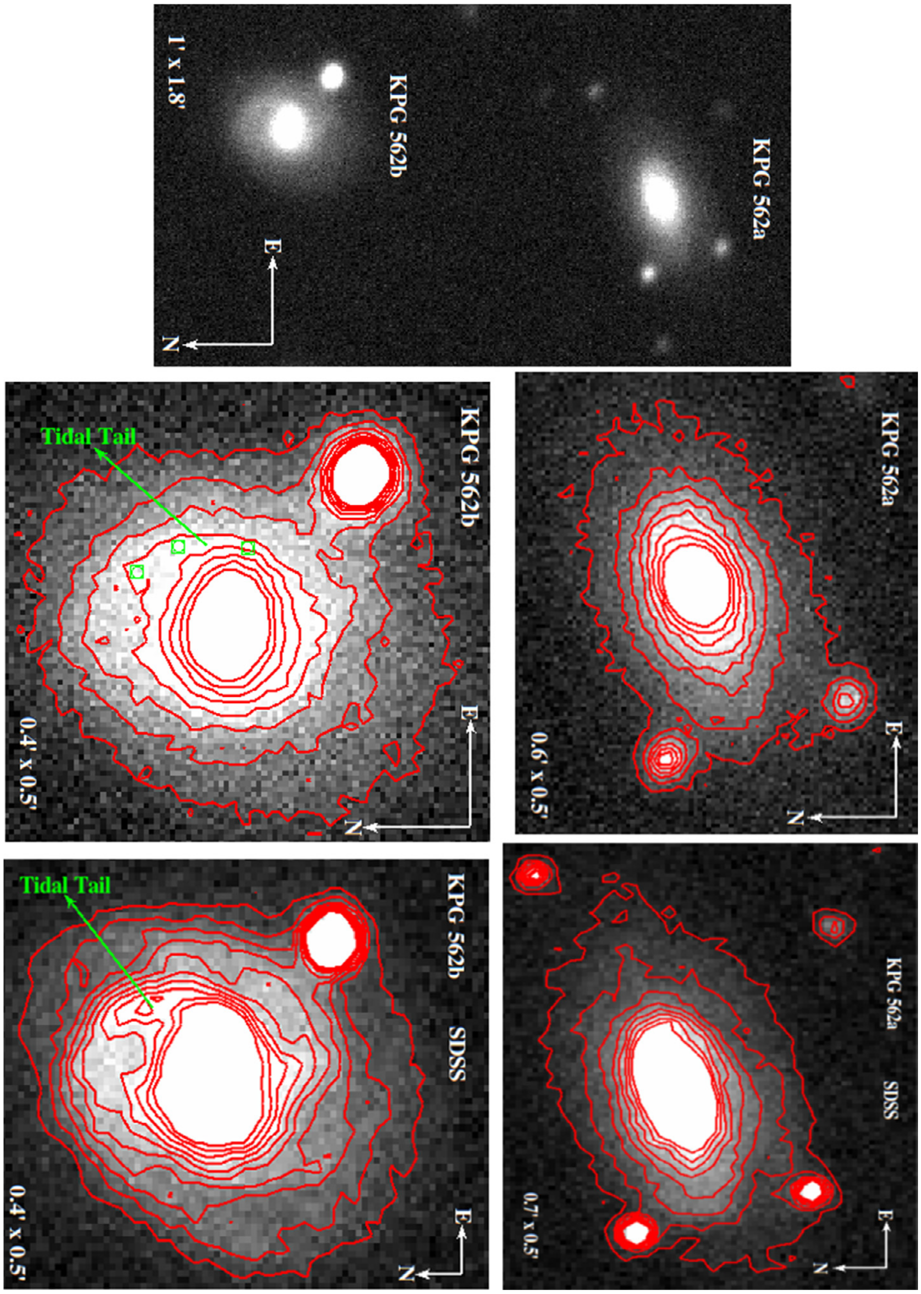

Fig. 1. The first panel: R- image, the second panel: contour maps overlaid on R-image of the system KPG 562 (present study). But the third panel: contour maps overlaid on *r*-image of SDSS survey of the system KPG 562.

Table 5
The surface brightness of the outer isophotes and the interval between successive isophotal contours.

Pair ID	SB mag/arcsec^2	Interval mag/arcsec^2	Comments
KPG 562a	22.50	0.27	Present study
	22.30	0.09	SDSS
KPG 562b	22.35	0.29	Present study
	22.15	0.13	SDSS

The separation between the components was determined and compared with result of Karachentsev (1987) (Table 6). The tidal tails interaction generally classified into Curved Line (CL) or Straight Line (SL), this is depended on shape of the tail, straight line or curved line. Our studied case (KPG 562), is curved line (Table 6).

4.2. The luminosity and color profile of the KPG 562

The surface brightness profile of the component KPG 562a in BVR bands is normal (Fig. 2a) and started to decrease from a = 3″ to a = 13.4″ in B band, in VR bands it decrease from a = 3″ to a = 18.8″. The luminosity profile confirms that the component KPG562a is normal; this is shown also in isophotal contour in Fig. 1. The inner parts within a ≤ 10″, the outer parts within a > 10″. The surface brightness profile of the component KPG 562b in BVR bands (Fig. 2b) is normal with many humps, and started to decrease from a = 3″ to a = 11.6″ in B band, in VR bands it decreases from a = 3″ to a = 16.4″. The inner parts within a ≤ 8″, the outer parts within a > 8″. We noticed that there are humps on the profile of the component KPG 562b in BVR bands at a = 14″ outward. This confirmed that the component KPG562 has signs of interaction as shown in Fig. 1.

The profiles B-V, V-R color index of the component KPG 562a is

Table 6
The geometric and photometric properties of the interaction signs for the galaxy pair KPG 562.

Pair ID	Tidal tail			Center to center separation	
	Length	Thickness	Interaction type[a]	X[b]	X[c]
KPG 562b	0.153 arcmin 8.7 kpc	0.025 arcmin 1.4 kpc	CL	1.07 arcmin 60.9 kpc	1.10 arcmin

[a] The interaction type. CL: curved line.
[b] The present work.
[c] Karachentsev (1987).

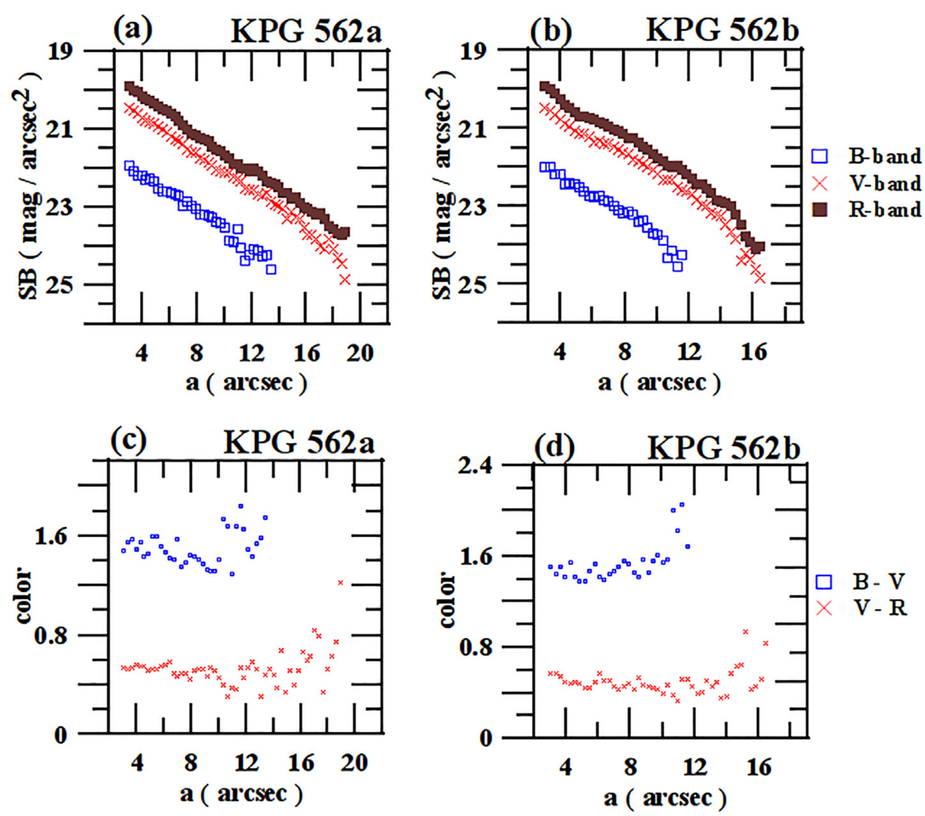

Fig. 2. The first panel presents luminosity profiles, while second panel presents the color profiles of the galaxy pair KPG 562.

presented in Fig. 2c. The color index within the inner parts < B-V > = 1.455 ± 0.086 is bluer than the outer parts < B-V > = 1.610 ± 0.159. The profiles B-V, V-R color index of the component KPG 562b is presented in Fig. 2d. The color index within the inner parts < B-V > = 1.471 ± 0.059 is bluer than the outer parts < B-V > = 1.651 ± 0.207.

4.3. The x and y isophotal center-shift of the KPG 562

The x and y isophotal center-shift in the BVR bands of the component KPG 562a were illustrated in Fig. 3a and c. The outer x and y center of the isophotes of the component KPG 562a in BVR bands starts to decrease from 10″ outward, i.e. toward the component KPG 562b. The x and y isophotal center-shift in the BVR bands of the component KPG 562b were illustrated in Fig. 3b and d. The outer x and y center of the isophotes of the component KPG 562b in BVR bands start to increase from a = 8″ outward, i.e. toward the component KPG 562a. The x and y isophotal center-shift of outer isophotes of component KPG 562a decreased in direction (i.e. shifted toward) component KPG 562b. This confirms that both components KPG 562a and KPG 562a have signs of interaction.

4.4. The position angle profiles of the KPG 562

The position angle profiles in the BVR bands of the component KPG 562a were given in Fig. 4a. The outer isophotes of the component KPG 562a in BVR bands (a > 10″) are twisted to the South West, i.e. away from component KPG 562b. The position angle profiles in the BVR bands of the component KPG 562b were given in Fig. 4b.

4.5. The ellipticity profile of the KPG 562

The ellipticity profile of the component KPG 562a is presented in Fig. 5a. The ellipticity in BVR bands in the inner parts increase within a = 3″–6″, decrease within a > 6″–8″, increase within a > 8″–10″, while in the outer parts the ellipticity stable within a > 10″–12″, increase within a = 12″–13″, decrease within a = 13″–14″, then increase from a > 14″ outward. The ellipticity profile of the component KPG 562b is presented in Fig. 5b. The ellipticity in BVR bands in the inner parts decrease within a = 3″–5″, increase within a > 5″–6″, decrease within a > 6″–8″, while in the outer parts decrease within a > 8″–11″, increase within a = 11″–12″, then decrease a > 12 outward. We noticed that ellipticity of the outer isophotes of component KPG 562a increased (i.e. more flatness), while the component KPG

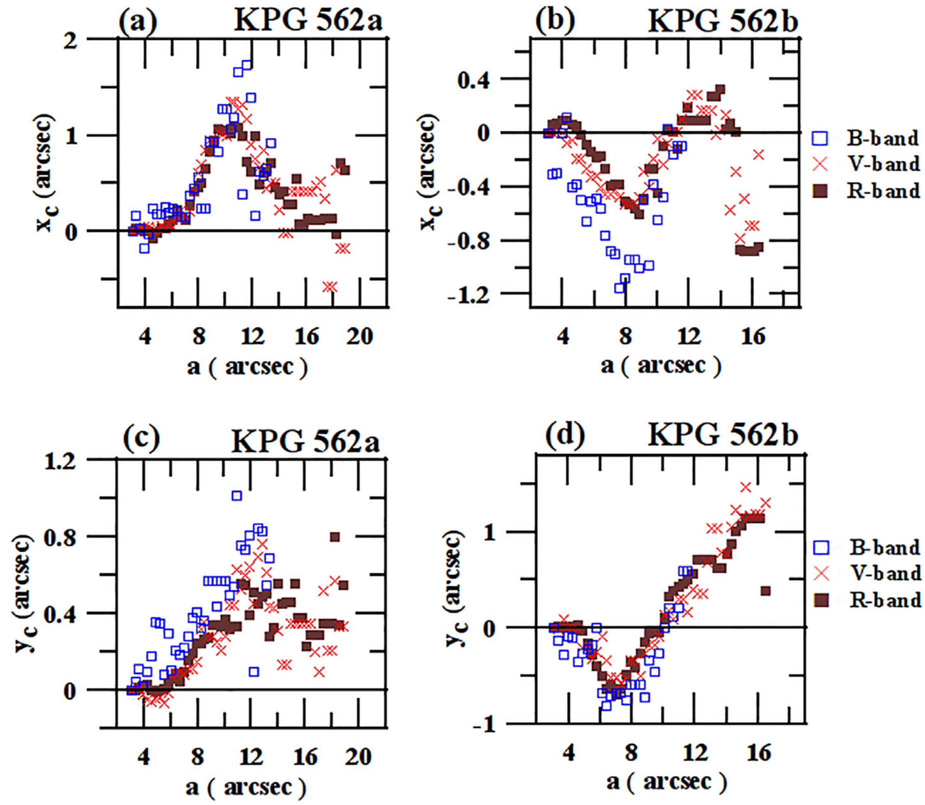

Fig. 3. The first panel presents x center-shift profiles, while second panel presents the y center-shift profiles of the galaxy pair KPG 562.

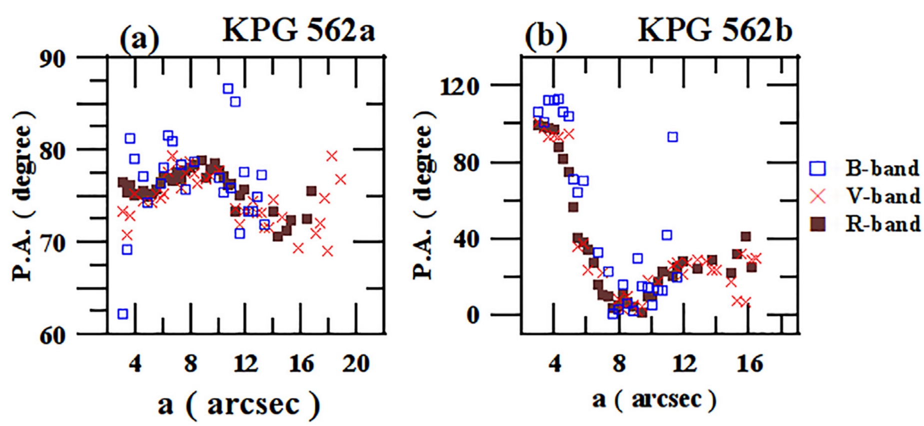

Fig. 4. The position angle profiles of the galaxy pair KPG 562.

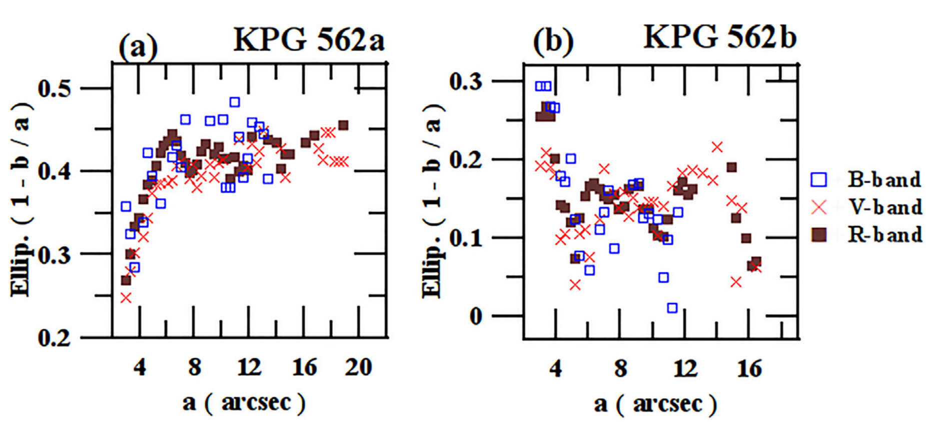

Fig. 5. The ellipticity profile of the galaxy pair KPG 562.

562b is decreased (i.e. less flatness). This is due to the gravitational interaction between the galaxies. The component KPG 562b strongly compressed the outer isophotes of component KPG 562a (i.e., component KPG 562a becomes more flatness). While the component KPG 562a also weakly compressed the outer isophotes of component a (i.e., component KPG 562b become less flatness).

5. Discussions and conclusions

We investigated the effect of the gravitational interaction between the components of isolated galaxy pair KPG 562. We found that the pair is connected with the tidal tail between galaxies as shown with visual inspection and isophotal contour (Fig. 1). By using our method (isophotal contours, luminosity profiles, color profiles, x and y isophotal center shift profiles, position angle profiles and ellipticity profiles, as shown in Figs. 1–5) to investigate signs of interaction between galaxies, we confirmed that the pair is interacting system.

We noticed from PA profiles that the outer isophotes of the component KPG 562b were twisted in direction North West, i.e. nearly parallel to the tidal tail.

The results of the surface photometry and geometric properties of the tidal tail of the sample are listed in Tables 4 and 6.

Acknowledgements

The NASA's Astrophysics Data System Bibliographic Service had used in this research. The NASA/IPAC Extragalactic Database (NED) which is operated by the Jet Propulsion Laboratory, California Institute of Technology, under contract with the National Aeronautics and Space Administration had used in this research.

We would like to acknowledge the usage of the HyperLeda database (http://leda.univ-lyon1.fr).

References

Ali, G.B., 1993. Morphological and Surface Photometric Investigation of Some Pairs Containing UV-Excess Galaxies, 1994. Cairo Univ, MSc.
Bell, E.F., Phleps, S., Somerville, R.S., Wolf, C., Borch, A., Meisenheimer, K., 2006. ApJ 652, 270.
Bundy, K., Fukugita, M., Ellis, R.S., Kodama, T., Conselice, C.J., 2004. ApJ 601, L123.
Carlberg, R.G., Cohen, J.G., Patton, D.R., Blandford, R., Hogg, D.W., Yee, H.K.C., Morris, S.L., Lin, H., Hall, P.B., Sawicki, M., Wirth, G.D., Cowie, L.L., Hu, E., Songaila, A., 2000. ApJ 532, L1.
Chilingarian, Igor V, Melchior, Anne-Laure and Zolotukhin, Ivan Yu, 2010, MNRAS, 405, 1409 (http://kcor.sai.msu.ru/).
Karachentsev, I.D., 1972, Comm. Spec. Astrophys. Obs 7. 1 (KPG).
Karachentsev, I.D., 1987, Binary Galaxies (Nauka, Moscow) [in Russian].
Landolt, A.U., 2009. AJ 137, 4186.
Le F'evre, O., Abraham, R., Lilly, S.J., Ellis, R.S., Brinchmann, J., Schade, D., Tresse, L., Colless, M., Crampton, D., Glazebrook, K., Hammer, F., Broadhurst, T., 2000. MNRAS 311, 565.
Lin, L., Koo, D.C., Willmer, C.N.A., Patton, D.R., Conselice, C.J., Yan, R., Coil, A.L., Cooper, M.C., Davis, M., Faber, S.M., Gerke, B.F., Guhathakurta, P., Newman, J.A., 2004. ApJ 617, L9.
Miyauchi-Isobe, N., Maehara, H., 1998. Publ. Natl. Astron. Observatory Japan 5 (2), 75–97.
Mohamed, Y.H., Reshetnikov, V.P., Sotnikova, N.Y., 2011. Astron. Lett. 37, 670.
Reshetnikov, V.P., Mohamed, Y.H., 2011. Astron. Lett. 37, 743.
Mohamed, Y.H., Reshetnikov, V.P., 2011. Astrophysics 54, 155M.
Patton, D.R., Carlberg, R.G., Marzke, R.O., Pritchet, C.J., da Costa, L.N., Pellegrini, P.S., 2000. ApJ 536, 153.
Patton, D.R., Pritchet, C.J., Carlberg, R.G., Marzke, R.O., Yee, H.K.C., Hall, P.B., Lin, H., Morris, S.L., Sawicki, M., Shepherd, C.W., Wirth, G.D., 2002. ApJ 565, 208.
Pych, W., 2004. PASP 116, 148.
Schlafly, Edward F., Finkbeiner, Douglas P., 2011. ApJ 737, 103S.
Sulentic, J., 1992. In: Busarello, G., Capaccioli, M., Longo, G. (Eds.), Morphplogical and Physical Classification of Galaxies. Kluwer, Dordrecht.
Stetson, P.B., 1990. PASP 102, 932.