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NSV 11321 LYR: VARIABILITY AND LIGHT ELEMENTS

Abstract

Visual and photoelectric observations were carried out on NSV 11321, a short period suspected variable in the constellation of the Lyra discovered by C. Hoffmeister in 1965. The 2478 visual estimates obtained suggested a period of $0^d.5776$ and allowed to determine a first ephemeris. Subsequent photoelectric measurements carried out using the T76 on the Jungfraujoch coupled to the photometer of Geneva allowed to construct a precise BV light curve and to determine the variability type. NSV 11321 Lyr is an eclipsing binary, EW type, varying in the range 10.96-11.47 V. The photoelectric ephemeris is 2450700.3444 + 0.577639 *E. In the present paper both visual and photoelectric studies are separately discussed.

Riassunto

Sono state effettuate osservazioni visuali e fotoelettriche su NSV 11321, una sospetta variabile di corto periodo nella costellazione della Lira, scoperta da C. Hoffmeister nel 1965. Le 2478 stime visuali ottenute hanno suggerito un periodo di $0^d.5776$ e hanno permesso di ottenere una prima effemeride. Le misure fotoelettirche ottenute utilizzando il T76 alla Jungfraujoch accoppiato al fotometro di Ginevra ci hanno permesso di ottenere una precisa curva di luce BV e di determinare il tipo di variabilità. NSV 11321 è una binaria ad eclisse di tipo EW, che varia in un intervallo 10.96-11.47 V. L'effemeride fotoelettrica è 2450700.3444 + 0.577639 *E. Nel presente articolo gli studi visuale e fotoelettrico sono separatamente discussi.

Résumé

Des observations visuelles et photoélectriques ont été faites sur NSV 11321, une variable suspecte de courte période dans la constellation de la Lyre, découverte par C. Hoffmeister en 1965. Les 2478 estimations visuelles obtenues ont suggéré une période de 0.5776j et ont permis de déterminer une première éphéméride. Les mesures photoélectriques successivement obtenues avec le T76 au Jungfraujoch, nous ont permis de construire une courbe précise de lumière BV et de déterminer le type de variabilité. NSV 11321 est une binaire de type EW, qui varie de 10.96 à 11.47 V. L'éphéméride photoélectrique est 2450700.3444 + 0.577639 *E. Dans cet article les études visuelle et photoélectrique sont discutées séparemment.

Resumen

Se han realizado observaciones visuales y fotoeléctricas de NSV 11321, una variable sospechosa de corto periodo en la constelación de la Lyra, descubierta por C. Hoffmeister en 1965. Las 2478 estimaciones visuales obtenidas han sugerido un periodo de $0^d.5776$ y han permitido determinar una primera efeméride. Las medidas fotoeléctricas obtenidas sucesivamente con el T76 de Jungfraujoch, nos han permitido obtener una precisa curva de luz BV y determinar el tipo de variabilidad. NSV 11321 es una binaria de tipo EW, que varía de 10.96 a 11.47 V. La efeméride fotoeléctrica es 2450700.3444 + 0.577369 *E. En este artículo, los estudios visuales y fotoeléctricos se discuten por separado.

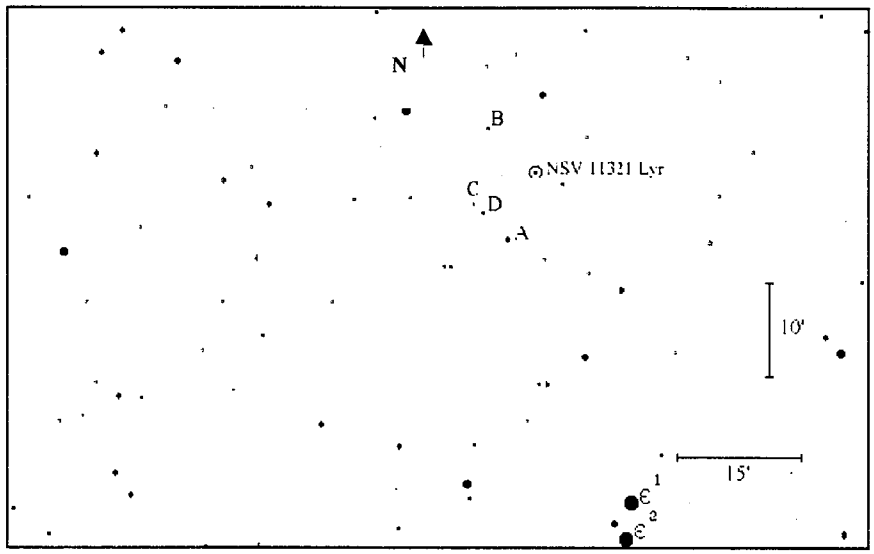
Introduction

The variability of the star classified as NSV 11321 Lyr was suspected for the first time by C. Hoffmeinster in 1965 and the star has been included in the New Catalogue of Suspected Variable Stars. This Catalogue states the star is a possible short period variable, its position in the sky being RA 18^h 45^m 06^s (2000) and Dec +40° 11' 12" (2000). The light variation is believed to be 10.95-11.50 in the mag (P).

Visual observations

The star has been followed using the finding chart reported below by 6 GEOS members from 1995 to 1997 and has afforded 2478 visual estimates.

Figure 1: finding chart of NSV 11321 Lyr



The following Table gives the list of the comparison stars used to visually monitor NSV 11321:

Table 1: star comparisons and their magnitudes

Comparison	Mag
A=GSC 3122:298	9.8
B=GSC 3122:2732	10.6
C=GSC 3122:809	10.9
D=GSC 3122:234	11.4

The following is a summary of all visual estimates reported:

Table 2: distribution of visual estimates

Observer	1995	1996	1997	Total
BIG	258			258
DDL	510	474	321	1305
DMT		34		34
MAA	46			46
VBR	164	67	40	271
VRR	114	164	286	564

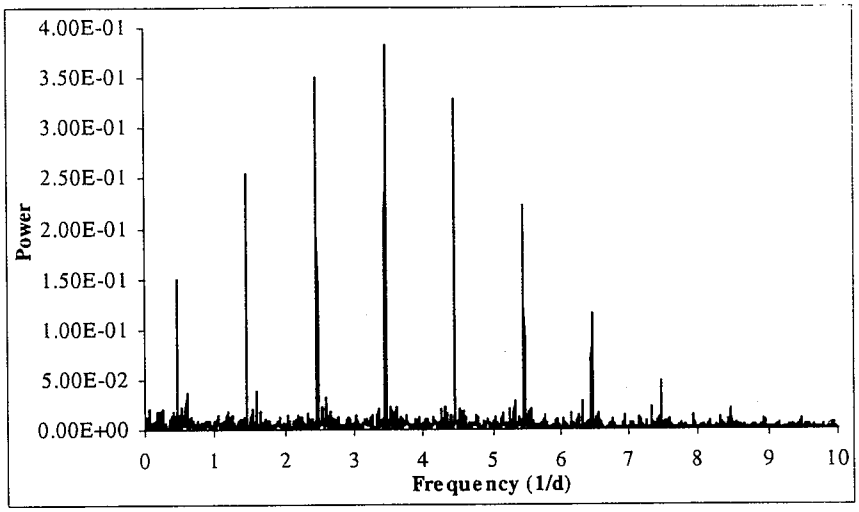
All estimates were carried out using the Argelander's method of estimation.

In autumn 1995 some of us agreed on the real variability of NSV 11321 Lyr but, at the same time, we disagreed, between us, about the value of the period and the type of variation. Starting at the end of 1995

these questions became clearer. In order to search for the best period of variation, the raw data, JD and visual magnitude, were grouped for each observer, and then treated by the Fourier Transform technique using the RCFM program (Gaspani).

However only data sets from the three most active observers could clearly show an available value of the period. The next Figure reports DDL's Fourier power spectrum, VBR's and VRR's being quite similar to it:

Figure 2: DDL's visual estimates power spectrum



All prominent peaks are spaced by one unit of frequency, the highest peak being at 3.4623 d^{-1} (DDL), 3.4621 d^{-1} (VBR-not shown) and 3.4624 d^{-1} (VRR-not shown). It identifies a period of about 0.289 days (close to 7 hours). Nevertheless it is important to consider the alias peaks, at frequency 2.462 d^{-1} and 4.462 d^{-1}, which give a value for the best period of 0.406 days and 0.224 days.

To identify the correct period of variation we looked at the shape of the light curve obtained according to these three periods. In all cases the light curve shape is almost sinusoidal, continuous and symmetrical, and the M-m value, determined in two nights, was about 3.5 hours. Being the M-m interval in a symmetrical-shape and corresponding to 0.5 period, we can state the best period is 0.289 days.

It remains to be determined if the star belongs to an RRc type with a period of 0.289 days rather than being an EW type with a double period (0.578 days). The photoelectric measurements confirmed the latter hypothesis (see section below).

Processing all raw data, it was possible to identify 44 minima of brightness. The distribution of minima per observer and per year is reported below:

Table 3: distribution of observed minima

Observer	1995	1996	1997
BIG	2		
DDL	12	12	4
MAA	1		
VBR	5	1	2
VRR	1	1	3

In Table 4 all minima times are in heliocentric Julian days, the error bars, the number of estimates for each minimum and the visual O-C are reported. Instants of minima were calculated by SOP program (Gaspani).

Table 4: NSV 11321 Lyr's minima times of brightness

Observer	HJD	nr	O-C_{vis}
BIG	2449841.444 ± 0.004	15	0.040
DDL	2449869.418 ± 0.023	9	-0.002
BIG	2449895.389 ± 0.004	14	-0.025
DDL	2449923.414 ± 0.015	15	-0.016
DDL	2449927.450 ± 0.008	11	-0.023
VBR	2449931.534 ± 0.015	11	0.018
DDL	2449934.386 ± 0.006	15	-0.019
VBR	2449939.581 ± 0.014	6	-0.022
VBR	2449940.472 ± 0.016	12	0.002
DDL	2449945.362 ± 0.022	15	-0.018
DDL	2449949.417 ± 0.013	13	-0.006
DDL	2449953.467 ± 0.011	11	0.000
VBR	2449964.463 ± 0.011	11	0.021
MAA	2449992.454 ± 0.010	8	-0.004
DDL	2449993.324 ± 0.015	13	0.000
DDL	2449997.366 ± 0.013	12	-0.002
DDL	2450002.267 ± 0.001	9	-0.011
VBR	2450012.379 ± 0.038	16	-0.007
DDL	2450017.300 ± 0.005	9	0.004
DDL	2450037.257 ± 0.012	6	0.032
VRR	2450041.254 ± 0.009	7	-0.014
DDL	2450213.401 ± 0.013	13	-0.005
DDL	2450218.364 ± 0.007	8	0.048
VRR	2450224.386 ± 0.007	5	0.005
DDL	2450224.386 ± 0.012	12	0.005
DDL	2450226.396 ± 0.002	11	-0.007
VBR	2450249.488 ± 0.014	15	-0.020
DDL	2450252.386 ± 0.048	13	-0.011
DDL	2450259.367 ± 0.012	9	0.039
DDL	2450269.433 ± 0.010	8	-0.004
DDL	2450274.358 ± 0.006	9	0.011
DDL	2450289.367 ± 0.011	10	0.001
DDL	2450339.346 ± 0.011	10	0.014
DDL	2450343.382 ± 0.004	9	0.007
DDL	2450400.268 ± 0.012	7	-0.005
VBR	2450571.525 ± 0.023	12	-0.019
VBR	2450597.486 ± 0.027	16	-0.052
DDL	2450611.401 ± 0.013	10	0.000
DDL	2450631.369 ± 0.010	9	0.039
VRR	2450637.387 ± 0.017	6	-0.008
DDL	2450639.408 ± 0.003	8	-0.009
VRR	2450691.400 ± 0.024	11	-0.005
VRR	2450700.347 ± 0.016	6	-0.011
DDL	2450722.324 ± 0.010	11	0.016

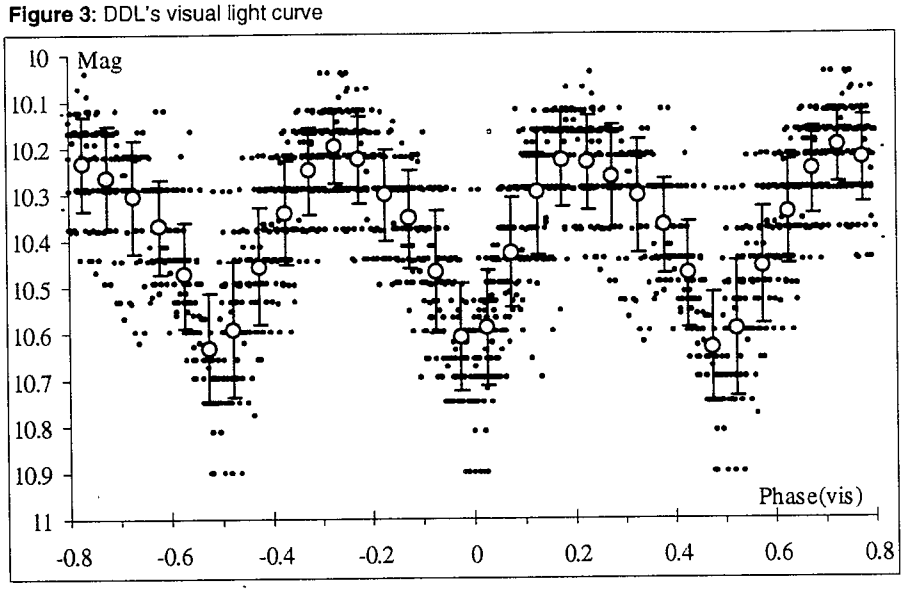
Processing all minima times by the least squares method we obtained the following ephemeris, by which we have subsequently calculated O-C_{vis} values:

$$\begin{array}{lll} \text{Min (HJD)} = & 2450700.357 + 0.577642 * E & \text{(VIS)} \\ & \pm 0.006 \quad \pm 0.000006 & \text{(95\% of confidence)} \end{array}$$

It was not possible to differentiate primary minima from secondary ones. However in light of the results obtained with the photoelectric measurements, we have reported this ephemeris using the double period.

In order to obtain the visual light curve, the largest set of data was phased according to the visual ephemeris. Points were then grouped in ranges of 0.05 phase and finally the average phase, magnitude and the standard deviation were calculated for each group. The result is shown in the following graph:

Figure 3: DDL's visual light curve



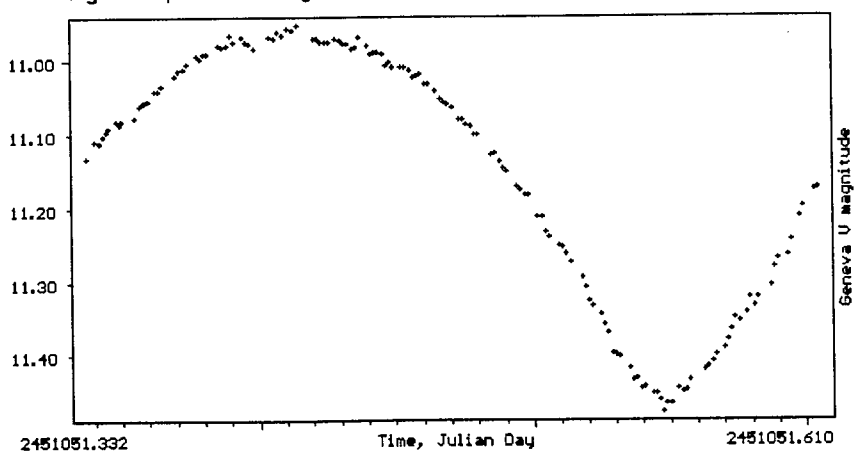
A similar light curve was also obtained applying the sets of data of VBR and VRR (not shown).

Photoelectric measurements

As we decided to monitor the star photoelectrically, visual estimates gave strong indications that NSV 11321 Lyr was a periodic variable star with a period close to 0.578 days. Our observations using the 76-cm reflector of the Jungfraujoch in the Swiss Alps, operated by the Geneva Observatory, were subsequently planned on the basis of these indications. We collected 322 Geneva BV photoelectric measurements using the "All Sky" method, collected in 5 nights over a 2 year interval.

In Figure 4 the photoelectric light curve of NSV 11321 obtained during one night is shown. Using the method of Kwee and Van Woerden (1956) the times of extrema were found. Between the two extrema there are 0.1355 days giving an indicative period of 0.542 days, which is in agreement with the prediction made by visual estimates.

Figure 4: photoelectric light curve of NSV 11321 Lyr obtained in one night.



Times of extrema: 2451051.4127 ± 0.0021
2451051.5484 ± 0.0009

Using the method of Kwee and Van Woerden, the heliocentric Julian Dates of three photoelectric minima were found and are tabulated in Table 5.

Table 5: Times of Photoelectric Minima of NSV 11321

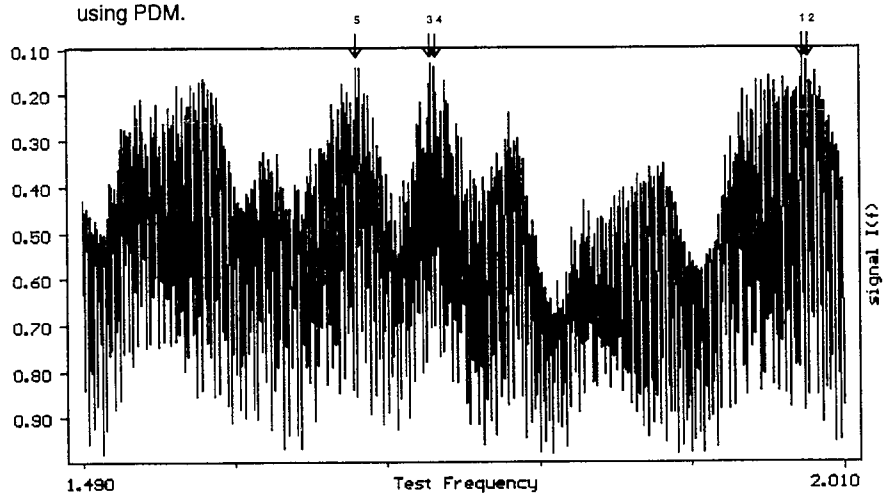
Minimum:	(I)	2450700.3444 ± 0.0011
	(II)	2451041.4434 ± 0.0006
	(I)	2451051.5484 ± 0.0009

The Phase Dispersion Minimisation method (PDM, Stellingwerf, 1978) for period finding was subsequently applied to the 322 photoelectric V measurements, to obtain a first photoelectric ephemeris (Table 5, Figure 5). We have chosen a small spectral window (frequencies from 1.5 to 2.0) since, as mentioned above, we expected to find a period close to 0.54-0.58 days which corresponds to frequencies of 1.85-1.72.

Table 6: best frequencies found

Nr	frequency	I(f)	Period
1	1.97297	0.11484	0.506850
2	1.97598	0.12616	0.506078
3	1.72973	0.13074	0.578125
4	1.73120	0.14002	0.577634
5	1.67968	0.14125	0.595351

Figure 5: Result of the period search applied on 322 photoelectric measurements using PDM.



Composites were subsequently made with the periods reported in the Table 6, which correspond to the 5 best periods found using PDM. We were able to construct a reasonable light curve using only the period of 0.577634 days. We have plotted an O-C diagram based on the two (I) minima using this value and calculated the following improved ephemeris:

$$\text{Min (HJD)} = 2450700.3444 + 0.577639 * E \qquad \text{(PE)}$$
$$\pm 0.0011 \pm 0.000004$$

The period found is very close to that coming from visual estimates based on 44 observed minima. The absolute V magnitudes and the B-V colour index phased at this period are plotted in Figure 6 with different symbols for each night. The V light curve and the B-V behaviour led us to expect this to be a contact system belonging to the W UMa type rather than beeing a pulsating star for the following reasons. First, the light curve shows sharp minima and well rounded maxima, as expected for an eclipsing binary. Second the B-V amplitude is not more than 0.04 mag., a very low value for a pulsating star. The faint reddening at both minima is probably due to the eclipse of the neck of contact binaries, which has normally an increased temperature. Third, when plotted on the 0.289 days period, the measurements show a larger scatter.

The variation range in V is from 11.47 ± 0.01 for both minima to 10.96 ± 0.01 for the maxima. Uncertainties of the measurements do not allow us to discriminate which is the primary minimum. The slight asymmetry in the maxima is probably indicative of star spots distributed asymmetrically on the surface(s) of the star(s).

Figure 6: V band light curve of NSV 11321.

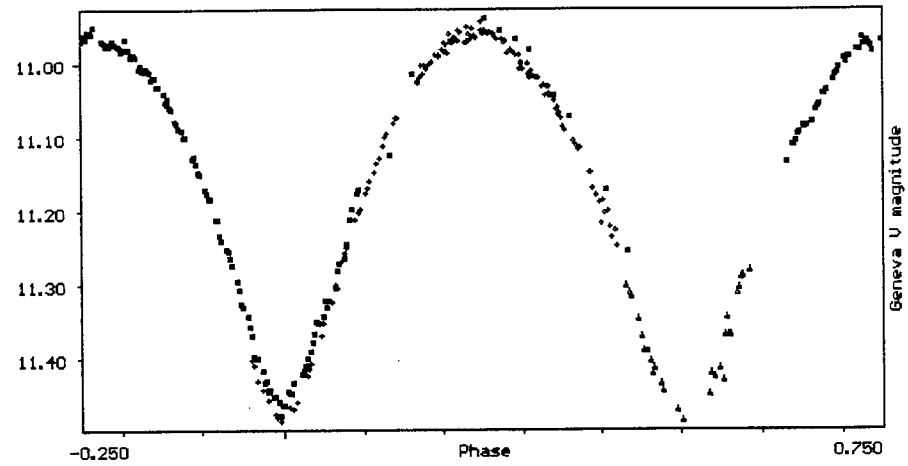
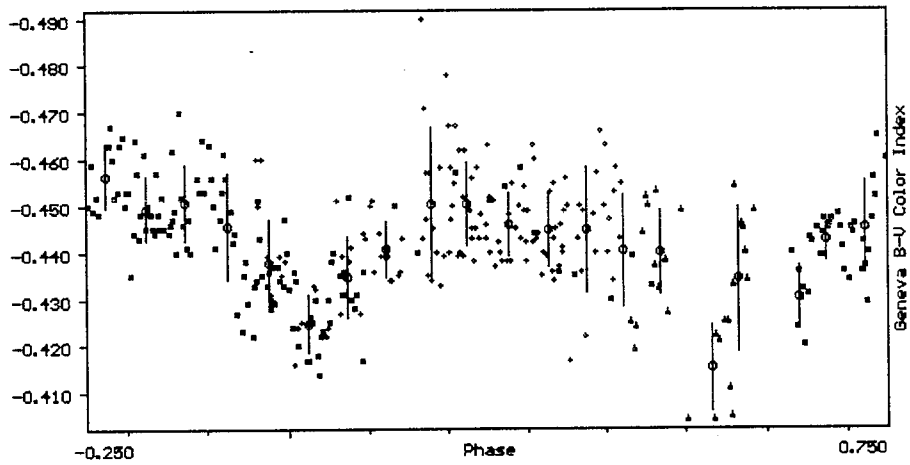


Figure 7: B-V colour index. Open circles represent mean values every 0.05 phase, and error bars represent the mean square error.



The average B-V colour index is -0.451 ± 0.004 at maximum light. Using the conversion formula described by Meylan and Hauck (1981), the resulting B-V colour index, considering NSV 11321 as a system belonging to the luminosity class V, is equal to 0.417. Applying the conversion table published by Cousins (1981), NSV 11321 Lyr approximately belongs to the spectral class F5. This evaluation is in agreement with the "period-colour" diagram of Rucinski (1997), in which it is shown, that the evolution of contact systems leads to longer periods and redder colours for more evolved ones.

Conclusions

The suspected variable star NSV 11321 Lyr can be ascribed as a new discovery of the GEOS. Over two thousand visual estimates independently carried out by 6 observers and 322 photoelectric measurements confirmed the light variation is due to an eclipsing binary of EW type, with a period of about 0.578 days. The first light elements and the photoelectric light curve are also reported.

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References:

Beltraminelli N., Dalmazio D., Remis J., Manna A., *Inf. Bull. Var. Stars*, submitted
Cousins, A. W., 1981, *SAAO Circ.*, **6**, 4
Gaspani A., *Period Search by Recursive Fourier Transform*, GEOS FT 62 and 69
Gaspani A., *Stochastic Optimisation Program*, ver. 5, BAV M,H, Jan. 1995
Hoffmeister, C., 1965, *Mitt. Ver. Sterne*, **B3**, 113
Jenkner, H., Lasker, B., Sturch, C., McLean, B., Shara, M., Russel, J., 1990, *AJ*, **99**, 2082
Kholopov P. et al., 1982, *New Catalogue of Susp. Var. Star*, nakua, Moskow
Kwee, K. K., van Woerden, H., 1956, *BAN*, **12**, 327
Meylan G., Hauck B., 1981, *A & A Suppl. Ser.*, **46**, 281
Rucinski, S. M., 1997, *AJ*, **113**, 407
Stellingwerf, R. F., 1978, *AJ*, **224**, 953