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PHOTOMETRIC OBSERVATIONS OF NINE SHAKHBAZIAN COMPACT GROUPS

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By observations with the 1.5m telescope at San Pedro Martir (OAN, UNAM, Mexico) the BVR magnitudes are determined for 66 member galaxies in Shakhbazian Compact Galaxy Groups ShCG 40, ShCG 176, ShCG 270, ShCG 278, ShCG 310, and ShCG 342. Three other groups were observed in two or only in one band. Seven galaxies in ShCG 298 were observed in B and R, six galaxies in ShCG 95 were observed in V, and seven galaxies in ShCG 345 were observed in V and R. The distribution of brightness of observed galaxies is determined. Signs of interaction between galaxies are detected in some groups.

Keywords: *galaxies:groups:photometry*

1. Introduction

Poor groups of galaxies that usually contain not more than 20 members are the most common systems in the universe [1-3]. The more interesting among the groups are the so-called compact groups (CGs) with space density reaching 10^4-10^5 galaxies in Mpc^3. The first detected Shakhbazian compact group (ShCG) [4] was assumed to be a dense cluster of red stars. However, Robinson and Wampler [5] showed that the members of this cluster are true galaxies. This stimulated a comprehensive search for similar compact groups carried out by Shakbazian, Petrosian, Baier, and Tiersch [6 and references therein]. The list of ShCGs contains nearly 400 groups.

The first spectral observations of a few ShCGs [e.g., 7-10] showed that redshifts of member galaxies differ

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insignificantly from each other, and that these groups are gravitationally confined physical systems. ShCGs were detected by visual inspection of the Palomar sky survey prints. Due to being overexposed, the images of some members of distant groups look like compact galaxies; therefore the groups were initially named compact groups of compact galaxies. The first detailed photographic observations [11-13] showed, however, that the so-called compact galaxies are in fact ordinary galaxies. Hence, Shakbazian groups are compact groups of ordinary, mostly E, galaxies.

Spectral and photographic observations of a large number of ShCG groups have been made by Tiersch et al. [14 and references therein] and Tovmassian et al. [15-23]. It was shown that the majority of the candidate group members were galaxies with accordant radial velocities (usually < 1000 km s^{-1}). It was found that only a few of the supposed members were stars. It was also found that some objects in the area of groups assumed to be stars for the compactness of images were in fact galaxies. The majority of member galaxies (70-75%) are mainly of early morphological types. Hence, though the groups were selected without knowledge of redshifts of their members, the majority of them are real physical systems.

In this paper we present results of photometric observations of nine ShCGs.

2. Observations and results

In 1996-1999 we carried out photometric observations of ShCG 40, ShCG 95, ShCG 176, ShCG 270, ShCG 278, ShCG 298, ShCG 310, ShCG 342, and ShCG 345. The group ShCG 40 is the central condensation of the cluster Zw 0122.4+0813. Observations were made at seeing better than 2 arcsec with the 1.5m telescope of the National Astronomical Observatory of the UNAM at San Pedro Martir. The TEK2 CCD with 1024 × 1024 pixels with sizes 24μ was used. The field of view is 4.3 × 4.3 arcmin and the image scale is 0.25"/pxl. Observations of six groups were made in the *B*, *V,* and *R* bands. The group ShCG 298 was observed in the *B* and *R*, the group ShCG 95 only in the *V* band, and the group ShCG 345 in the *V* and *R* bands.

The images were processed using the MIDAS image processing package. The night sky was eliminated by means of a program developed by Shergin and Kniazev at SAO (Russia). First, the bias and the sky background were subtracted, and then the image frames were divided by the evening and morning twilight fields of blank areas (Christian et al. [24]) to normalize the variations from pixel to pixel caused by different optical transmission and quantum efficiency. Stellar magnitudes were calibrated in the Kron/Cousins photometric system. The star clusters M 67 and NGC 4147 have been used as standards. Outer isophots in all three colors in some cases reach surface brightness $\mu < 26^{m}.5/\mathrm{arcsec}^2$. The *BVR* magnitudes are estimated, however, till $\mu = 26^{m}.5/\mathrm{arcsec}^2$. The limiting surface brightness of galaxies with superimposed halos does not reach this value. In such cases the galaxies were sliced into disturbed and undisturbed parts, and the galaxy magnitudes were calculated by a special MIDAS program that fits the elliptical isophots using the undisturbed part of the galaxy. We assumed that the galaxies retained their symmetry despite overlapping. If a galaxy is embedded in a common halo with another galaxy, then the last undisturbed isophot (brighter than $\mu = 26^{m}.5/\mathrm{arcsec}^2$) determines the magnitude.

The estimated accuracy of magnitudes is generally about $0^{m}.06$. In the case of overlapped images the error could be somewhat higher. The measured magnitudes were corrected for the galactic extinction Q_B (Schlegel, Filkbeiner,

TABLE 1. Photometric Parameters of Galaxies in ShCG 40, ShCG 95, ShCG 176, ShCG 270, ShCG 278, ShCG 298, ShCG 310, ShCG 342, and ShCG 345

Gal	*B*	*V*	*R*	*b/a*	PA	Gal	*B*	*V*	*R*	*b/a*	PA
1	2	3	4	5	6	1	2	3	4	5	6
ShCG 40						ShCG 176					
1	15.21	14.02	13.26	0.78	45	1	18.04	16.16	15.80	0.82	9
2	17.89	16.79	16.09	0.74	39	4	17.99	16.96	16.15	0.77	25
3	17.24	16.03	15.30	0.78	-55	5	18.94	18.04	17.20	0.65	70
4	18.67	17.80	17.12	0.79	45	6	18.69	17.59	16.65	0.76	-25
5	18.38	17.19	16.49	0.73	-78	9	17.04	16.16	15.66	0.89	-23
6	18.40	17.17	16.42	0.66	43	10	20.01	18.34	17.30	0.76	32
7	18.31	17.14	-	0.88	64	ShCG 270					
8	17.09	16.34	15.86	0.53	-59	1	17.93	16.19	14.92	0.75	48
9	18.90	17.81	-	0.91	-19	2	17.77	16.54	15.33	0.96	-23
10	19.04	18.19	-	0.51	17	3	17.82	16.42	15.42	0.96	-21
24	18.94	17.46	16.58	0.99	-24	4	17.81	16.78	15.57	0.97	-9
25	17.96	16.84	16.00	0.78	60	5	18.64	16.86	15.64	0.51	-25
26	19.05	17.86	17.04	0.88	12	6	18.65	16.97	15.81	0.80	-36
27	18.02	16.78	15.93	0.94	46	7	19.69	18.30	16.97	0.66	89
28	18.19	17.09	16.17	0.85	-31	9	18.62	17.49	16.47	0.66	-43
46	18.56	17.89	-	0.61	-14	10	19.14	17.79	16.41	0.77	-41
47	17.59	16.47	15.65	0.74	-72	ShCG 278					
48	17.33	16.35	15.44	0.69	-77	1	17.62	16.11	15.08	0.98	-21
49	17.65	17.11	16.35	0.94	75	2	18.01	16.60	15.96	0.85	-81
50	18.24	17.05	16.42	0.69	32	3	18.33	17.04	16.14	0.81	37
51	18.30	18.10	-	0.83	-61	4	17.06	16.67	16.39	0.93	-65
55	18.60	17.64	16.77	0.54	-47	5	18.77	17.84	16.64	0.88	-12
56	17.54	16.33	15.59	0.82	-62	6	18.96	17.73	16.85	0.87	-18
57	16.65	15.41	14.69	0.37	-48	7	20.09	18.52	17.36	0.69	-78
ShCG 95						ShCG 298					
1	-	15.22	-	0.91	-32	1	19.28	-	17.11	0.69	-44
2	-	17.27	-	0.80	76	2	19.39	-	17.33	0.70	84
3	-	16.54	-	0.82	4	3	19.47	-	17.43	0.86	16
4	-	17.65	-	0.86	-77	4	19.26	-	17.53	0.74	68
5	-	17.89	-	0.90	-41	5	19.43	-	17.56	0.88	50
6	-	18.94	-	0.92	-34						

Table 1 (conclusion)

1	2	3	4	5	6
6	20.21	-	18.05	0.77	54
7	19.66	-	18.19	0.74	11
ShCG 310					
1	18.31	16.89	15.63	0.89	-1
2	18.79	17.32	16.25	0.96	-13
3	17.36	16.05	14.77	0.62	-59
4	17.26	15.66	14.47	0.72	-29
5	18.74	17.12	15.85	0.80	13
6	19.22	18.05	16.79	0.59	-8
7	20.03	18.65	17.54	0.82	-8
8	19.35	18.22	17.16	0.50	-37
9	19.25	18.04	16.95	0.75	53
12	19.73	18.74	17.88	0.72	41
13	20.52	19.37	18.28	0.66	29
ShCG 342					
1	17.93	15.89	14.92	0.92	-64
2	17.76	16.12	15.38	0.82	-42
3	18.37	16.29	14.96	0.74	63
4	18.35	16.85	15.45	0.75	49
5	19.03	17.61	16.51	0.65	-31
6	18.05	16.63	15.49	0.63	-21
7	19.12	17.54	16.41	0.63	-27
10	18.56	16.53	15.62	0.92	40
11	18.32	16.95	15.88	0.75	-51
ShCG 345					
1	-	17.03	16.05	0.90	37
2	-	17.18	15.78	0.65	32
3	-	17.13	15.85	0.72	-57
5	-	18.09	17.01	0.97	32
6	-	17.99	16.95	0.71	-51
8	-	17.66	16.72	0.85	70
9	-	19.17	17.90	0.49	-15

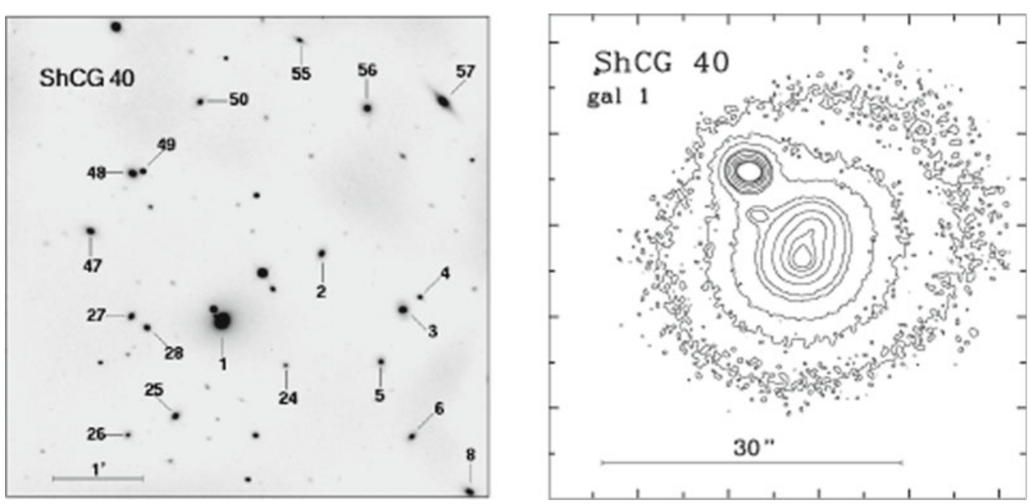

Fig. 1. The image of ShCG 40 (left panel) in the *R* band and isophotal contour plots of the central galaxy (right panel). North is up, east is left. The object at the north-east is a star. The units of surface brightness μ of isophots starting from the innermost one: $17^m.5$, $17^m.7$, $18^m.4$, $18^m.8$, $19^m.2$, $19^m.7$, $20^m.7$, $21^m.2$, $22^m.1$.

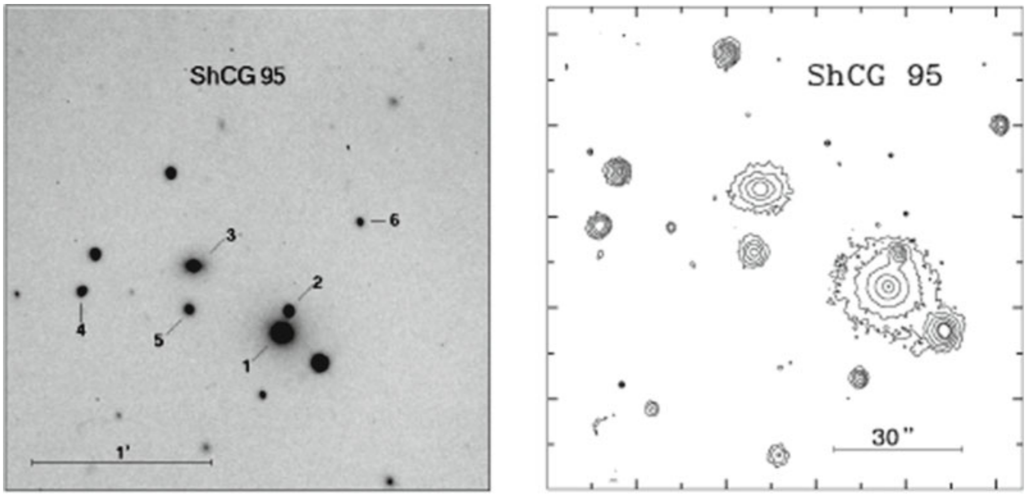

Fig. 2. The image of ShCG 95 (left panel) in the *V* band and isophotal contour plots of galaxies (right panel). North is up, east is left. The units of surface brightness μ of isophots starting from the innermost one: $19^{m}.4$, $20^{m}.6$, $21^{m}.9$, $22^{m}.7$, $23^{m}.6$, $24^{m}.6$.

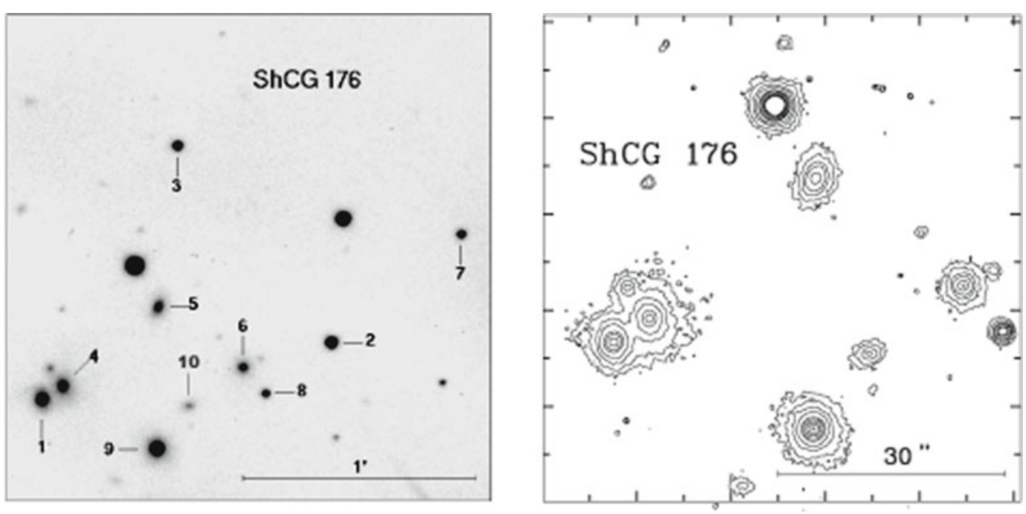

Fig. 3. The image of ShCG 176 (left panel) and isophotal contour plots of galaxies (right panel). The units of surface brightness μ of isophots starting from the innermost one: $18^{m}.3$, $19^{m}.1$, $19^{m}.8$, $20^{m}.1$, $20^{m}.6$, $21^{m}.1$.

and Davis [25]) given in NED (NASA/IPAC Extragalactic Database). The inner individual extinction within spiral galaxies observed in the *B* band is estimated according to $A_i = 0.72 \log \cos i$. The inclination angle i is determined by the procedure in MIDAS. The extinctions in *V* and *R* are calculated by $E_{B-V} = 0.238 Q_B$ and $E_{V-R} = 0.59 Q_B$, respectively. The axial ratios *b*/*a* and the position angles PA of galaxies are deduced from $26^{m}.5$/arcsec^2 isophots. In the case of overlapping halo the outermost fitted ellipse and the extrapolated surface brightness profile down to the local background was used.

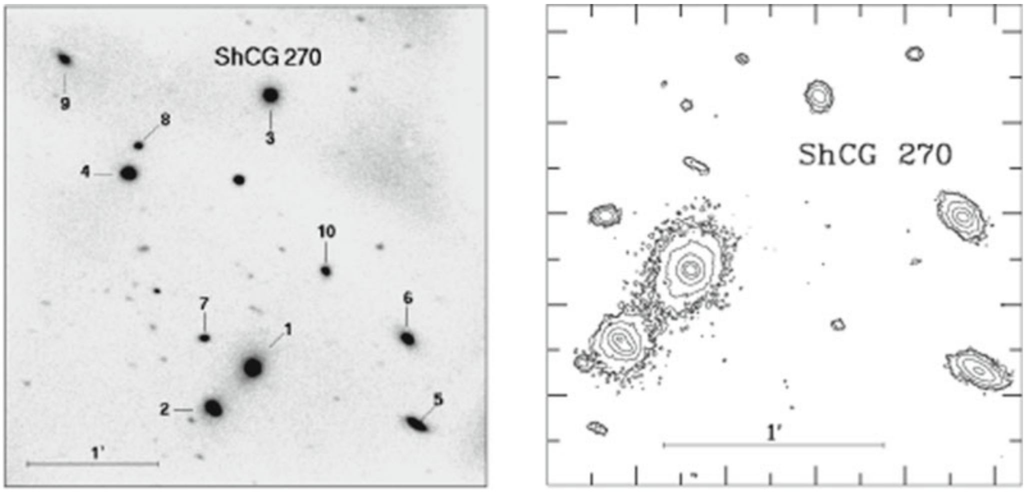

Fig. 4. The same as Fig. 3 for ShCG 270. The units of surface brightness μ of isophots starting from the innermost one: $18^{m}.8$, $19^{m}.4$, $20^{m}.0$, $21^{m}.8$, $24^{m}.8$.

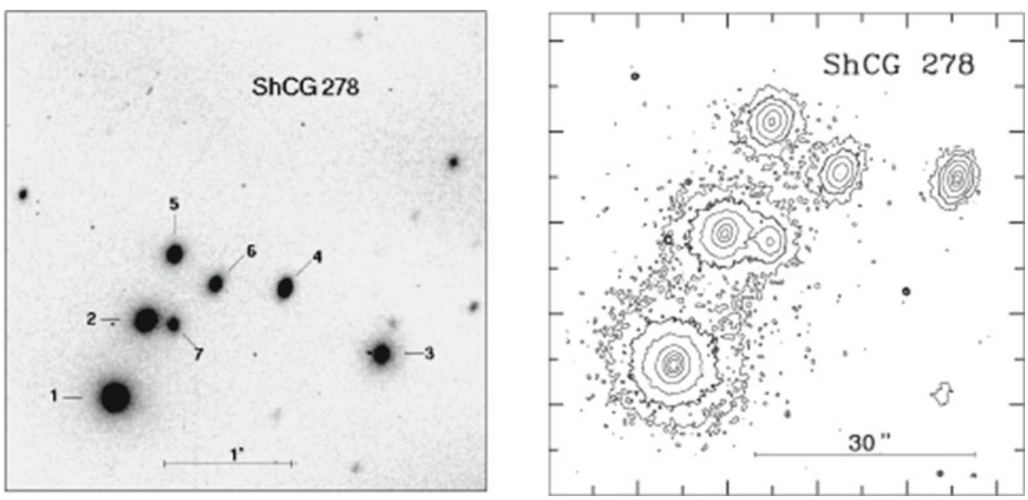

Fig. 5. The same as Fig. 3 for ShCG 278. The units of surface brightness μ of isophots starting from the innermost one: $18^{m}.2$, $18^{m}.5$, $19^{m}.8$, $19^{m}.2$ $19^{m}.8$, $20^{m}.7$, $21^{m}.7$, $22^{m}.8$.

The results of the photometry of the studied groups are presented in Table 1, in which the following information is given: 1, the galaxy identification number according to [26-30]; 2-4, the stellar magnitudes in the *B*, *V*, and *R* bands, respectively; 5, the axial ratio *b/a;* and 6, the position angle, *i*, of the large axis. The prime images of the studied groups and the surface brightness isophots are presented in Fig.1-9.

Consideration of the isophots shows that some of the candidate members of the groups (objects 2, 3, 7 and 8 in ShCG 176, object 8 in ShCG 270, objects 8 and 9 in ShCG 342, and objects 4, 5, and 7 in ShCG 345) are most probably stars.

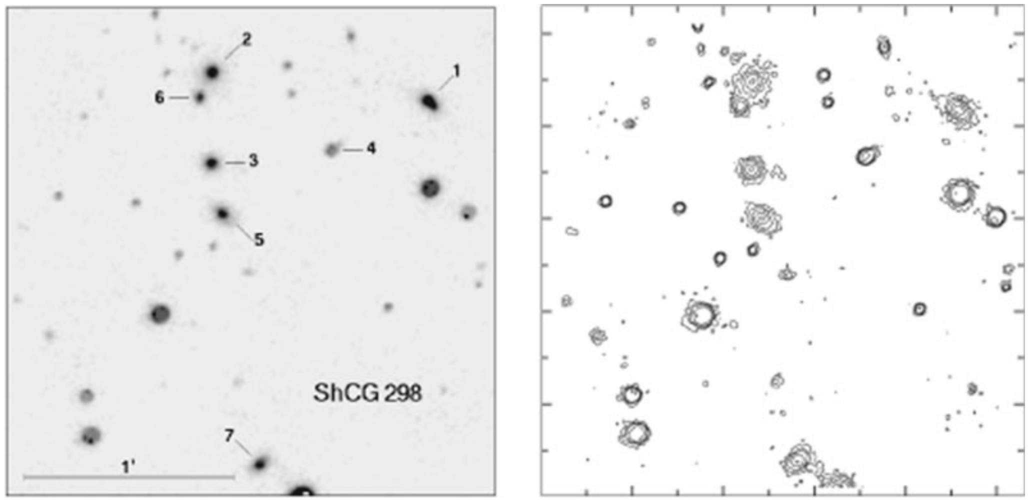

Fig. 6. The same as Fig. 3 for ShCG 298. The units of surface brightness $\mu\mu$ of isophots starting from the innermost one: $22^m.4$, $23^m.4$, $24^m.2$, $24^m.7$, $26^m.5$.

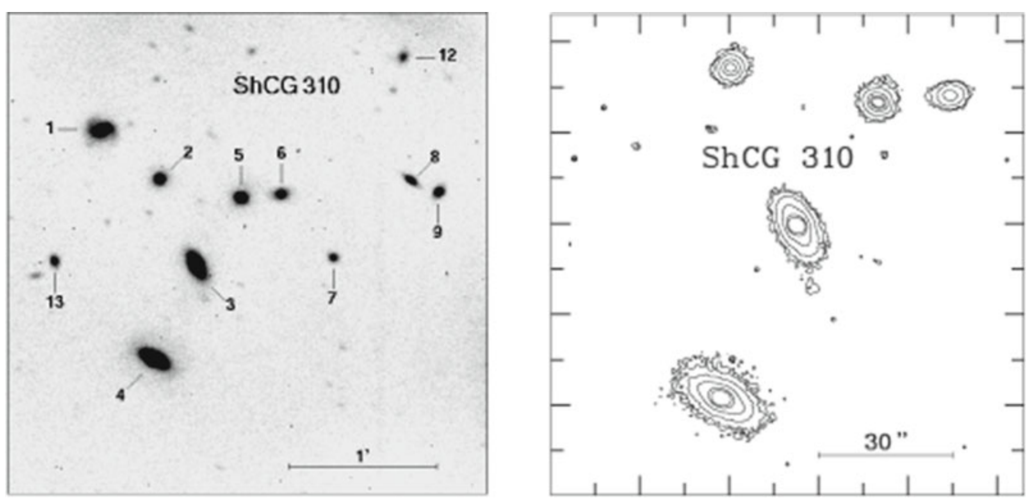

Fig. 7. The same as Fig. 3 for ShCG 310. The units of surface brightness μ of isophots starting from the innermost one: $19^m.4$, $20^m.1$, $20^m.8$, $21^m.5$, $22^m.2$, $22^m.6$.

A large number of interacting galaxies are detected among ShCG members [14,15-23]. There are a few possibly interacting galaxies also in the studied groups. The isophots of galaxies 1 and 3 in ShCG 95 (Fig.1), 1 and 4 in ShCG 176 (Fig.2), 1 and 2 in ShCG 270 (Fig.3), and 1, 2, and 7 in ShCG 278 are enlarged. Such isophots, according to Barnes [31,32], are a sign of interaction. Except for the enlarged isophots, the inner part of galaxy 1 in ShCG 270 is extended towards galaxy 2. The isophots of galaxy 2 in ShCG 298 (Fig.4) seem also to be enlarged, though no signs of distortion are seen in the galaxy 6 which is possibly projected nearby to galaxy 2. The galaxy 2 is probably interacting with galaxy 1 located at a projected distance of about 200 kpc.

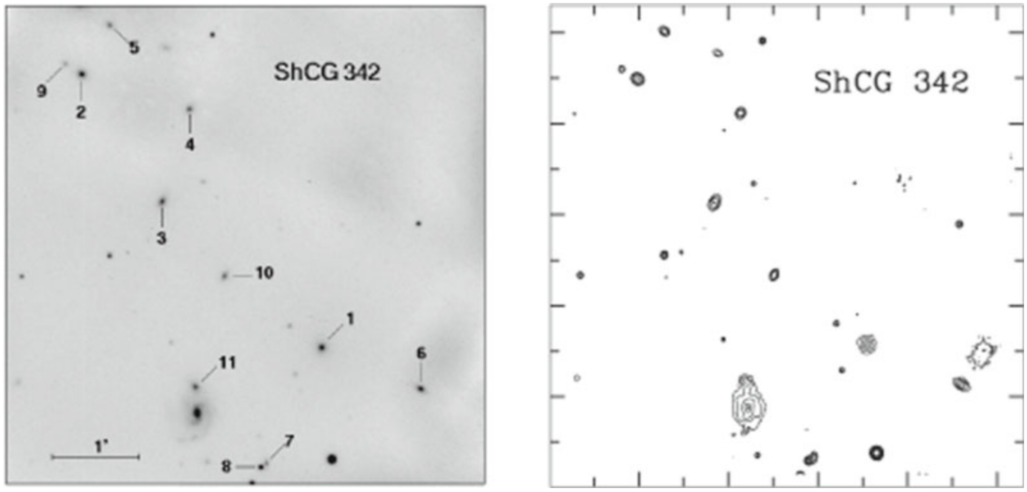

Fig. 8. The same as Fig. 3 for ShCG 342. The units of surface brightness μ of isophots starting from the innermost one: $19^{m}.4$, $20^{m}.3$, $21^{m}.3$, $23^{m}.7$.

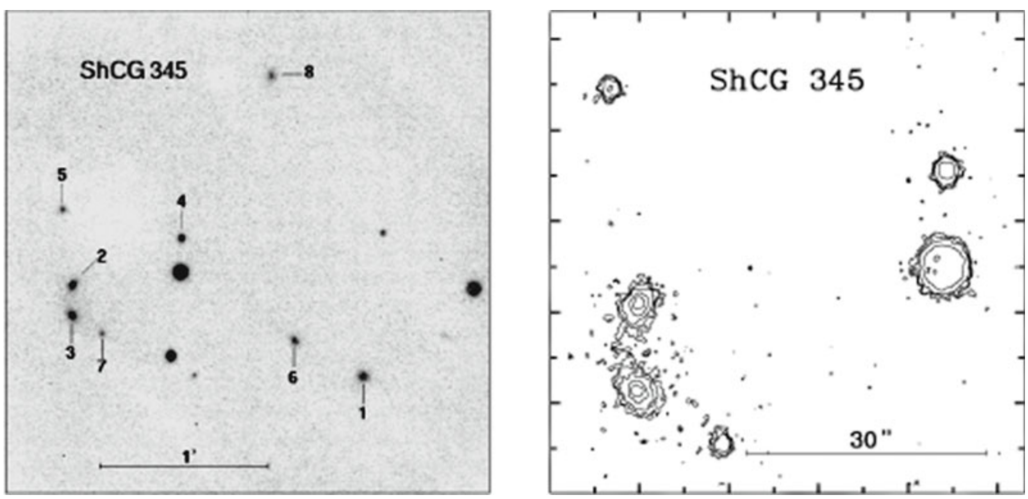

Fig. 9. The image of ShCG 345 (left panel) in *R* band and the isophotal contour plots of galaxies (right panel). The units of surface brightness μ of isophots starting from the innermost one: $18^{m}.4$, $19^{m}.4$, $19^{m}.2$, $20^{m}.2$, $20^{m}.8$, $21^{m}.5$.

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