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PHOTOMETRIC RESEARCH OF SEYFERT GALAXIES MRK 766, MRK 6, MRK 1040, MRK 1513

Abstract. The paper presents the results of the photometric observations of the Seyfert galaxies from the Markarian list: MRK 766, MRK 6, MRK 1040, MRK 1513. The observations were carried out on “the Eastern“ 1-meter telescope, located at the Tien-Shan Astronomical Observatory of the Fesenkov Astrophysical Institute. The observational data were processed using the MaximDL6 software package. The brightness was estimated by differential photometry, using standard stars in the vicinity of galaxies. This paper presents the light curves of the galaxies: Mrk 766, Mrk 6, Mrk 1040, Mrk 1513. It has been noted, that in Mrk 766, there is a tendency to a gradual weakening of the brightness in the three filters. Photometric changes of the galaxy Mrk 6 during 2016-2019 occurred synchronously in all three filters. The weakening of its brightness began in 2017 and by 2019 it reached $\sim 0^m.9$. During the investigation period, irregular brightness fluctuations were registered in galaxies Mrk 1040 and Mrk 1513 with amplitudes of $\sim 1^m.0$ and $0^m.8$, respectively.

Key words: Seyfert galaxies, photometry, B V R values.

Introduction

The regular observations of active galactic nuclei (AGNs) from the list of Markaryan galaxies are carried in Fesenkov Astrophysical Institute since 1971. Variability is the main feature of AGNs. Its maximum manifestations are recorded in the X-ray region [1,2]. It is believed that their brightness variability is associated with inhomogeneities of their accretion disks, flashes, and jets. The study of variability allows to understand the structure of the nuclear regions and to identify the processes responsible for certain observable characteristics. Photometric studies of AGNs in the BVR photometric system have been conducted at AFIF over the past ten years.

The Mrk 766, Mrk 6, Mrk 1040, Mrk 1513 galaxies belong to the Seyfert galaxies (SG) of the NLSy1 class (Seyfert 1 galaxy with narrow emission lines). This subclass of SG, discovered by Osterbrok, is distinguished by the following properties: relatively narrow lines of the Balmer series (FWHM (H β) < 2000 km / s), strong FeII lines and weak forbidden lines [3].

1. Observations and research methods. Photometric observations of the galaxies from the Markaryan list were carried out on the “Eastern” 1-meter telescope of the Richie-Chretien system (focal length 6.5 m) using the Apogee Alta F16M CCD camera and the Astrodon BVR filter set. The angular scale of the frame with the image of the object corresponds to 0.563 "/ pixel. The MaximDL6 software package was used to process the observational data. The standard procedure of processing consists of correction with the Dark, Bias and Flat field files. The brightness was estimated using differential photometry, standard stars were used located in the vicinity of galaxies. The obtained instrumental data were transferred to the international Johnson-Morgan system using the following equations transition:

$$\begin{aligned}
(B - V)_{calc} &= 1,035 \cdot (B - V)_{obs} - 0,013 - 0.0512 \cdot \text{sec } Z \\
(V - R)_{calc} &= 1.009 \cdot (V - R)_{obs} - 0.0021 - 0.0881 \cdot \text{sec } Z \\
V_{calc} &= V_{obs} - 0.014 \cdot (B - V)_{calc} - 0.016 - 0.2627 \cdot \text{sec } Z \\
B_{calc} &= V_{calc} + (B - V)_{calc} \\
R_{calc} &= V_{calc} - (V - R)_{calc}
\end{aligned}
\tag{1}$$

Typical errors of brightness measurements do not exceed $\pm 0^m.01$, the real accuracy of the results is limited by the accuracy of the standards [4].

2. Processing and analysis of results.

Mrk766 = NGC4253 refers to the Seyfert galaxies of the Sy1 class with supermassive central body (SMBH). The mass of the central body is $1.29 \times 10^6 M_{Sun}$ [7]. Equatorial coordinates of the galaxy: $\alpha(2000)=12^h18^m26^s,51552$; $\delta(2000)=+29^048'46,5187''$. Red shift $z=0.01271 \pm 0.00005$.

A star with coordinates $\alpha(2000)=12^h18^m17^s,75547$; $\delta(2000)=+29^053'00,4561''$

$B=14.72$; $V=14.2$; $R=13.0$ was used as the photometric standard. The following two stars were chosen as check stars:

- Pul-3-920040 with coordinates $\alpha(2000)=12^h18^m19^s,495$;
 $\delta(2000)=+29^050'53,8036''$, $B=16,14$; $V=15,2$;

- GPM 184.6072220+29.83269 with coordinates $\alpha(2000)=12^h18^m25^s,765$;
 $\delta(2000)=+29^049'47,9247''$, $B=15,7$.

As a rule, such galaxies are characterized by the rapid variability in the X-ray range, the source of which is usually considered to be dynamical processes in the nearest vicinity of the central body (CB) [5, 6].

Table 1 - The light curves of the Sy Mrk 766 in filters B, V, R for 2015-2019.

Date of observation	JD-2440000	B	V	R
10.04.2015	17122	14,57	13,837	12,412
11.04.2015	17123	14,564	13,798	12,351
04.04.2016	17482	14,543	13,813	12,358
15.12.2016	17737	14,745	13,983	12,576
09.02.2017	17793	14,769	13,979	12,571
05.03.2017	17817	14,737	13,973	12,568
08.03.2017	17820	14,728	13,964	12,563
11.06.2017	17915	14,774	14,021	12,615
18.04.2017	17861	14,718	13,961	12,571
11.04.2018	18219	14,894	14,116	12,701
12.04.2018	18220	14,861	14,165	12,686
24.01.2018	18142	14,878	14,108	12,707
05.05.2018	18243	14,818	14,063	12,657
05.06.2018	18274	14,858	14,102	12,68
11.03.2019	18553	14,792	14,047	12,608

Figure 1 shows the light curves of Sy Mrk 766 in BVR filters for the period 2015- 2019

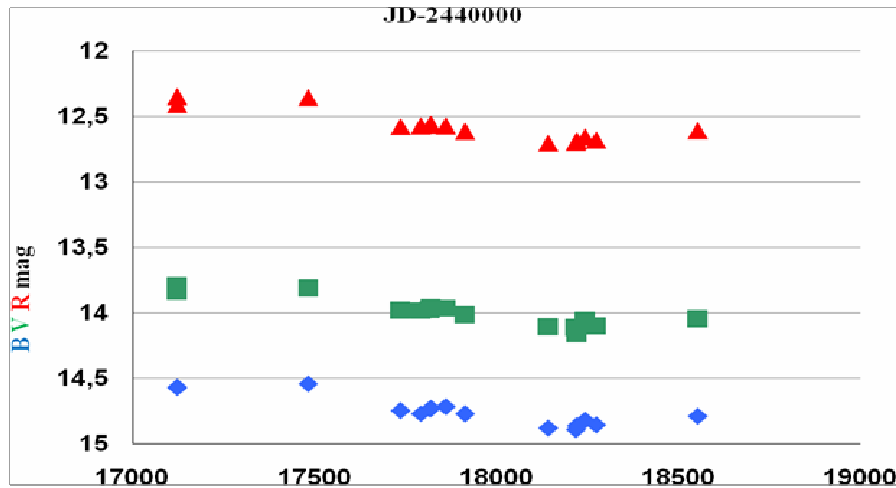


Figure 1 – the light curves of the Sy Mrk 766 in filters B (rhombus), V (square), R (triangle). The X-axis is the Julian date scale, the Y-axis is the magnitudes

Figure 1 shows a tendency to decrease the brightness of the Sy Mrk 766 in the three (BVR) filters.

Mrk 6 = IC450 – Seyfert galaxy with equatorial coordinates: $\alpha(2000)=06^h52^m12^s,323$; $\delta(2000) = +74^025'37,2376''$, red shift $z = 0.018676 \pm 0.000834$.

Distance to the galaxy 79 Mpc. This object belongs to the Sy 1.0-1.5 class. The mass of the central body (CB) of the galaxy is $(1-2) \times 10^8 M_{Sun}$ [8]. In AFIF, observations of Mrk6 in the BVR photometric system have been carried out since 2016.

The star GSC04371-00113 with coordinates $\alpha(2000)=06^h51^m54^s,31965$; $\delta(2000)=+74^021'37,6672''$, $B=15,06$; $V=14,44$; $R=14,33$ was used as the photometric standard. The following two stars were used as the check stars:

- TYC 4771-167-1 with coordinates $\alpha(2000)=06^h51^m02^s,63561$; $\delta(2000)=+74^027'37,7407''$, $B=12,81$; $V=11,32$;
- TYC 4371-867-1 with coordinates $\alpha(2000)=06^h52^m01^s,02391$; $\delta(2000)=+74^022'46,0150''$, $B=12,07$; $V=11,16$.

Table 2 - Light curves of Sy Mrk 6 in filters B, V, R for 2016-2019.

Date observation	JD-2440000	B	V	R
05.04.2016	17483	14,102	13,477	13,158
24.11.2016	17716	14,153	13,503	13,14
15.12.2016	17737	14,068	13,438	13,097
17.01.2017	17770	14,065	13,433	13,086
27.02.2017	17811	14,272	13,595	13,29
28.03.2017	17840	14,554	13,823	13,411
14.12.2017	18101	15,178	14,301	13,883
27.01.2018	18145	15,123	14,278	13,858
07.01.2019	18490	15,287	14,458	14,029
23.01.2019	18506	15,189	14,375	13,975
29.01.2019	18512	15,081	14,297	13,911
18.03.2019	18560	14,97	14,163	13,756

Figure 2 shows the light curves of Sy Mrk 6 in BVR filters for a specified period of time.

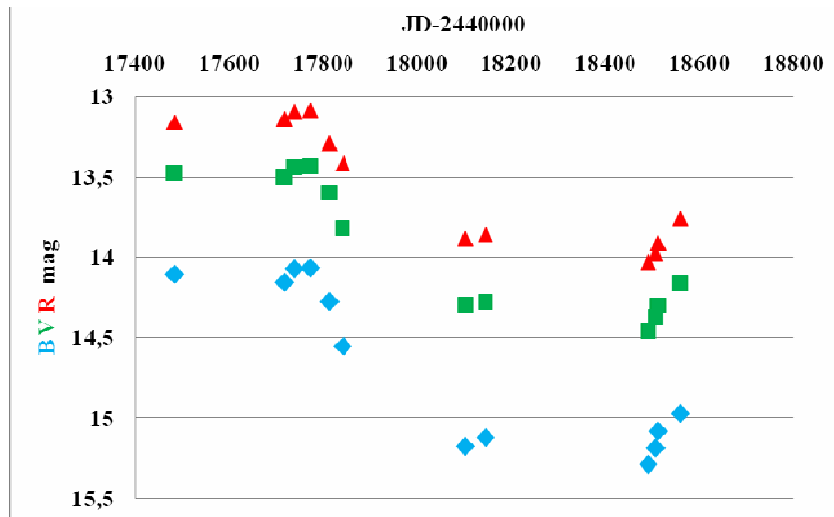


Figure 2 - light curves of the Sy Mrk 6 in filters B (rhombus), V (square), R (triangle). The X axis is the Julian date scale, the Y axis is the stellar magnitudes

It can be seen from Figure 2 that the weakening of brightness started in early 2017 and by 2019 it reached $\sim 0^m.9$. A slight increase of brightness is observed at the end of our observation period. In general, it should be noted that all changes occur synchronously in the three filters (Fig.2).

Mrk1040 = NGC931 – the bright spiral galaxy of Sy1 type. Equatorial coordinates of the galaxy: $\alpha(2000)=02^h28^m14^s,469$; $\delta(2000)=+31^018'41'',467$, red shift $z = 0.016338 \pm 0.000314$. Distance to the galaxy 340 Mpc. The high-resolution spectral data for the Seyfert galaxy Mrk1040, obtained in the X-ray range in 2013- 2014 with the Chandra space telescope, were analyzed in [11].

The mass of the central body is $(7.64 \pm 0.40) \times 10^7 M_{Sun}$ [9]. The physical and spectral characteristics of Mrk 1040 are considered in [11].

The last photometric studies of this galaxy were carried out by Doroshenko et al. In 2005 [12]. In FAPHI Mrk 1040 observations in the BVR photometric system have been made since 2015.

The star TYC 2323-1484-1 with coordinates $\alpha(2000)=02^h27^m48^s,777$; $\delta(2000)=+31^021'40,994''$, $B=11,47$; $V=10,49$; $R=10,16$ was used as the photometric standard The star TYC2323-282-1 with coordinates $\alpha(2000)=02^h27^m59^s,79154$; $\delta(2000)=+31^011'10,4625''$, $B=12,29$; $V=10,97$; $R=10,476$, was chosen as the check star.

Table 3 - Light curves of the SG Mrk1040 in filters B, V, R for 2015-2019.

Date of observation	JD-2440000	B	V	R
10.09.2015	17275	15,253	13,646	13,06
11.09.2015	17276	14,977	13,314	12,861
15.12.2015	17371	15,379	13,86	13,212
20.01.2016	17407	15,527	14,143	13,532
05.09.2016	17636	15,172	13,648	12,947
24.11.2016	17716	15,369	13,852	13,237
13.12.2016	17735	15,481	14,397	13,846
27.08.2017	17992	15,269	13,943	13,357
15.10.2017	18041	15,384	14,166	13,587
13.12.2017	18100	15,408	14,044	13,469
29.01.2018	18147	15,49	14,566	14,05
08.01.2019	18491	15,471	14,37	13,79
28.01.2019	18511	15,504	14,364	13,777

Figure 3 shows the light curves of Sy Mrk1040 in BVR filters for a specified period of time.

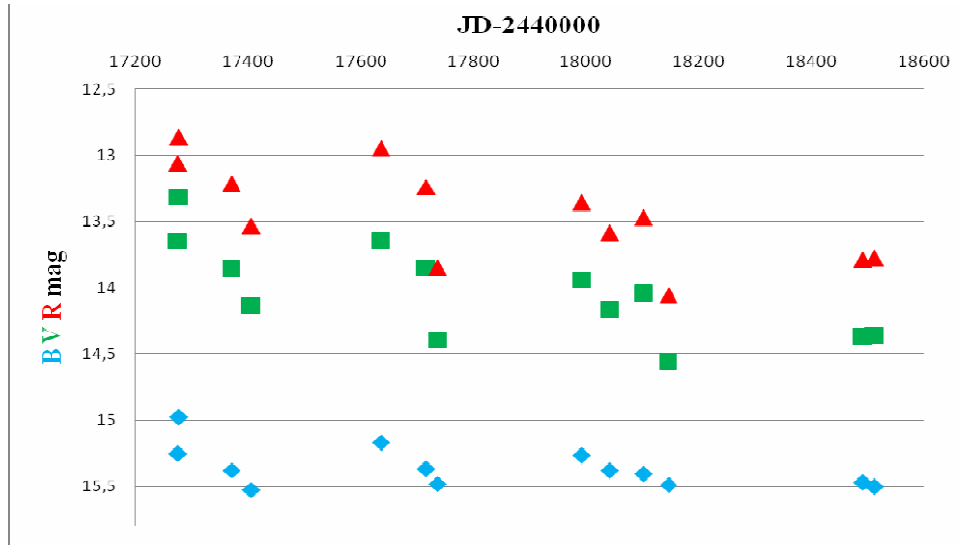


Figure 3 - light curves of the Sy Mrk 1040 in filters B (rhombus), V (square), R (triangle). The X axis is the Julian date scale, the Y axis is the stellar magnitudes

Obtained data indicate that the investigating object is constantly experiencing irregular brightness fluctuations in all three filters with an amplitude of $\sim 1^m$. In addition, there is a gradual decrease in the average level of brightness (Fig. 3).

2.4 Mrk 1513 = UGC 11763 = II Zw 136 = PG 2130+099. Equatorial coordinates of the galaxy: $\alpha(2000)=21^h32^m27^s,8$; $\delta(2000)=+10^008'19''$, red shift $z=0.061990 \pm 0.000947$. Distance to galaxy 257 Mpc.

The bright compact galaxy Mrk 1513 was originally classified as NLSy1 (Seyfert 1 with narrow lines), but in the mid-80s it was “transferred” to the quasar group (radio-quiet, low luminosity quasar). By luminosity ($M=-22^m,9$) this object is located on the border between quasars ($M_{\min}=-23^m$) и Sy [13].

In FAPHI, observations of Mrk 1513 in the BVR photometric system have been carried out since 2015.

The star BD +094836 with coordinates $\alpha(2000)=21^h32^m00^s,1017$; $\delta(2000)=+10^009'31,681''$, $B=11,1$; $V=9,98$; $R=9,48$ was used as the photometric standard. A star with coordinates: $\alpha(2000) = 21^h32^m22^s,33$; $\delta(2000)=+10^007'49,7''$, $B=15,708$; $V=14,741$; $R=14,266$ was selected as the check one.

Table 4 - Light curves of the Sy Mrk1513 in the B, V, R filters for 2015-2018.

Date of observation	JD-2440000	B	V	R
17.08.2015	17251	14,16	13,125	12,907
18.08.2015	17252	14,503	13,424	13,162
19.08.2015	17253	14,552	13,414	13,38
11.09.2015	17276	14,363	13,252	12,975
16.09.2015	17281	14,615	13,541	13,155
17.09.2015	17282	14,702	13,515	13,147
23.09.2015	17288	14,694	13,836	13,471
06.10.2015	17301	14,327	13,273	13,066
19.06.2016	17558	14,456	13,477	13,146
04.09.2016	17635	14,261	13,231	13
11.06.2017	17915	14,769	13,919	13,621
22.07.2017	17956	14,734	13,768	13,477
30.07.2017	17964	14,728	13,835	13,504
12.10.2017	18038	14,848	13,865	13,489
09.07.2018	18308	14,778	13,823	13,444

Figure 4 shows the light curves for the Sy Mrk 1513 in BVR filters over a specified period of time.

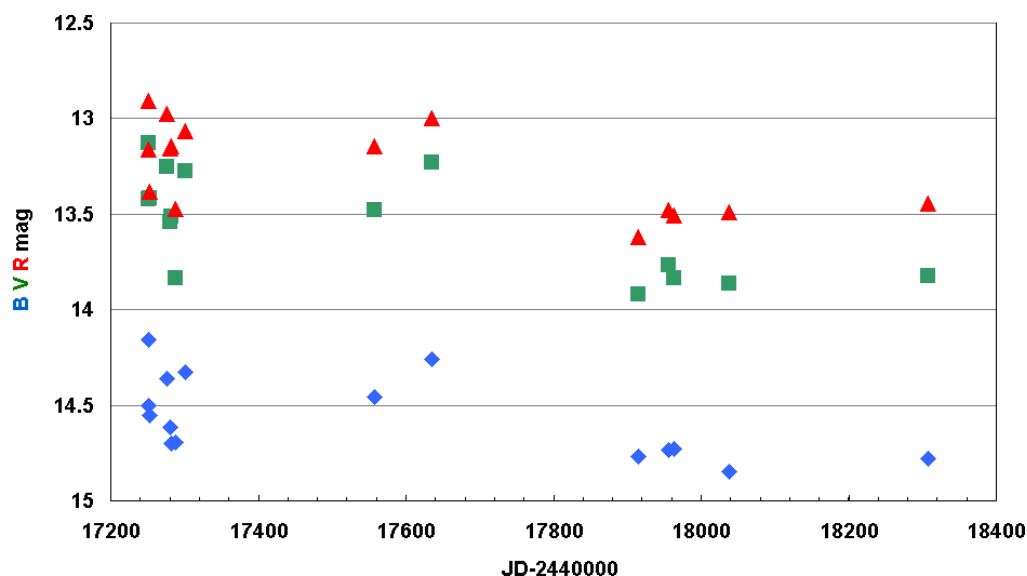


Figure 4 – The light curves of the Sy Mrk 1513 in filters B (rhombus), V (square), R (triangle). The X axis is the Julian date scale, the Y axis is the stellar values in the BVR filters

High galaxy instability, within $0^m.6$, was observed in 2015. Since mid-2017, the level of the brightness has decreased in all three filters, by about $0^m.8$ and it is still now at a rather low level (Fig.4).

3. Conclusion. Variability of the active nuclei of galaxies from the Markarian list is manifested in a wide range of wavelengths. In particular, the optical variability of different degrees of activity is registered in the all studied objects. During observable period a gradual decrease in the level of brightness were noted in the Sy Mrk 6, Mrk766 and Mrk1513. The results of photometric observations of the Seyfert galaxies in the optical range can be used together with X-ray data to determine the physical and dynamic characteristics of individual zones near the nuclear regions of the AGN and to create adequate models of these objects.

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MRK 766, MRK 6, MRK 1040, MRK 1513 ОБЪЕКТЛЕРІНЕ ФОТОМЕТЛІК ЗЕРТТЕУЛЕР

Аннотация: Мақалада, Маркарян тізіміндегі: MRK 766, MRK 6, MRK 1040, MRK 1513 сейферт ғаламдарының фотометрлік бақылауларының нәтижелері берілген. Бақылаулар В.Г. Фесенков атындағы Астрофизика институтының Тянь-Шань астрономиялық бақылау базасында орналасқан диаметрі 1 метрлік «шығыс» телескобының көмегімен жүргізілді. Бақылау мәліметтерін өңдеуге MaximDL6 пакет бағдарламасы қолданылды. Ғаламдардың маңында орналасқан стандарт жұлдыздардың көмегімен, объектілердің жарқырауы дифференциалдық әдіс арқылы өлшенді. Жұмыста, Mrk 766, Mrk 6, Mrk 1040, Mrk 1513 жарқырау кисықтары келтірілген. Mrk 766 үш фильтрда біртіндеп жарқырауының азайғаны бақыланады. Mrk 6 ғаламының зерттеу уақыт аралығында (2016-2019жж.) фотометрлік айнымалылық үш фильтр бойынша синхронды. 2017 жылдың басында жарқырауының әлсіреуі байқалады, $\sim 0^m.8$. Mrk 1040 және Mrk 1513 ғаламдарының жарқырауы дұрыс емес айнымалы болып келеді, амплитудалары $\sim 1^m$ (Mrk 1040) және $\sim 0^m.8$ (Mrk 1513) жұлдыздық шамаларына тең.

Түйін сөздер: стандартты жұлдыздар, фотометрия, B V R шамалары.

УДК 524.7

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ФОТОМЕТРИЧЕСКИЕ ИССЛЕДОВАНИЯ СЕЙФЕРТОВСКИХ ГАЛАКТИК

MRK 766, MRK 6, MRK 1040, MRK 1513

Аннотация. В статье приводятся результаты фотометрических наблюдений сейфертовских галактик из списка Маркаряна: MRK 766, MRK 6, MRK 1040, MRK 1513. Наблюдения проводились на «восточном» 1-метровом телескопе, расположенном на Тянь-Шаньской астрономической обсерватории Астрофизического института им. В.Г. Фесенкова. Для обработки наблюдательных данных применялся пакет программ MaximDL6. Оценка блеска выполнялась методом дифференциальной фотометрии, использовались стандартные звезды в окрестностях галактик. В работе приводятся кривые блеска галактик: Mrk 766, Mrk 6, Mrk 1040, Mrk 1513. В Mrk 766 выявлена тенденция к постепенному ослаблению блеска в трех фильтрах. Установлено, что фотометрические изменения в галактике Mrk 6 в исследуемый период (2016-2019 гг.) происходили синхронно во всех трех фильтрах. С начала 2017г. началось ослабление её блеска и к началу 2019 г. оно достигло $\sim 0^m.9$. Для галактик Mrk 1040 и Mrk 1513 за исследуемый период были характерны нерегулярные колебания блеска с амплитудами $\sim 1^m$ и $\sim 0^m.8$, соответственно.

Ключевые слова: сейфертовские галактики, фотометрия, В V R величины.

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