АСТРОФИЗИКА

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OBSERVATIONAL EVIDENCES OF MULTIPLE SHOCK WAVES IN X-RAY SELECTED BL LACERTAE OBJECTS

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The results of optical *R*-band photometry of three X-ray selected BL Lacertae objects IES 0502+675, IES 0806+524 and IES 1959+650 from the Einstein Slew Survey are presented. The observations are performed during 1997-2006 with 70-cm meniscus type telescope of Abastumani Astrophysical Observatory. The objects show clear long-term variability with timescales of 1-3 years without evident periodicity. Main results consist in the discovery of multiple-peak structures on historical lightcurves as predicted theoretically on basis of the assumption that long-term variability of blazars are triggered by ultrarelativistic shock waves propagating through their jets. They are the direct evidence of existence of reverse shocks besides the main one arisen by a single disturbance. Two-peak maxima are found for IES 0502+675 and IES 0806+524. More complicated structure shows IES 199+650 - a maximum with four consequent peaks. Relative strengths of main and reverse shocks are mainly equal according to the shape of respective peaks. Brightness dip between them is in average 60% less than in case of consequent main shocks. Optical maximum epochs, covered well by the observations, show that main shocks are either not always accompanied by reverse ones or the laters aren't always enough strong to be discovered by the observations.

Key words: *BL Lacertae objects - individual: IES 0502+675: IES 0806+524:IES 1959+650*

1. *Introduction.* Blazars are the most extreme class of Active Galactic Nuclei. The term "Blazar" was introduced three decades ago by Ed Speigel in order to denote the objects which come forward with following characteristics (e.g. [1]): a) strong radio emission; b) smooth spectra, featureless or with very week lines with equivalent width less than 5 Å [2] except for the occasional presence of strong quasar emission lines; c) violent variability throughout all the spectral diapasons; d) strong and variable polarization especially in the optical range; e) most of them have been proven to possess highly relativistic jets with apparent superluminal motion. Besides, blazars come forward as γ-loud objects - the bulk of identified TeV sources are blazars [3].

Blazars are divided into BL Lacertae objects and Flat Spectrum Radio Quasars (FRSQs). They are found to be the active galactic nuclei of bright ($M_R \sim -23^m.1$), large ($r_e \sim 7$ kpc) and fairly round ($\varepsilon = 0.1 - 0.3$) eliptical galaxies (e.g. [4], [5]), whose bulk properties do not differ significantly from the population of inactive giant ellipticals. The central engine is assumed to be a supergiant black hole with masses of $\sim 10^7$-$10^8 M_{\odot}$ (e.g. [6]). It's generally accepted that one of blazar jets is pointed towards to the observer, so, in fact, we are able to observe only its nonthermal emission. Relativistically hot, magnetize plasma, collimated into the jets, should flow outward with speeds up to at least 0.995*c* [7]. Presumably, an oppositely directed jet should emanate from blazar nucleus, but it's invisible for us [7]. Emission lines with equivalent width in excess of 5 Å have been detected several times ([8-10]) suggesting that blazars should possess a broad line region (BLR), but it would be usually obscured by the beamed synchrotron emission of the jet.

The spectral energy distributions (SEDs) of blazars are characterised by a double-peak structure. The peak at lower energies (from radio through UV or X-rays) is generally explained by Doppler-boosted synchrotron radiation from relativistic electrons in a jet which is closely aligned to the line of sight, while the high frequency bump (MeV-TeV energy range) is produced by inverse Compton scattering from the same electron population interacting either with the synchrotron photons (SSC, Synchrotron-Self Compton models, e.g.[11]) or with other photons that originated in the local environment (ERC, External Radiation Compton models, [12]).

Depending on the position of low-energy peak, one divides BL Lacertae objects into LBLs (low-frequency peaked BL Lac) and HBLs (high-frequency peaked BL Lacs). LBLs are intermediate between the FSRQs and HBLs, having much higher bolometric luminosities, when the laters are the least luminous among blazars [13]. The peak of their low-frequency component is located at IR or optical wavelengths, their high-frequency component peaks at several GeV, and the γ -ray output is of the order of or slightly higher than the level of the low-frequency emission [14]. Above mentioned two peaks are situated at relatively high UV/X-ray and GeV/TeV energies for XBLs. It's notable that most of the detected TeV blazars (16 of 17) belong to HBLs [15].

One of the key blazar characteristics is their violent variability. The time-scales of optical variability are broadly divided into 3 classes: intra-day variability (IDV) or micro-variability, short term outbursts and long term trend. Short term outburst and long term trends can have time scales range from few weeks to several months and several months to years, respectively [16].

Long-term outbursts could be triggered by an increase in the accretion rate provoking formation and downstream propagation shock waves[13]. It's inherent to shock waves to decelerate supersonic flows to subsonic velocities [7]. A forward shock decelerates the downstream fluid, overtaken the energy from it (in the rest frame of shock front). Consequently, shock front propagates supersonically relative to downstream fluid. A reverse shock, on other hand, slows high-velocity upstream fluid entering the shocked region from behind down to subsonic speeds, as measured in the frame of reverse shock front. The reverse shock front propagates downstream, but more slowly than does either the forward shock front or the upstream, unshocked gas. A given disturbance can have only a forward shock or both a forward and a reverse shock, with the relative strength of the shocks depending on the details of time-variable flow. One or more reverse shocks separate very rapidly flowing, rarefied gas from slower but denser and higher pressured material behind a forward shock. The structure is therefore complex and blazar lightcurve should reflect this occasion to some extent. According to Marscher [7], it's therefore possible to deal with bumps and even multiple peaks on lightcurves (plus flattening of the spectrum near the peak because of presence of multiple components) even if there has only been a single disturbance in the jet.

The direct evidences of multiple shocks are found for three XBLs during the optical monitoring of their variability behaviour at Abastumani Astrophysical Observatory.

2. *The sample.* Our sample belongs to the Einstein Slew Survey [17]. These objects discovered in 1980 by Einstein (HEAO2) X-ray satelite operating in a "slow" mode. Their optical identification, as BL Lacertae objects, was made

Table 1

LIST OF TARGET OBJECTS WITH POSITIONS AND REDSHIFTS

Object	α_{2000}	δ_{2000}	z	Reference
1ES 0502+675	05:07:56.18	+67:37:24.3	0.314	[18]
1ES 0806+524	08:09:49.19	+52:18:58.4	0.138	[19]
1ES 1959+650	19:59:59.8522	+65:08:54.668	0.048	[18]

* http://simbad.u-strasbg.fr/simbad/sim-fid

by Shachter et al. [20], using the spectra obtained with Michigan/Darthmouth/MIT 1.3 telescope. Optical spectra of our sample was later obtained with 2.1m telescope of Kitt Peak National Observatory. The spectra exhibited very weak absorption features, allowing to determine the redshifts of the blazars [18,19].

1ES0502+675 was observed by Hubble Space Telescope (03/02/96; 740 second exposition, [19]). At such resolution, the object is clearly double, with separation of only 0".33 and surrounded by a galaxy. A careful comparison of the two radial profiles showed that the brighter object is more extended than the fainter one. Even at HST resolution the alleged companion is unresolved. Optical spectra of 1ES 0502+675 and their companions were obtained again on 2001 March 9 with the Space Telescope Imaging Spectrograph (STIS) [21]. The companion object spectra with their absorption features indicate that it is a star of intermediate spectral type (likely F or G), leading to an idea that we deal with foreground galactic star projection. 1ES 0806+524 consists of a nucleus surrounded by a bright elliptical galaxy. An unusual thing is the large arc-like structure 1".93 south of the nucleus[19]. 1ES 1959+650 is hosted by an elliptical galaxy plus a point source. Some small deviations from de Vaucouleurs law indicate a disturbed morphology. An unusual dust lane is apparent along the major axis, about 0".2 north to the nucleus [4]. Latest (June 2001) optical spectral observations of 1ES 1959+650 belong to Falomo et al. [6] , in order to determine BH mass by stellar dispersion, using the 2.5-m Nordic Optical Telescope (NOT). One obtained $\log(M_{BH}) = 8.12 \pm 0.13(M_\odot)$.

Up to now very little data are published about optical photometry of our sample. A POSS "O" magnitude of $18^m.5$ ($V \sim 18^m.0$) is found for 1ES 0502+675 by Schachter et al. [20] when identifying the object optically, while Perlman et al. [18] report $V = 17^m.0$. Reiteri et al. [22] carried out R-band photometry of the object since 1996 October 18 with 1.05 m telescope of Torino Observatory. The lightcurve shows an increasing trend with maximum variation of $\Delta R = 0^m.58$. Villata et al. [23] observed 1ES 1959+650 with the same telescope during 1996-1997 through B, V and R bands. Rapid brightness flickerings were revealed. In particular, a decrease of $0^m.28$ in 4 days was recorded on June 8-12, 1996. Tagliaferri et all. [24] observed the object for about nine hours in R-band during the night of September 28-29 2001 with the 50 cm telescope of the Astronomical Station of Vallinfreda (Rome). The source remained constant around a mean value of $R = 14^m.67$. In order to evaluate the contribution of the host galaxy within used photometric radius, one computed its R magnitude integrating de Vaucouleurs profile, finding $R = 15^m.66$ following Scarpa et al. [21] and $R = 15^m.95$ following Heidt et al. [25]. Preliminary results of optical monitoring of 1ES 1959+650 carried out since 1994 by the Roma and Perugia groups are also provided. The source shows a flux variability between $R = 14^m.4$ and $R = 15^m.2$, without evident periodicity.

Later 1ES 1959+650 was observed by Krawczynski et al. [26] with 0.4m Boltwood Observatory telescope during multiwavelength campaign 2002 between May 18 and August 16, using broadband B, V and I filters. One revealed the variations of about $0^m.1$ with typical timescales of about 10 days. The mean optical brightness increased from the first 4 weeks to the last 2 weeks of the campaign by about $0^m.1$ in all the bands. Moreover, the object was observed with Bordeaux optical telescope in V-band between May 2, 2003 and June 7, 2003. The flux measured during 54 nights between varied between $14^m.89$ and $15^m.67$ with an average of $15^m.21 \pm 0^m.05$. During the 2002 VHE flaring phase, the V-magnitudes varied in $15^m.4$-$15^m.7$ [27].

Last times 1ES 1959+650 was observed with the AIT (0.40m) of the Perugia Observatory and with both the KVA telescope on La Palma and the Tuorla 1.03m telescope as a part of the Tuorla blazar monitoring program from June 2004 to August 2006 [28]. R-band data shows that the source was in a relatively active state. During the more intense monitoring of May-June 2006, the source showed a variability of 0.1-0.2 magnitude around a mean value of

$14^m.4$ (including the galaxy). In particular, in the period May 25 - June 1, the *R*-flux increased by about 40%), at odd with the 2-10 keV X-ray flux, that instead shows a decrease in the period May 25-29.

The only optical polarimetric observations of our sample was performed by Marcha et al. [29] for 1ES 1959+650 during 1992-1993 using 90- and 61-inch telescopes of Steward Observatory. It's polarization was found to be above 2%.

Radio observations of our sample are little too. NRAO VLA observations detected neither extended structure nor radio flux density variability between different observational epochs for 1ES 0502+675 [21]. 1ES 0806+524 turned out to be a heavily core-dominated source with a short (about 5 mas), northbound (PA ~ 13°) jet. Very faint, diffuse extended emission surrounds the jet, suggesting it has a broad opening angle which may be as wide as 70°. Between two observational epochs (1998-2002) flux density varied at 1.4 GHz and 5 GHz are found [30]). 1ES 1959+650 exhibited a broad, diffuse jet to the north. High frequency (15 GHz) radio observations suggests a 1 mas jet to the southeast [31]. The 4.8 and 14.5 GHz observations carried out with 26m paraboloid of Michigan University didn't show significant flux variations between 2002 May 5 and August 9 [26].

On the contrary, the sample is much frequently observed in high-energy diapasons. BeppoSAX spectral observations of 1ES 0502+675 carried out on 1996 October 6/7 through 1.3-10 keV passband didn't revealed any X-ray variabilities [32]. As for 1ES 1959+650, it was observed with EXOSAT (0.07-2.4 keV range [33]), ROSAT (0.4-2.4 keV range, [33]), BeppoSAX [34,24], USA (Unconventional Stellar Aspect Experiment, 1-17 keV [35]), RXTE (Rossi X-Ray Timing Explorer [35]). In later two cases, which lasted 2000 July - November, the source was bright and variable in the X-ray band, with the X-ray spectrum significantly harder than observed during the epochs of lower brightness. Variability of a factor ~6 was detected within 20 days and a factor ~3 within 7 days. The source did not appear to vary significantly shorter than a day. RXTE observed 1ES 1959+650 during multiwavelength campaign 2002 in a flare state [26]. 10 keV X-ray flux was strongest on May 18-20 which decreased by a factor of 18.7 from the maximum on May 20 to a minimum on June 17. RXTE re-observed the object during 2003 May 2 - 2003 June 7 revealing an increased level of X-ray activity [27]. High-signal-to-noise X-ray spectrum of 1ES 1959+650 was obtained by the XMM-Newton X-ray telescope on 2002 November 23 which does not show any spectral lines, contrary to expectations from some previous observations [36]. Suzaku and Swift-XRT observed the object from 2006 May 19 to 2006 May 26 in the 0.2-12 keV band [28]. Besides the variability with a factor of 2, the peak of the synchrotron component, situated in 0.3-10 keV diapason, moves to higher energies with the increasing flux. During the monitoring the source showed also some rapid variabilities.

No results of γ-ray observations of 1ES 0502+675 are mentioned in the literature. 1ES 0806+52.4 was observed by HEGRA during 1996-2002. No TeV photons are detected [37].

1ES 1959+650 is very interesting object in point of TeV astrophysics. First EGRET and Whipple observations above 300 GeV detected no VHE photons and only upper limits was set [38]. Subsequent EGRET observations allowed Hartmann et al. [39] to put it in the third EGRET catalog at the energies above 100 MeV. TeV photons were detected by Nishiyama et al. [40] using the Utah Seven Telescope Array detector (1998 May 18 - August 30) with a significance of 5.3σ between May 22 and 31 and 5.0σ between July 1 and 28. VHE flux variability of a day-scale were found. TeV photons were afterwards detected by Whipple 10m telescope [41,26] during its strong outburst 2002 between May 16 and July 28 reaching a maximum of 5 Grab. The variability timescales were as short as 7 hours. On 2002 June 4, the source flared dramatically without coincident increase in the X-ray emission, providing the first example of an "orphan" gamma-ray flare. Whipple observations were confirmed by the HEGRA [42] and CAT [43]. MAGIC observations carried out during 2004 September-October show no significant variations [44]. Later (2006 May 21-27) it found 10.4σ signal above 400 GeV. VHE spectrum was well described by a simple power law from 150 GeV to 3 TeV [28]. VHE flux remained steady near its low level during VERITAS 2006-2008 observations [45].

3. *Observations and Data Reduction.* Bulk of observational material is obtained with ST-6 CCD camera attached to the Newtonian focuse of the 70 cm (1/3) meniscus telescope. Since September 2006 it was replaced by APOGEE-6 camera attached to the prime focus of the same telescope.

ST-6 camera consists of a thin, back-illuminated chip TC241 with 375 x 242 array and 23 x 27 microns pixel size. Array area is 8.63 mm x 6.53 mm. Readout noise is nearly $30\,e^-$. Thermoelectric (Petlier-type) cooler allows to cool the device about 40° C less than the ambient temperature (minimum setpoint is - 50°). Peak quantum efficiency is about 60% at 675 nm. QE(400 nm) $\approx$ 30%. Typical Dark Current is 13 e^-/pixel/s at -20° C. APOGEE - 6 camera possesses a thin, back-illuminated Kodak KAF 1001E chip with 1024 x 1024 array and 24 x 24 microns pixel size. Readout noise is $8\,e^-$. One uses a thermoelectric cooler with forced air. Maximum cooling is - 50° C below ambient temperature. Peak quantum efficiency of more than 72% is at 560 nm. QE(400 nm) $\approx$ 39%. Typical Dark Current - 1 e^-/pixel/s at -25° C.

All the observations were performed using glass filter which match the standard R_c band of Johnson - Cousin system well. Exposure time varied between 300 and 500 seconds depending on source brightness and observing conditions. Image processing or pre-processing (bias and dark current subtraction, flat-fielding and cosmic rays removal) are performed using standard routines in IRAF (Image

Reduction and Analysis Facility). Besides, we use ST6OPS and MaxImDL softwares developed specially for ST6 and APOGEE-6 devices respectively. Photometric reduction or processing of the data were performed by means of DAOPHOT software. For each observing night we generated a master bias by taking median of all bias frames in the night. Master bias frame is subtracted from all the target image frames and flat field image frames of the night.

Reference stars are selected from Villata et al. [23] and Fiorucci et al [46].

Table 2

LIST OF USED REFERENCE STARS

Blazar Name	Star No.	*R* magnitude (error)	Reference
1ES 0502 +675	1	13.69 (0.05)	[25]
	3	13.89 (0.04)	
	5	14.31 (0.03)	
	6	14.49 (0.03)	
1ES 0806+524	C2	13.86 (0.04)	[48]
	C3	14.04 (0.05)	
	C5	14.99 (0.06)	
1ES 1959+650	4	14.08(0.03)	[25]
	6	14.78(0.03)	
	7	14.79(0.03)	

4. *Results and discussion.*

a) *1ES 0502+675.* The observations were carried out between 1997 November 9 and 2007 March 10. Totally 186 frames are selected. Unfortunately, the observations aren't distributed uniformly per above mentioned term due to several reasons. The constructed historical lightcurve shows clear long-term variability, which timescales are of 3 year order (according to minima 1,2,3). No evident periodicity is exhibited. The greatest observed amplitude is $\Delta R = 1^m.23$. No intranight variabilities are detected. The fastest observed change is an increase of optical radiation with $0^m.24$ in two days.

Let's consider the part of the lightcurve situated between maxima 2 and 4. The later is covered by the observations in contrast to Maximum 2, which should been located near JD=2451250. Consequently, 1100-1200 day intervals (or 3 year order timescale in observer's frame) are typical for single perturbations arising in the jet . The depth of Minimum 3 ($15^m.97$-$16^m.35$-$15^m.93$) is much less than the same of minima 1, 2, 4 ($15^m.68$-$16^m.91$-$16^m.23$, $16^m.23$-$16^m.79$-$15^m.97$, $15^m.93$-$16^m.69$-$15^m.95$ respectively). So, two consequent peaks noted as maxima 3 and 4 (separated by the interval of only 493 days and Minimum 3, well covered by the observations) should be considered as a result of double shocks provoked by one disturbance. In fact this peaks are similar each to other and their heights are the same, leading to the suggestion, that the main and reverse shocks are of the same power in this case. There is another interesting picture around Maximum 2 epoch, but we are not able to draw any conclusion in point of multiple shocks because of bad coverage with the observations.

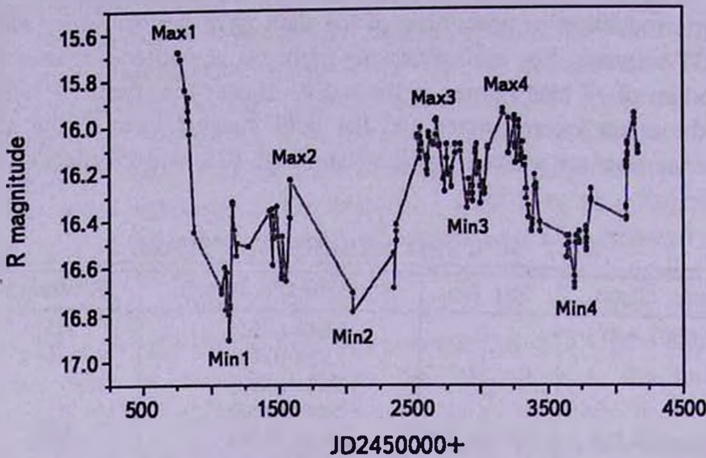

Fig.1. Historical R-band lightcurve of 1ES 0502+675.

b) *1ES 0806+52.4.* The observations are performed between 1997 December 28 and 2007 May 14. Totally 263 frames are obtained. Despite some suspensions in observations, long-term variability with the scales of greater than 2 years are found, according to the variability trend. The greatest observed amplitude is $\Delta R = 0^m.85$. No intra-night variabilities are disclosed. The fastest change - a decrease with $0^m.23$ in 4 days.

Unfortunately, minima 2 and 4, which might have the same depth as for Minimum 1, aren't covered by the observations. Presumably, well covered maxima 3 and 4 are the results of a double shock arisen from a single disturbance. The height of later peak is greater than previous one, which might

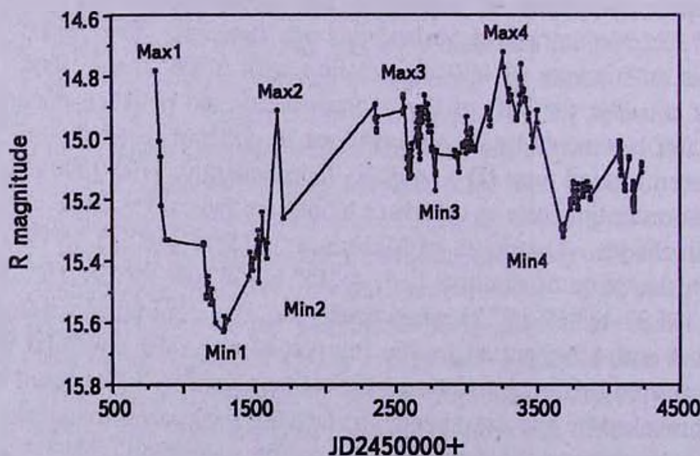

Fig.2. Historical R-band lightcurve of 1ES 0806+524.

be the result of microvariabilities imposed on long-term trend. The depth of well covered Minimum 3 ($14^m.86 - 15^m.17 - 14^m.72$) is much less than the same of Minimum1 ($14^m.78 - 15^m.63 - 14^m.91$). The intrinsic depths of Minimum 2 and 4 should be of the same order as Minimum1 is and greater than of Minimum 3.

c) *1ES 1959+650.* The observations were carried out between 1997 May 16 and 2007 July 25. Totally 1835 frames are selected. 1ES 1959+650 is most frequently observed object in our sample, but some observation gaps are presented too. According to constructed historical lightcurve, we deal with more rapidly variable object than other two objects of our target. No evident periodicity is shown. On basis of minima 1, 3-8 we may conclude, that the terms between mayor disturbances are confined within1 and 3 years. The maximum observed amplitude is $\Delta R = 0^m.82$. No intra-night variabilities are detected. The fastest observed change in optical brightness - a fade with $0^m.1$ in about 1.5 days.

Presumably, we deal with double-peak structure situated between minima 1 and 3. This interval is relatively well covered with the observations in opposite

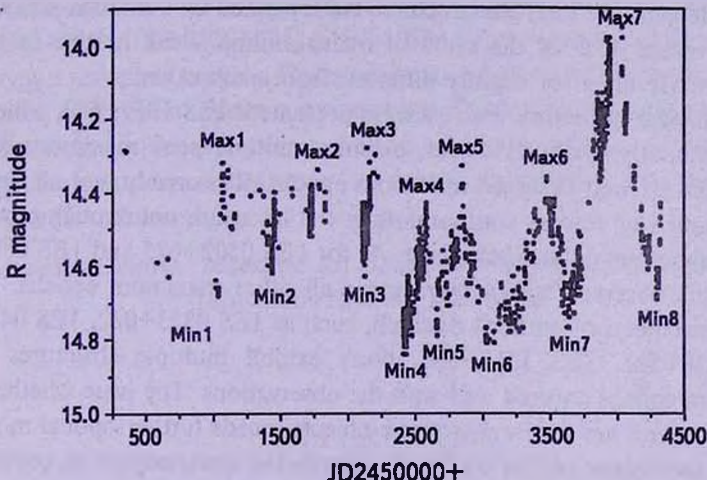

Fig.3. Historical *R*-band lightcurve of 1ES 1959+650.

of above mentioned minima. Max 1 and 2 (superimposed by the microvariabilities) should be considered as the peaks reflecting the existence of double-shock event. The depths of the Min 2 ($14^m.32 - 14^m.60 - 14^m.34$) is much less than the same of minima 4-8 ($14^m.30$ - $14^m.84$ - $14^m.43$ - $14^m.79$ - $14^m.33$ - $14^m.81$ - $14^m.35$ - $14^m.77$ - $13^m.95$ - $14^m.69$) covered well with the observations. On basis of excellent expressed maxima 4-7, which are the results of different single disturbances, we should conclude that no every disturbance arisen at jet basis is able to produce multiple-peak structure.

5. *Conclusions and future works.* As mentioned above, our target have no long history of the investigation. Only 15 years passed after their optical identification as BL Lacertae objects and nothing to wonder that they are less investigated. The observations, presented in this paper, are much numerous and cover greater interval compared to other investigations for the sample published so far. Despite many efforts, the obtained data do not cover uniformly all the observational term. Nevertheless we are able to make up some conclusions.

All the objects of our sample exhibit evident long-term variability without periodical behaviour. Long-term variability scales are of several years order. The observed variability amplitude doesn't exceed $1^m.23$. So, it is small relative to FSRQs and RBLs (see e.g. [47,48]). The hights of the peaks are not equal each to other. Consequently, respective shock waves are characterized by different powers.

The experimental confirmations of theoretical suggestion of Marscher [7] on possible existence of multiple shock waves arisen by single disturbance in blazar jet are found. Two peak structures are found for each target object. The single peaks of multiple structures are separated by a minima which depths are in average 40% of the same of main minima. Peak heights in multiple structures are equal or slightly different from each other.

Multi-peak structures aren't always presented. 1ES 1959+650, which is the most frequently observed object, exhibits multiple-peak maximum only one times from six well observed maximum epochs. Reasonably, not all shocks are accompanied by reverse counterparts or the laters are not enough powerful to influence blazars optical behaviour. As for 1ES 0502+675 and 1ES 0806+524, they aren't observed sufficiently during all other maximum epochs.

Other objects of author's research, such as 1ES 0323+022, 1ES 0414+009, 1ES 1028+511, 1ES 1517+656, don't exhibit multiple structures for the maximum epochs covered well with the observations. The issue whether multi-peak structures are inherent to these objects, needs further optical monitoring with as numerous and as uniformly distributed observations as possible.

Besides the future planned research of optical behaviour of our target objects, it's sensible to re-examine published long-term variability data both XBLs and other blazar subclasses in point of multiple-peak structures, which could make us capable to see how much this event is inherent to blazars and make some statistical and theoretical conclusions.

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НАБЛЮДАТЕЛЬНЫЕ ДОКАЗАТЕЛЬСТВА СУЩЕСТВОВАНИЯ КРАТНЫХ УДАРНЫХ ВОЛН В РЕНТГЕНОВСКИХ ЛАЦЕРТИДАХ

Б.З.КАПАНАДЗЕ

Представлены результаты оптической фотометрии трех рентгеновских блазаров 1ES 0502+675, 1ES 0806+524 и 1ES 1959+650 из каталога Einstein Slew Survey в цвете *R* системы Джонсона-Кузена. Наблюдения проведены в 1997-2006гг. на 70-см менисковом телескопе Абастуманской астрофизической обсерватории. Объекты показывают ярко выраженные крупномасштабные изменения блеска с длительностью 1-3 года без очевидной периодичности. Главный результат заключается в обнаружении структур с кратными пиками на кривых блеска исследуемых объектов, что теоретически предсказано на основе допущения о возможном инициировании изменения блеска блазаров распросранением ультра-релятивистских ударных волн в их джетах. Эти структуры представляют собой наглядное доказательство существования обратных ударных волн, помимо главных, вызванных однократным возмущением в основе джета. Максимумы с двумя пиками найдены для 1ES 0502+675 и 1ES 0806+524, а 1ES 1959+650 показывает более сложную структуру с четырьмя пиками. Падение блеска между этими пиками составляет в среднем 40% глубин главных минимумов. Те максимумы, которые хорошо покрыты наблюдениями, показывают, что если не все волны сопровождаются обратными волнами, то их мощь не всегда достаточна, чтобы они были обнаружены наблюдениями.

Ключевые слова: *объекты BL Лацерта - объекты:IES 0502+675: IES 0806+524:IES 1959+650*

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