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The Optical Gravitational Lensing Experiment. The Catalog of Periodic Variable Stars in the Galactic Bulge. II. Periodic Variables in Four Baade's Window Fields: BW1, BW2, BW3 and BW4*

by

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ABSTRACT

We present the second part of the OGLE Catalog of Periodic Variable Stars in the Galactic bulge. 800 variable stars found in four Baade's Window fields BW1, BW2, BW3 and BW4 are presented. Among them 71 are classified as pulsating, 465 as eclipsing and 264 as miscellaneous type. The Catalog and individual observations are available in digital form from the OGLE Internet archive.

Key words: *Catalogs – Stars: variables*

1. Introduction

The Optical Gravitational Lensing Experiment (OGLE) is a long term observing project with the main goal of probing dark matter in our Galaxy with microlensing phenomena (Paczyński 1986). After three seasons of observations toward the Galactic bulge 12 microlensing events have been detected (Udalski *et al.* 1993, 1994b, 1994c).

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* Based on observations obtained at the Las Campanas Observatory of the Carnegie Institution of Washington

The huge amount of photometric measurements of a few million stars collected during the OGLE experiment is an unique material for studying the stellar variability. Large number of detected variable stars, in some cases significantly exceeding the number of all known variables of a given type, should considerably contribute to our knowledge about origin and evolution of different classes of variable stars and about structure and evolution of our Galaxy.

The search for periodic variable stars in the OGLE photometric databases has already been performed and the first part of the OGLE Catalog of Periodic Variable Stars in the Galactic bulge has been published (Udalski *et al.* 1994d; hereafter Paper I). First part of the Catalog included 213 periodic variable stars from the center of the Baade's Window field designated as BWC. This paper is a continuation of the Catalog – variable stars from four next fields: BW1, BW2, BW3 and BW4 (Udalski *et al.* 1994a) are presented in a similar form as in the first part of the Catalog.

2. The Catalog

The photometric data presented here were collected during three observing seasons of the OGLE microlensing search starting from April 13, 1992 through September 16, 1994. Full logs of observations can be found in Udalski *et al.* (1992, 1994a, 1995). Observations were made at the Las Campanas Observatory, Chile which is operated by the Carnegie Institution of Washington. The 1-m Swope telescope equipped with 2048 $\times$ 2048 Ford/Loral CCD detector was used. Details of data pipeline, reduction technique and period search technique can be found in Paper I.

Present edition of the Catalog contains periodic variable stars with $\langle I\rangle$ brighter than 18 mag. In the following updates the Catalog will be extended toward fainter stars. There is also a lower limit of magnitude: $I \approx 14$ – resulting from saturation of stellar images on CCD frames. The period search was limited to periods within 0.1 – 100 days range. The second part of the Catalog presents variable stars

Table 1

Coordinates of BW1, BW2, BW3 and BW4 fields.

Field	α_{2000}	δ_{2000}	l	b
BW1	$18^{h}02^{m}24^{s}$	$-29^{\circ}49'05''$	1.1	–3.6
BW2	$18^{h}02^{m}24^{s}$	$-30^{\circ}15'05''$	0.7	–3.8
BW3	$18^{h}04^{m}24^{s}$	$-30^{\circ}15'05''$	0.9	–4.2
BW4	$18^{h}04^{m}24^{s}$	$-29^{\circ}49'05''$	1.3	–4.0

from four Baade's Window fields: BW1, BW2, BW3 and BW4. Each field covers approximately $15' \times 15'$ on the sky. Equatorial and galactic coordinates of these fields are given in Table 1. Each of BW1 – BW4 fields overlaps slightly (about $1' \times 1'$) with the central BWC field. The variable stars discovered in the overlapping areas during the BWC field search (Paper I) are not presented here to avoid ambiguity. In total 17236, 12681, 10779 and 13345 suspected for variability stars were searched for periodic light variations in fields BW1, BW2, BW3 and BW4, respectively.

The structure of the Catalog is identical as in the first part (Paper I). Detected variable stars from each field are grouped into three categories: pulsating stars, eclipsing stars and miscellaneous type variables. The latter category consists of stars which cannot be classified unambiguously as pulsating or eclipsing stars. It contains mostly late type, chromospherically active stars, and likely some ellipsoidal variables.

For every field and group of stars the Catalog consists of a Table with basic parameters for every periodic variable object and an atlas containing the phased light curves and $30'' \times 30''$ finding charts – part of the I-band frames. North is up and East is to the left.

The basic parameters for every object include star designation, right ascention and declination (J2000), period in days and heliocentric Julian Date of maximum light (minimum for eclipsing variables), I magnitude at maximum brightness, $V-I$ color at maximum brightness, I-band amplitude, classification and eventual remarks.

Designation of the object follows the scheme from Paper I: OGLE *field* V*number*, *e.g.*, OGLE BW2 V22. The variable stars in every field are initially sorted according to magnitude. Thus lower number means brighter star.

The equatorial coordinates of variable stars were calculated using transformation derived from position of stars from the HST Guide Star Catalog (Lasker *et al.* 1988). Typically about 20 GSC stars were identified in each field. Accuracy of coordinates is about $1''$.

Because of strategy adopted in the microlensing search, the vast majority of measurements was made in the I-band (typically 100 – 190 observations). Only about 10 V-band measurements were collected for each field. Thus, the $V-I$ color at maximum light is accurate to 0.05 mag. In some cases the color is not given – it could not be derived because either V-band coverage around maximum was not good enough or the star could not be identified in the V-band database.

Classification within pulsating and eclipsing star groups follows the scheme of the General Catalog of Variable Stars (Kholopov *et al.* 1985).

3. Catalog of Periodic Variable Stars of the BW1, BW2, BW3 and BW4 Fields

Tables 2 – 13 and Appendices A – L contain the catalog of pulsating, eclipsing and miscellaneous periodic stars in BW1, BW2, BW3 and BW4 fields.

71 variable stars were classified as pulsating. Most of them are RR Lyr stars type ab and c. Remaining 18 objects are short period δ Scuti type pulsating stars. The periods of majority of them fall below the lower limit (0.1 day) of period search, but these stars were identified with $2 \times P$ period. Thus they probably do not represent complete sample of this type of stars in the Baade's Window. Some of RR Lyr type stars in the Baade's Window were studied by Blanco (1984). Out of 22 objects from Blanco list located in fields BW1 – 4, 18 were identified in the Catalog as pulsating stars. Two more objects previously classified as RRc type by Blanco are classified as W UMa-type eclipsing variables. Two remaining objects are missing due to reduction technique drawbacks (see Paper I). Cross-identification is given in "Remarks" column of appropriate Tables.

Table 2

Pulsating Variable Stars in the BW1 field

Star ID OGLE	α_{2000}	δ_{2000}	P	T_0 – 2 448 000	I	$(V-I)$	ΔI	Type	Remarks
BW1 V7	$18^h01^m56\overset{s}{.}02$	$-29°50'55\overset{''}{.}7$	$0\overset{d}{.}46006$	724.5715	$14\overset{m}{.}88$	–	$0\overset{m}{.}33$	RRab	Blanco3
BW1 V10	$18^h01^m59\overset{s}{.}50$	$-29°44'30\overset{''}{.}8$	$0\overset{d}{.}55564$	724.2323	$15\overset{m}{.}05$	$0\overset{m}{.}91$	$0\overset{m}{.}67$	RRab	Blanco4
BW1 V11	$18^h01^m53\overset{s}{.}72$	$-29°54'09\overset{''}{.}7$	$0\overset{d}{.}38434$	724.8422	$15\overset{m}{.}09$	$1\overset{m}{.}22$	$0\overset{m}{.}29$	RRc	
BW1 V14	$18^h02^m26\overset{s}{.}57$	$-29°43'46\overset{''}{.}9$	$0\overset{d}{.}49322$	724.4588	$15\overset{m}{.}11$	$0\overset{m}{.}95$	$0\overset{m}{.}77$	RRab	Blanco11
BW1 V18	$18^h02^m38\overset{s}{.}98$	$-29°51'56\overset{''}{.}3$	$0\overset{d}{.}52956$	724.5916	$15\overset{m}{.}27$	$0\overset{m}{.}86$	$0\overset{m}{.}79$	RRab	Blanco20
BW1 V19	$18^h02^m42\overset{s}{.}99$	$-29°54'19\overset{''}{.}6$	$0\overset{d}{.}44444$	724.4639	$15\overset{m}{.}30$	–	$0\overset{m}{.}81$	RRab	Blanco22
BW1 V21	$18^h02^m22\overset{s}{.}08$	$-29°53'37\overset{''}{.}5$	$0\overset{d}{.}45411$	724.4644	$15\overset{m}{.}35$	$0\overset{m}{.}94$	$0\overset{m}{.}76$	RRab	
BW1 V23	$18^h02^m36\overset{s}{.}82$	$-29°47'16\overset{''}{.}9$	$0\overset{d}{.}18958$	724.9236	$15\overset{m}{.}42$	$0\overset{m}{.}93$	$0\overset{m}{.}31$	DSCT	Blanco17
BW1 V25	$18^h02^m44\overset{s}{.}96$	$-29°53'08\overset{''}{.}4$	$0\overset{d}{.}60023$	724.0545	$15\overset{m}{.}44$	$1\overset{m}{.}00$	$0\overset{m}{.}51$	RRab	Blanco24
BW1 V31	$18^h02^m15\overset{s}{.}55$	$-29°42'18\overset{''}{.}0$	$0\overset{d}{.}42434$	724.4630	$15\overset{m}{.}58$	$1\overset{m}{.}03$	$0\overset{m}{.}80$	RRab	Blanco10
BW1 V32	$18^h02^m27\overset{s}{.}45$	$-29°44'22\overset{''}{.}1$	$0\overset{d}{.}30529$	724.7401	$15\overset{m}{.}59$	$0\overset{m}{.}90$	$0\overset{m}{.}29$	RRc	Blanco12
BW1 V34	$18^h02^m06\overset{s}{.}08$	$-29°44'57\overset{''}{.}9$	$0\overset{d}{.}63271$	724.4245	$15\overset{m}{.}63$	$1\overset{m}{.}13$	$0\overset{m}{.}52$	RRab	Blanco5
BW1 V36	$18^h02^m13\overset{s}{.}97$	$-29°55'51\overset{''}{.}6$	$0\overset{d}{.}44856$	724.4715	$15\overset{m}{.}66$	$1\overset{m}{.}18$	$0\overset{m}{.}89$	RRab	
BW1 V40	$18^h02^m10\overset{s}{.}98$	$-29°50'04\overset{''}{.}4$	$0\overset{d}{.}61175$	724.5475	$15\overset{m}{.}69$	$1\overset{m}{.}16$	$0\overset{m}{.}36$	RRab	
BW1 V43	$18^h02^m49\overset{s}{.}60$	$-29°44'19\overset{''}{.}7$	$0\overset{d}{.}42178$	724.5970	$15\overset{m}{.}79$	$0\overset{m}{.}73$	$0\overset{m}{.}74$	RRab	Blanco28
BW1 V50	$18^h02^m39\overset{s}{.}02$	$-29°41'55\overset{''}{.}0$	$0\overset{d}{.}31992$	724.8027	$15\overset{m}{.}94$	$1\overset{m}{.}03$	$0\overset{m}{.}30$	RRc	
BW1 V53	$18^h01^m58\overset{s}{.}09$	$-29°56'23\overset{''}{.}9$	$0\overset{d}{.}31963$	724.7035	$15\overset{m}{.}98$	$1\overset{m}{.}09$	$0\overset{m}{.}27$	RRc	
BW1 V90	$18^h01^m48\overset{s}{.}85$	$-29°50'25\overset{''}{.}4$	$0\overset{d}{.}0780319$	724.9573	$16\overset{m}{.}45$	$1\overset{m}{.}34$	$0\overset{m}{.}14$	DSCT	
BW1 V109	$18^h02^m00\overset{s}{.}34$	$-29°48'43\overset{''}{.}0$	$0\overset{d}{.}1068444$	724.9040	$16\overset{m}{.}72$	$0\overset{m}{.}99$	$0\overset{m}{.}22$	DSCT	
BW1 V154	$18^h01^m59\overset{s}{.}53$	$-29°52'34\overset{''}{.}4$	$0\overset{d}{.}0984631$	724.9036	$17\overset{m}{.}16$	$1\overset{m}{.}05$	$0\overset{m}{.}26$	DSCT	
BW1 V155	$18^h02^m42\overset{s}{.}02$	$-29°43'31\overset{''}{.}2$	$0\overset{d}{.}0686364$	724.9088	$17\overset{m}{.}15$	$1\overset{m}{.}33$	$0\overset{m}{.}39$	DSCT	
BW1 V195	$18^h02^m45\overset{s}{.}76$	$-29°46'01\overset{''}{.}9$	$0\overset{d}{.}0741104$	724.8849	$17\overset{m}{.}57$	$0\overset{m}{.}85$	$0\overset{m}{.}37$	DSCT	
BW1 V207	$18^h02^m14\overset{s}{.}90$	$-29°54'08\overset{''}{.}7$	$0\overset{d}{.}0856008$	724.9361	$17\overset{m}{.}64$	$1\overset{m}{.}03$	$0\overset{m}{.}42$	DSCT	
BW1 V209	$18^h02^m10\overset{s}{.}23$	$-29°51'58\overset{''}{.}4$	$0\overset{d}{.}0597840$	724.8822	$17\overset{m}{.}68$	$1\overset{m}{.}01$	$0\overset{m}{.}40$	DSCT	

Table 3

Pulsating Variable Stars in the BW2 field

Star ID OGLE	α_{2000}	δ_{2000}	P	T_0 – 2 448 000	I	$(V-I)$	ΔI	Type	Remarks
BW2 V8	$18^h02^m08.^s75$	$-30^\circ17'18.''6$	$0.^d39402$	724.9397	$15.^m13$	$1.^m06$	$0.^m33$	RRc	
BW2 V10	$18^h02^m06.^s02$	$-30^\circ21'59.''0$	$0.^d50784$	724.1798	$15.^m23$	$1.^m04$	$0.^m28$	RRc	
BW2 V14	$18^h01^m48.^s48$	$-30^\circ13'33.''1$	$0.^d77102$	724.1728	$15.^m38$	–	$0.^m49$	RRab	
BW2 V17	$18^h01^m48.^s96$	$-30^\circ19'36.''5$	$0.^d47838$	724.3797	$15.^m53$	–	$0.^m78$	RRab	
BW2 V18	$18^h02^m37.^s89$	$-30^\circ19'26.''9$	$0.^d62432$	724.6076	$15.^m58$	$1.^m26$	$0.^m11$	RRc	
BW2 V23	$18^h02^m49.^s26$	$-30^\circ12'54.''3$	$0.^d49276$	724.7982	$15.^m65$	$0.^m82$	$0.^m90$	RRab	
BW2 V24	$18^h02^m08.^s23$	$-30^\circ12'10.''0$	$0.^d59743$	724.3630	$15.^m72$	$1.^m27$	$0.^m31$	RRab	
BW2 V42	$18^h02^m37.^s56$	$-30^\circ15'29.''9$	$0.^d28954$	724.7172	$16.^m25$	$0.^m98$	$0.^m41$	RRc	
BW2 V44	$18^h02^m29.^s70$	$-30^\circ22'29.''7$	$0.^d0729190$	724.9140	$16.^m28$	–	$0.^m15$	DSCT	
BW2 V51	$18^h02^m23.^s18$	$-30^\circ12'18.''6$	$0.^d18893$	724.8517	$16.^m40$	$1.^m08$	$0.^m25$	DSCT	
BW2 V142	$18^h02^m17.^s59$	$-30^\circ08'18.''3$	$0.^d0707246$	724.9463	$17.^m50$	–	$0.^m54$	DSCT	
BW2 V143	$18^h02^m44.^s10$	$-30^\circ19'50.''8$	$0.^d0594495$	724.9700	$17.^m51$	$1.^m15$	$0.^m44$	DSCT	
BW2 V152	$18^h01^m53.^s62$	$-30^\circ18'52.''4$	$0.^d0711784$	724.8876	$17.^m63$	$1.^m08$	$0.^m23$	DSCT	

Table 4

Pulsating Variable Stars in the BW3 field

Star ID OGLE	α_{2000}	δ_{2000}	P	T_0 – 2 448 000	I	$(V-I)$	ΔI	Type	Remarks
BW3 V11	$18^h04^m41.^s27$	$-30^\circ17'18.''6$	$0.^d65494$	724.1999	$15.^m04$	$1.^m21$	$0.^m62$	RRab	
BW3 V13	$18^h03^m55.^s94$	$-30^\circ12'45.''6$	$0.^d45751$	724.3847	$15.^m21$	$1.^m08$	$0.^m80$	RRab	Blanco67
BW3 V16	$18^h04^m10.^s83$	$-30^\circ16'52.''7$	$0.^d60354$	724.2752	$15.^m38$	$1.^m20$	$0.^m57$	RRab	
BW3 V17	$18^h03^m54.^s78$	$-30^\circ20'37.''4$	$0.^d40333$	724.4190	$15.^m50$	$0.^m89$	$0.^m88$	RRab	
BW3 V21	$18^h03^m49.^s95$	$-30^\circ20'10.''1$	$0.^d77304$	723.8747	$15.^m55$	$1.^m26$	$0.^m28$	RRab	
BW3 V26	$18^h03^m46.^s63$	$-30^\circ15'55.''1$	$0.^d33435$	724.5482	$15.^m69$	$0.^m93$	$0.^m33$	RRc	
BW3 V41	$18^h04^m30.^s99$	$-30^\circ17'01.''9$	$0.^d26263$	724.7130	$15.^m88$	$1.^m04$	$0.^m34$	RRc	
BW3 V43	$18^h04^m21.^s88$	$-30^\circ19'39.''5$	$0.^d64089$	724.8402	$15.^m88$	$1.^m49$	$0.^m21$	RRab	
BW3 V46	$18^h04^m14.^s12$	$-30^\circ17'00.''2$	$0.^d48653$	724.8762	$15.^m92$	$1.^m24$	$0.^m61$	RRab	
BW3 V48	$18^h03^m47.^s12$	$-30^\circ19'00.''7$	$0.^d25073$	724.8579	$15.^m99$	$1.^m11$	$0.^m22$	RRc	
BW3 V61	$18^h04^m05.^s52$	$-30^\circ12'53.''8$	$0.^d54160$	724.5200	$16.^m22$	$1.^m06$	$0.^m69$	RRab	Blanco70
BW3 V65	$18^h04^m43.^s25$	$-30^\circ22'15.''0$	$0.^d47484$	724.3779	$16.^m26$	–	$0.^m86$	RRab	
BW3 V66	$18^h04^m40.^s63$	$-30^\circ16'11.''3$	$0.^d29103$	724.7840	$16.^m29$	$1.^m09$	$0.^m31$	RRc	
BW3 V76	$18^h04^m23.^s70$	$-30^\circ17'38.''3$	$0.^d0757692$	724.9578	$16.^m39$	$1.^m47$	$0.^m15$	DSCT	
BW3 V81	$18^h04^m18.^s48$	$-30^\circ19'41.''6$	$0.^d50818$	724.4182	$16.^m47$	–	$0.^m51$	RRab	
BW3 V93	$18^h04^m41.^s73$	$-30^\circ15'02.''3$	$0.^d0962651$	724.9051	$16.^m62$	$1.^m12$	$0.^m31$	DSCT	
BW3 V99	$18^h04^m46.^s22$	$-30^\circ20'42.''3$	$0.^d56046$	724.2993	$16.^m72$	$1.^m53$	$0.^m74$	RRab	
BW3 V111	$18^h04^m30.^s20$	$-30^\circ12'15.''8$	$0.^d0706662$	724.9529	$16.^m90$	$1.^m17$	$0.^m25$	DSCT	

Table 5

Pulsating Variable Stars in the BW4 field

Star ID OGLE	α_{2000}	δ_{2000}	P	$T_0 -$ 2 448 000	I	$(V-I)$	ΔI	Type	Remarks
BW4 V4	$18^{h}04^{m}23.^{s}35$	$-29^{\circ}56'04.''9$	$0.^{d}31997$	724.4857	$14.^{m}98$	$1.^{m}10$	$0.^{m}13$	RRc	
BW4 V5	$18^{h}04^{m}22.^{s}47$	$-29^{\circ}54'41.''0$	$0.^{d}47468$	724.6631	$15.^{m}05$	$1.^{m}14$	$0.^{m}62$	RRab	Blanco75
BW4 V8	$18^{h}04^{m}04.^{s}21$	$-29^{\circ}56'45.''1$	$0.^{d}51586$	724.5073	$15.^{m}09$	$1.^{m}10$	$0.^{m}66$	RRab	Blanco69
BW4 V9	$18^{h}03^{m}52.^{s}77$	$-29^{\circ}51'46.''5$	$0.^{d}46317$	724.7684	$15.^{m}11$	$0.^{m}91$	$0.^{m}80$	RRab	Blanco66
BW4 V11	$18^{h}04^{m}40.^{s}88$	$-29^{\circ}43'28.''2$	$0.^{d}60169$	723.8842	$15.^{m}16$	$1.^{m}10$	$0.^{m}38$	RRab	
BW4 V12	$18^{h}04^{m}14.^{s}95$	$-29^{\circ}45'05.''3$	$0.^{d}63958$	724.3851	$15.^{m}18$	$1.^{m}12$	$0.^{m}54$	RRab	
BW4 V22	$18^{h}03^{m}45.^{s}56$	$-29^{\circ}47'56.''5$	$0.^{d}56093$	724.6486	$15.^{m}53$	$1.^{m}31$	$0.^{m}52$	RRab	
BW4 V25	$18^{h}04^{m}28.^{s}46$	$-29^{\circ}55'54.''8$	$0.^{d}32191$	724.6693	$15.^{m}58$	$1.^{m}05$	$0.^{m}32$	RRc	Blanco78
BW4 V27	$18^{h}04^{m}30.^{s}95$	$-29^{\circ}55'32.''3$	$0.^{d}34744$	724.6782	$15.^{m}65$	$1.^{m}46$	$0.^{m}12$	RRc	?
BW4 V31	$18^{h}03^{m}53.^{s}74$	$-29^{\circ}42'58.''1$	$0.^{d}32701$	724.9616	$15.^{m}70$	$1.^{m}00$	$0.^{m}31$	RRc	
BW4 V43	$18^{h}04^{m}29.^{s}62$	$-29^{\circ}51'32.''8$	$0.^{d}55992$	724.4077	$15.^{m}84$	$1.^{m}13$	$0.^{m}48$	RRab	
BW4 V46	$18^{h}04^{m}06.^{s}66$	$-29^{\circ}56'34.''0$	$0.^{d}26256$	724.9190	$15.^{m}88$	$0.^{m}98$	$0.^{m}37$	RRc	Blanco71
BW4 V55	$18^{h}04^{m}26.^{s}30$	$-29^{\circ}44'10.''8$	$0.^{d}15958$	724.9648	$16.^{m}15$	$1.^{m}04$	$0.^{m}09$	DSCT	
BW4 V57	$18^{h}04^{m}28.^{s}33$	$-29^{\circ}45'08.''8$	$0.^{d}29085$	724.5074	$16.^{m}18$	$0.^{m}90$	$0.^{m}27$	RRc	
BW4 V94	$18^{h}04^{m}02.^{s}62$	$-29^{\circ}44'22.''3$	$0.^{d}0659688$	724.9417	$16.^{m}59$	$1.^{m}13$	$0.^{m}13$	DSCT	
BW4 V132	$18^{h}04^{m}41.^{s}02$	$-29^{\circ}51'06.''8$	$0.^{d}65076$	724.8978	$17.^{m}04$	$1.^{m}14$	$0.^{m}64$	RRab	

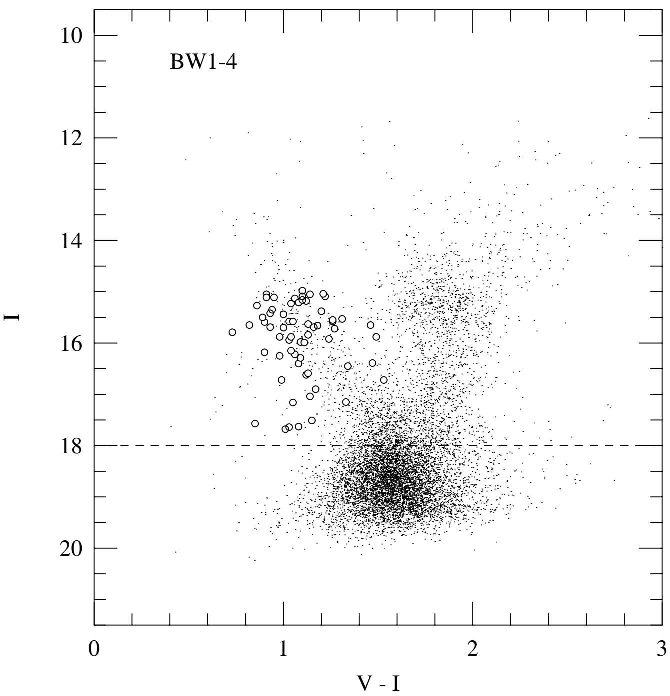

Fig. 1. CMD of stars in the direction of the Baade's Window with positions of pulsating stars from BW1, BW2, BW3 and BW4 fields at maximum brightness denoted by open circles. Dashed horizontal line marks the brightness limit of the present search for periodic variable stars.