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66 NEW VARIABLE STARS FROM SAVS SKY SURVEY

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Abstract: Light curves of 66 new variable stars discovered by the Semi-Automatic Variability Search are presented. We report on discovery of 23 eclipsing binaries, 5 regular pulsating stars, 14 semi-regular variables, and 24 irregular ones among the others.

We present 66 new variable stars discovered by the Semi-Automatic Variability Search (Niedzielski et al., 2003) operating at the Astronomical Observatory of the Nicolaus Copernicus University in Piwnice, near Toruń. Photometric data were collected with the semi-automatic telescope equipped with a 135/2.8 telephoto lens and SBIG ST-8XE CCD camera with KAF-1602E chip. Observations were collected between January 2006 and April 2007 while monitoring selected 15 fields (each $4^\circ \times 6^\circ$ wide) spread in the sky between declination $+20^\circ$ and $+75^\circ$ (see Lewandowski (2007) for details). In a total area of 360 square degrees about 79000 stars brighter than 14 mag were observed in near-Johnson V band. The list of observed fields, detailed hardware specification and description of data reducing software, as well as original data, are available on survey's web site http://www.astri.uni.torun.pl/~gm/SAVS .

CCD frames were processed with a standard procedure including subtraction of dark frames and flat-fielding. Instrumental stellar magnitudes were derived by the means of differential aperture photometry against selected standard stars which magnitudes were taken from the literature. The aperture diameter was calculated for individual objects as 3σ of the stellar profile. The instrumental coordinates of stars were transformed into equatorial ones using positions of stars brighter than 10 mag in a given field extracted from the Tycho-2 Catalog (Høg et al., 2000). The candidates for new variable stars were selected from the V-band database using the analysis of variance method (ANOVA, Schwarzenberg-Czerny, 1996). The search for candidates was performed on all detected stars what allowed us to find variables with very small amplitudes, comparable to our photometric precision. The variability of all variables was verified with the photometric data extracted from Northern Sky Variability Survey (NSVS, Woźniak et al., 2004a). The preliminary classification of the periodic variables was based on an automatic algorithm described in Maciejewski & Niedzielski (2005). To verify that detected here variable are actually yet unknown, we checked in IBVS, Peremennye Zvezdy, OEJV, as well as in papers of Woźniak et al. (2004b), Wils et al. (2006), Kinemuchi et al. (2006), Gettel et al. (2006), and Hoffman et al. (2008). Only the newly detected variables with no previous reference in available literature are presented here.

The list of new eclipsing binaries is presented in Table 1 and their phased light curves are shown in Fig. 1. The contact binaries (EW) dominate in the sample with 13 systems. The remaining systems are 6 detached and 4 semi-detached binaries.

The regular pulsating variables are listed in Table 2 and their phased light curves are plotted in Fig. 2. Among them there are two Cepheids (DCEP), two RR Lyrae with

Table 1. List of new eclipsing variables. SAVS ID – identifier consisted of Right Ascension and Declination of a star calculated for J2000.0, Other ID – cross-identification with other catalogues, Type – type of variability, $m_{\max}$ – the observed maximal brightness in near-Johnson V band, $\Delta m_{\rm I}$ – the depth of primary minimum, $\Delta m_{\rm II}$ – the depth of secondary minimum, $T_{\rm minI}$ – the time of a primary minimum, P – period of variation in days.

SAVS ID	Other ID	Type	$m_{\max}$ (mag)	$\Delta m_{\rm I}$ (mag)	$\Delta m_{\rm II}$ (mag)	$T_{\rm minI}$ HJD-2450000	P (days)
012053+433856	GSC 02825 00603	EW	12.91	0.66	0.59	3966.1471	0.544307(46)
013227+413635	GSC 02822 01558	EB	12.22	0.92	0.72	3761.5190	0.323488(15)
023049+493755	GSC 03303 01583	EW	11.88	0.63	0.54	3966.3399	0.451162(26)
025750+494214	TYC 3305 01469	EW	10.27	0.28	0.28	4000.1946	0.609868(54)
105032+420825	GSC 03011 01150	EW	12.40	0.39	0.38	3818.2860	0.576967(56)
171626+693504	GSC 04421 00400	EW	13.21	0.61	0.61	3818.2929	0.332967(17)
171954+694743	GSC 04421 00050	EA	12.71	1.04	0.76	3817.7773	0.314218(13)
173316+704227	GSC 04424 01787	EB	12.22	0.79	0.21	3817.9239	0.631832(71)
183856+602352	TYC 4215 01480	EA	10.44	0.45	0.27	3747.7723	0.744805(82)
185600+720544	GSC 04439 01124	EW	12.54	0.28	0.22	3818.7546	0.417827(31)
193000+701238	GSC 04448 01301	EW	13.36	0.62	0.53	3746.5772	0.333096(15)
194132+715717	GSC 04453 01543	EA	11.95	0.44	0.37	3823.5896	1.67047(47)
194753+724745	GSC 04453 00432	EW	12.02	0.46	0.46	3850.4900	0.559461(41)
194940+701832	GSC 04449 01278	EW	11.04	0.35	0.35	3817.7890	0.463535(33)
224116+444744	GSC 03226 01616	EW	12.11	0.28	0.28	3967.3634	0.98132(21)
224247+452103	GSC 03621 00711	EW	10.00	0.27	0.26	3965.7081	0.326997(17)
224833+584522	GSC 03996 00791	EA	10.97	0.64	0.27	3968.6413	2.04862(49)
224953+571206	TYC 3992 02365	EA	10.86	0.31	0.25	3972.2645	2.34723(82)
225002+590055	GSC 03996 01098	EW	12.69	0.45	0.37	3965.3635	0.352084(18)
225544+562832	TYC 3993 01515	EA	10.49	0.43	0.22	3969.3667	2.02170(61)
230244+575357	GSC 03993 00729	EW	11.35	0.20	0.20	3771.6686	0.71719(11)
231003+580829	BD+57 2700	EB	10.27	0.30	0.17	3763.1978	1.51853(46)
231217+585840	GSC 04010 00212	EB	11.24	0.31	0.22	3967.8633	1.22544(27)

Table 2. List of new pulsating variables. SAVS ID – identifier consisted of Right Ascension and Declination of a star calculated for J2000.0, Other ID – cross-identification with other catalogues, Type – type of variability, $m_{\max}$ – the observed maximal brightness in near-Johnson V band, Δm – the amplitude of variation, $T_{\max}$ – the time of maximum, P – period of variation in days, and $M-m$ – the interval between the phases of maximum and minimum.

SAVS ID	Other ID	Type	$m_{\max}$ (mag)	Δm (mag)	$T_{\max}$ HJD-2450000	P (days)	$M-m$
110231+423040	BD+43 2072	DCEP	9.95	0.19	3851.0498	22.910(28)	0.66
183958+585554	GSC 03917 01909	DCEP	13.08	0.38	3857.0949	21.771(78)	0.59
224618+435209	HD 215686	RRAB	8.33	0.21	3966.1657	0.245445(11)	0.69
224727+455328	GSC 03621 00004	RRAB	13.32	0.88	3966.0082	0.326669(17)	0.61
231317+582928	GSC 04010 00434	DSCT	12.96	0.29	3965.7587	0.121982(3)	0.58

asymmetric light curve (RRAB), and one δ Scuti pulsating star (DSCT). For these stars the interval between the phases of maximum and minimum was determined to describe the light-curve asymmetry.

The semi-regular and irregular variables are collected in Tables 3 and 4, respectively. For semi-regular pulsators the period that dominates in a periodogram was given as a rough estimation of the time scale of variation. The light curves are displayed in Fig. 3 and 4 where the raw data were binned with a one-day bin size to calculate mean brightness for every observed night. The error bars denotes standard deviations of mean magnitudes.

Table 3. List of new semi-regular variables. SAVS ID – identifier consisted of Right Ascension and Declination of a star calculated for J2000.0, Other ID – cross-identification with other catalogues, $m_{\max}$ – the observed maximal brightness in near-Johnson V band, Δm – the amplitude of variation, P – dominating time scale of variation in days

SAVS ID	Other ID	$m_{\max}$ (mag)	Δm (mag)	P (days)
023628+521630	GSC 03307 01476	13.10	0.52	∼54
025028+492214	IRAS 02470+4909	13.04	1.03	∼235
025919+515031	IRAS 02557+5138	12.09	0.77	∼240
090508+520351	GSC 03430 00653	11.01	0.28	∼23
171452+674207	GSC 04421 02551	10.64	0.35	∼28
171936+705321	GSC 04424 01873	11.35	0.91	∼125
175429+684859	GSC 04428 01499	11.01	0.54	∼27
183205+402958	GSC 03109 00377	11.63	0.32	∼22
185449+603507	IRAS 18541+6031	11.11	0.85	∼92
185609+593743	GSC 03931 00581	11.68	0.75	∼74
224902+444100	GSC 03226 01225	13.17	0.35	∼36
225016+565541	GSC 03992 01793	12.27	0.44	∼52
225629+453044	GSC 03622 01445	12.44	0.69	∼103
232818+572857	IRAS 23259+5712	11.97	0.43	∼240

The $J-H$ *vs.* $H-K_{\rm S}$ diagram (Fig. 5) was constructed for all non-eclipsing variables reported in this paper. The near infra-red magnitudes were taken from the 2MASS All-Sky Catalogue of Point Sources (Cutri et al., 2003). The location of a variable in this diagram may give helpful hint regarding its variability type (see Pojmański & Maciejewski (2004) for details). As one can see in Fig. 5, the distribution of data points is similar to the expected one. The semi-regulars and the irregulars form a red clump while regular pulsators occupy bluer colours. Only three stars – SAVS 002121+591427, SAVS 023548+491758, and 183205+402958 – are located outside the areas that would be expected considering variability type.

SAVS 002121+591427 and SAVS 023548+491758 are located in the area of short period pulsating stars. Their light curves show long term, irregular variability. Based on NSVS photometry its time scales were found to be ∼300–350 days.

SAVS 183205+402958 is located in the Cepheids area. Its light curve, obtained by us, reveals variability typical for DCEP type. However, the photometry from the NSVS clearly shows the semi-regular variation in a long time scale.

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Table 4. List of new irregular variables. SAVS ID – identifier consisted of Right Ascension and Declination of a star calculated for J2000.0, Other ID – cross-identification with other catalogues, $m_{\max}$ – observed mean brightness in near-Johnson V band, Δm – amplitude of variation.

SAVS ID	Other ID	$m_{\max}$	Δm
002121+591427	GSC 03665 00138	12.24	0.97
002615+580536	GSC 03661 00885	12.94	0.32
005251+572419	IRAS 00498+5708	10.99	0.32
011832+443707	GSC 02812 01491	11.70	0.45
012522+444848	IRAS 01224+4433	11.96	0.58
022237+501856	IRAS 02192+5005	12.47	0.75
023100+484930	IRAS 02276+483	10.55	0.51
023548+491758	TYC 3303 01008	10.21	0.57
024236+495026	GSC 02392 4937	11.82	0.77
024430+490124	IRAS 02411+4848	11.50	0.45
024918+510510	IRAS 02458+5052	11.57	0.26
030524+495834	IRAS 03018+4946	10.87	0.79
110522+442751	TYC 3012 02312	10.31	0.58
173045+703150	GSC 04424 02086	11.49	0.72
182140+400431	GSC 03108 00859	11.98	0.48
183145+403801	IRAS 18301+4035	10.23	0.42
183533+601521	IRAS 18349+6012	9.44	0.35
191333+702846	IRAS 19139+7023	11.64	0.40
191832+701236	GSC 04448 02052	11.80	0.46
195603+690211	IRAS 19559+6854	11.91	0.42
223408+443459	IRAS 22319+4419	11.21	0.44
223424+463545	IRAS 22323+4620	10.99	0.33
225537+555034	IRAS 22535+5534	9.96	0.39
225816+565832	IRAS 22561+5642	9.83	0.33

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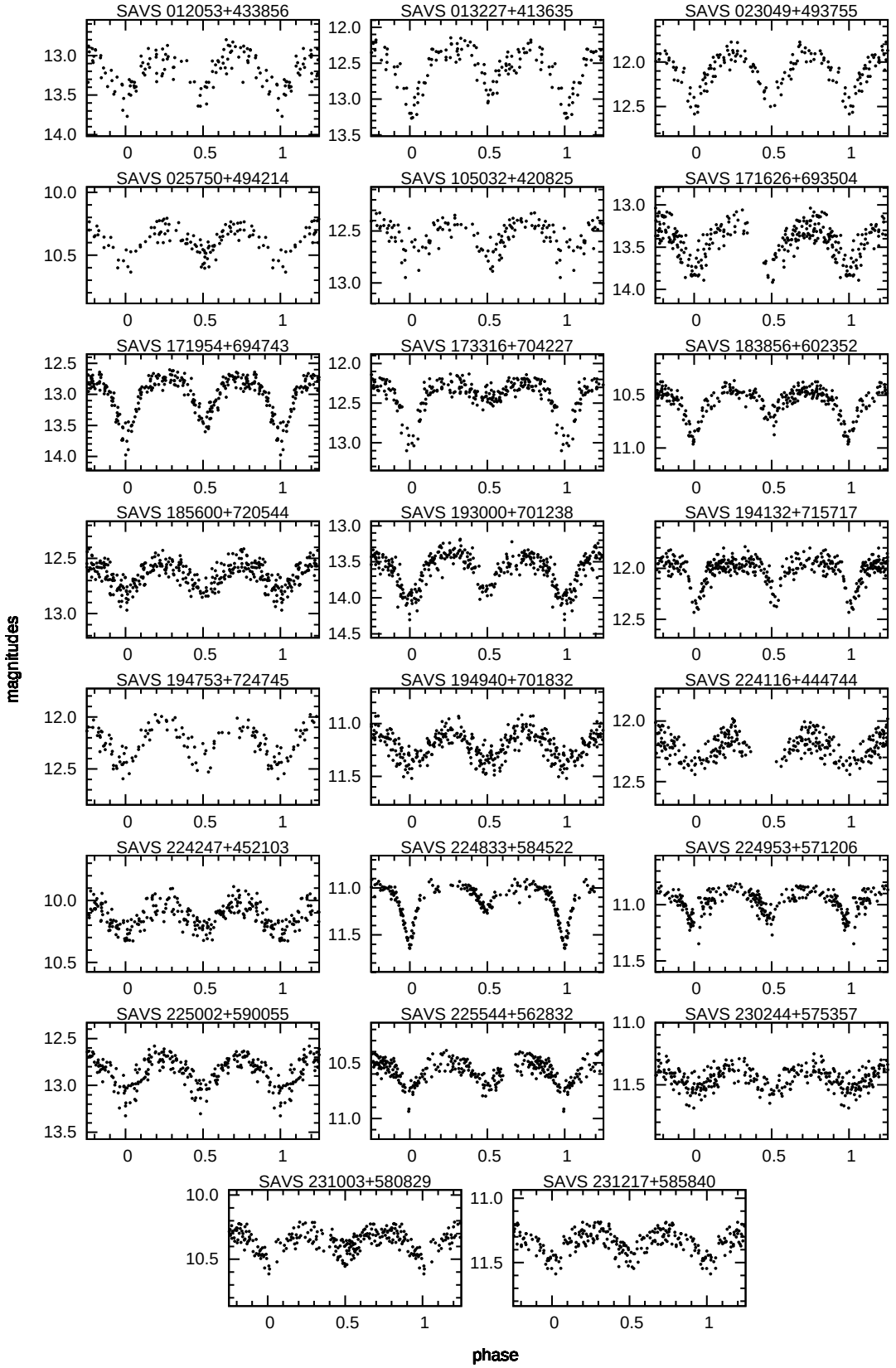

Figure 1: Light curves of new eclipsing binaries.

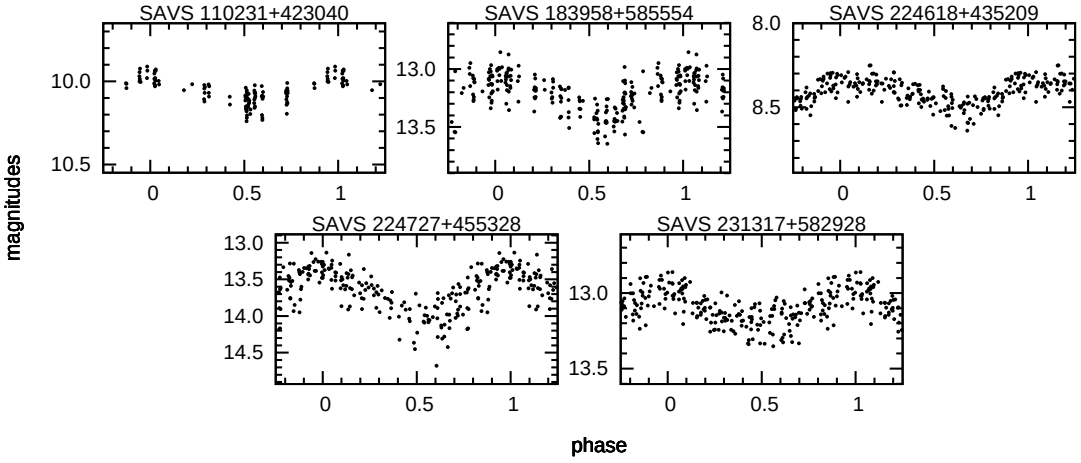

Figure 2: Light curves of new pulsating variables.

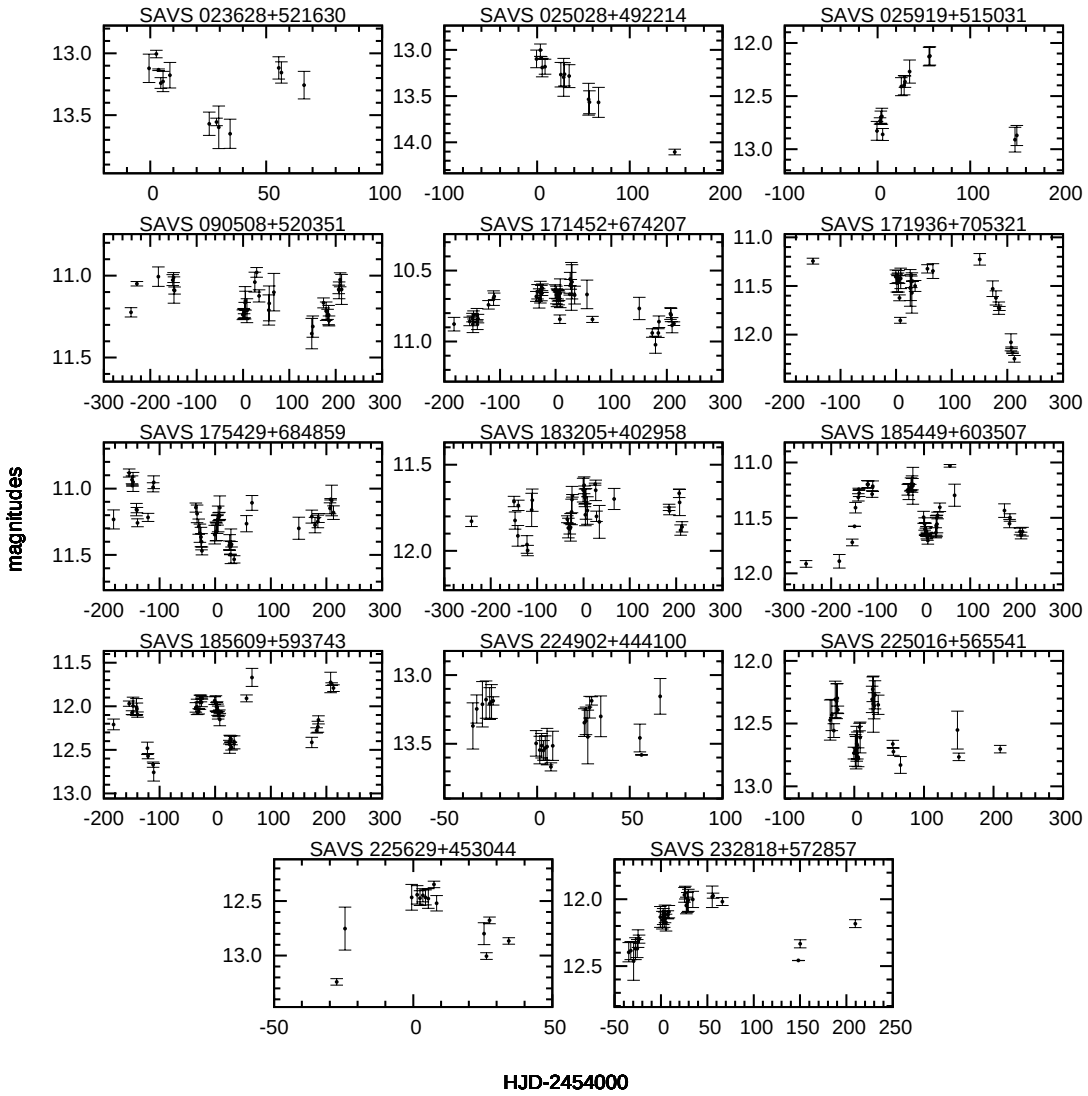

Figure 3: Light curves of new variables classified as semi-regular, binned in one-day intervals.

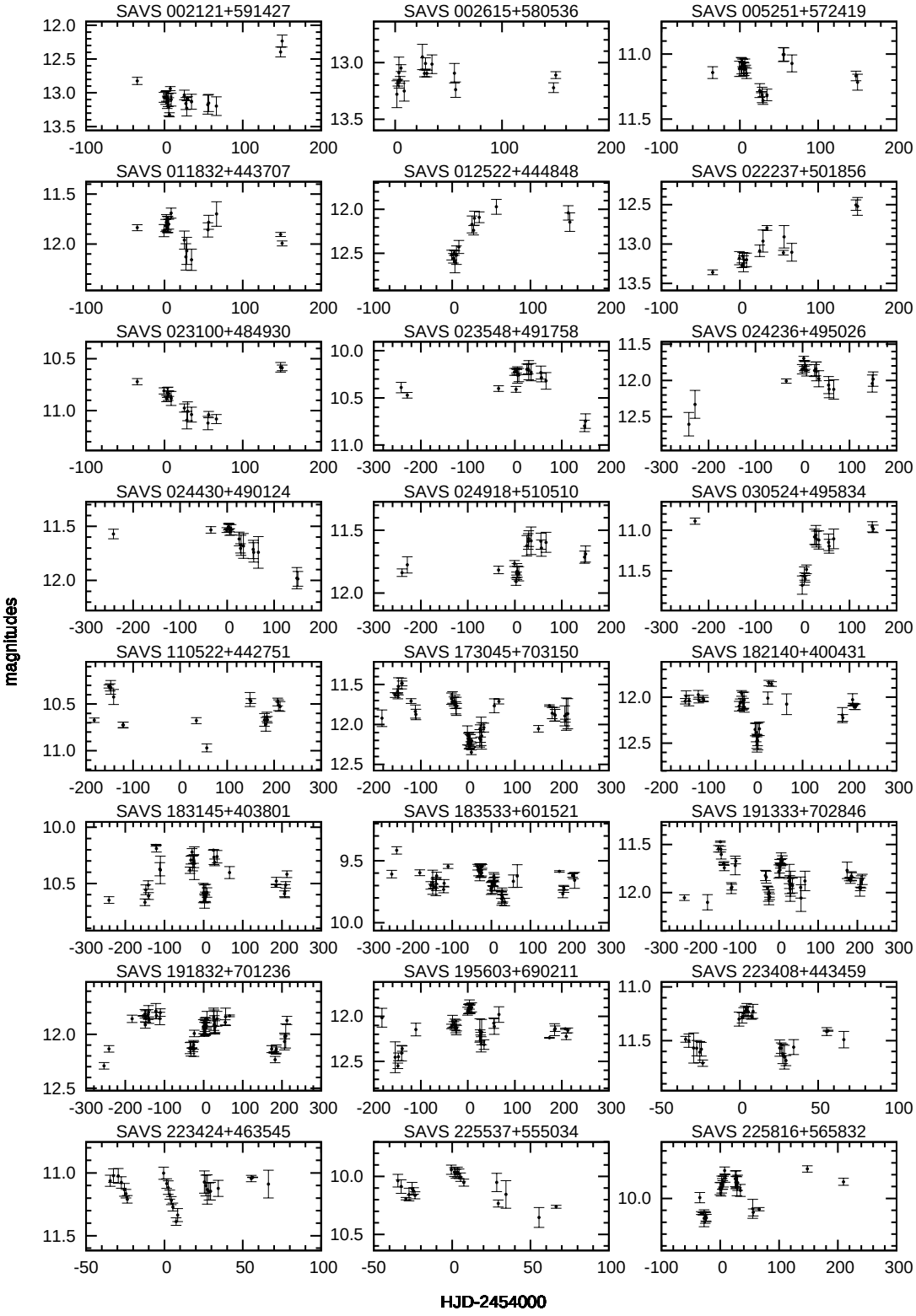

Figure 4: Light curves of new irregular variables, binned in one-day intervals.

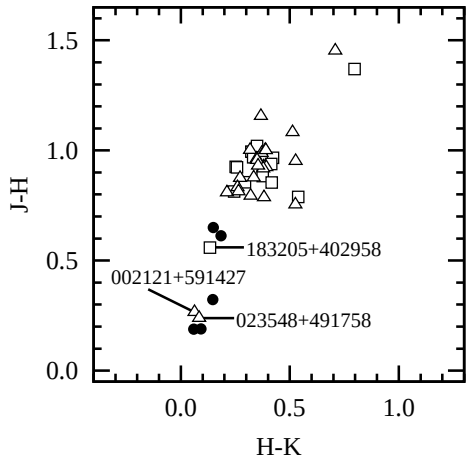

Figure 5: The $J-H$ *vs.* $H-K_{\rm S}$ diagram plotted for pulsating stars. The open triangles denote irregular variables, open squares – semi-regular ones, and filled circles – regular pulsating variables (δ Scu, RR Lyr, and Cepheids). The stars discussed in the text are labelled.