Peremennye Zvezdy (*Variable Stars*) **32**, No. 4, 2012

Received 1 July; accepted 15 August.

New Variables in Pegasus: How Can We Use WASP0 Data

E. V. Kazarovets[1], E. N. Pastukhova[1], N. N. Samus[1,2], E. M. Bogdanova[2]

[1] Institute of Astronomy, Russian Academy of Sciences, Pyatnitskaya Str. 48, 119017 Moscow, Russia; e-mail: helene@inasan.ru, pastukhova@sai.msu.ru, samus@sai.msu.ru

[2] Sternberg Astronomical Institute, Lomonosov Moscow University, University Ave. 13, 119992 Moscow, Russia

In the course of our work on the 80th Name-List of Variable Stars, we encountered a field in Pegasus with about 70 variable stars announced as new discoveries from the WASP0 survey. Our analysis shows that the amount of wrong information published for these stars is unacceptably large. We present correct information on WASP0 variables, both those that still remain unstudied by other authors and those with reliable studies in the literature. Our new information is based on publicly available sky surveys. We also discuss requirements to presentation of data on new variable stars that permit to include information into variable-star catalogs without a too large amount of extra work for catalog compilers.

1 Introduction

In the era of data-intensive astronomy, new Name-Lists of the General Catalogue of Variable Stars (GCVS) become very large. A large amount of information on new variable stars comes from sky surveys, partially or completely automatic. Such surveys use different (often small) wide-angle telescopes, they differ in limiting magnitude, photometric system, pixel size, time coverage. Extracting information from them, also often semi-automatic, results in rather heterogeneous and sometimes not very reliable results. Understandably, large amounts of data make it impossible for GCVS compilers to always address raw data and thus derive reliable variability information for catalog purposes.

By now, two of the three parts of the 80th Name-List of Variable Stars (NL80) have been published (Kazarovets et al. 2011ab). The third part, now in preparation, will present new variable stars in the right ascension range between $16^{\rm h}$ and $24^{\rm h}$. Working on the third part, we encountered a number of new variable stars reported by Kane et al. (2005) in a field of Pegasus as a result of observations with the Wide Angle Search for Planet Prototype (WASP0) instrument. Preparing information on these stars for the NL80, we spent considerable effort and obtained a number of new results worth publishing. Besides, we think that this study teaches us important lessons on how to present results of variable-star research in a form permitting catalog compilers to easily incorporate new variable stars into the GCVS.

For complete understanding of the following discussion, it is necessary to know some details of the WASP0 survey. The aperture of the telescope is 6.3 cm. The field of view is 9°, with a 2000×2000-pixel unfiltered, rather red-sensitive CCD. The size of a pixel on the sky is $16''$. In the field in Pegasus, Kane et al. (2005) announced 75 variable stars between magnitudes 7.69 and 13.76, 73 of them believed to be new. For all 75 stars, periods were presented (to one thousandth of a day). 14 stars were announced δ Scuti variables; 2 stars, possible δ Scuti variables; 18 stars, EW-type eclipsing variables; 9 stars, possible EW variables; 4 stars, RR Lyrae variables; 3 stars, BY Draconis variables (two of them uncertain); 2 stars, EB-type eclipsing variables; 2 stars, EA eclipsing variables; 3 stars, possible eclipsing variables (no subtype specified); and 18 stars have unknown types. The stars in the cited paper are identified with their numbers in the Tycho or USNO B1.0 catalog.

Periods were determined by Kane et al. (2005) using the Lomb–Scargle statistics. It should be noted that the observations were too time-limited and rather unfavorably distributed in time (about 6 hours per night for a total of four nights; "each of these nights was spaced seven nights apart"). Thus, there exists a possibility of not only one-day aliases of the true periods but also of one-week aliases.

2 Data Analysis and Results

Kane et al. (2005) indicate two of the 75 variable stars, Nos. 54 and 69, as known variable stars; they are AV Peg and NSV 25772. Actually, their list also contains the GCVS stars CY Peg, known since 1934 (No. 40), and VV Peg, known since 1910 (No. 53). Though improved coordinates for all GCVS stars in Pegasus were published slightly later (Samus et al. 2006), the GCVS coordinates for VV Peg used before that time are quite accurate; those used, at that time, for CY Peg differ by less than 50″ (about 3 WASP0 pixels) from the accurate coordinates.

For 47 stars listed in the Table, we were able to check catalog identifications suggested in Kane et al. (2005) using the publicly available ROTSE-I/NSVS (Woźniak et al. 2004), ASAS-3 (Pojmanski 2002), SuperWASP (Butters et al. 2010), Catalina (http://www.lpl.arizona.edu/css/) sky surveys. Identifications suggested by Kane et al. for variables No. 17 and No. 43 are wrong, they are respectively in 55″ and 40″ of the correct positions; our finding charts are presented in Figs. 1 and 2. The correct identification of No. 17 (ASAS 220149+1759.7, GSC 1684.00522) was first suggested by Otero et al. (2006). Our light curve of the variable No. 43 is reproduced in Fig. 3. A special case is No. 30 (Fig. 4). This close pair (8″ separation) has a single entry in the USNO-B1.0 catalog, with coordinates between the two components. The good angular resolution of the Catalina survey permitted us to establish the variable component of the pair. The identification currently (August 2012) adopted in the International Variable Star Index (VSX) corresponds to the other component.

Besides the coordinates, the Table contains types and periods from Kane et al. (2005) as well as those we adopted for the NL80; variation ranges (magnitudes marked V and B are close to standard V and B bands of the Johnson system; R are ROTSE-I/NSVS red magnitudes; CV means V-calibrated instrumental Catalina magnitudes); magnitudes in the secondary minimum, if appropriate; remarks and references. Our information on types and periods was either derived by us using the publicly available surveys or resulted from research of other authors (see the column "Ref.").

Figure 5 is another example of a light curve based on Catalina data (star No. 46, type EA). The Catalina survey provides good light curves for stars fainter than 13^{m}. This light curve presents the variable's eclipses much better than it would be possible with ROTSE-I/NSVS data.

Table. WASP0 variable stars

No.	RA (J2000.0) h, m, s	Dec (J2000.0) °, ′, ″	WASP0 type	WASP0 P, d	GCVS type	P, d	Range	MinII	Rem.	Ref.
3	21 58 32.7	+21 49 25	DSCT	0.081	DSCT	0.080784	12.33–12.54V		1	1
4	22 17 34.8	+15 31 33	DSCT	0.087	DSCTC	0.096321	11.24–11.33V			2
5	21 48 27.4	+22 37 02	DSCT	0.094	DSCT	0.090257	12.5 –12.7 V		1	2
7	21 51 52.3	+17 44 43	DSCT	0.113	DSCT	0.10772127	13.4 –13.9 V			3
8	21 47 44.3	+19 29 08	DSCT	0.120	DSCTC	0.13683:	10.36–10.40R			4
12	21 52 47.7	+18 17 34	DSCT	0.153	EW	0.312817	9.43– 9.52V	9.51	2	2
13	22 20 54.4	+16 18 35	DSCT	0.168	EW	0.58566	12.9 –13.4 V	13.3		1
14	22 12 17.2	+15 11 46	DSCT	0.200	EB	0.436739	11.85–12.12V	12.03		5
17	22 01 49.3	+17 59 42	?	0.207	EW	0.41521	11.77–12.08V	12.00		6
18	22 08 27.1	+18 35 25	?	0.217	EW:	0.38510	11.12–11.17R	11.16:		4
19	22 00 36.1	+16 15 01	?	0.230	EW	0.459624	13.1 –13.5 V	13.4		2
22	21 49 56.1	+20 58 43	EW	0.271	EW	0.295664	13.65–14.32CV	14.18	1	7
23	22 12 47.5	+18 24 10	EW	0.276	EW	0.265106	13.08–13.36CV	13.34		7
27	22 00 14.2	+23 05 01	EW	0.292	EW	0.298323	12.85–13.45CV	13.30	1	7
28	22 13 46.9	+18 21 03	EW	0.297	EW	0.303093	13.16–13.86CV	13.71		7
30	22 05 42.0	+19 55 08	EW	0.310	EW	0.303620	11.76–12.00V	11.95		5
32	21 55 01.2	+20 20 26	EW	0.342	EW	0.274751	11.65–11.75V	11.75	1	1
33	22 16 52.2	+22 29 34	EW	0.346	EB	0.346453	13.0 –14.2 V	13.7	1	8
34	21 50 25.6	+17 43 43	EW	0.347	EW	0.3305685	11.60–12.15V	12.05		5
35	21 50 23.7	+17 46 22	EW?	0.349	EA:	1.14228:	13.1 –13.6 R	13.5		4
36	22 08 25.9	+18 34 57	EW?	0.349	EW	0.385135	13.16–13.50CV	13.48		7
37	22 15 38.7	+22 19 34	EW?	0.370	EW	0.343122	13.39–13.88CV	13.86	1	7
39	21 59 29.0	+14 58 17	EW	0.389	EW	0.412371	11.37–11.52V	11.51		2
40	21 49 47.2	+21 08 38	RR	0.399	RRAB	0.64793	12.0 –13.2 V		3	2
41	21 56 42.1	+22 03 12	EW?	0.406	EW	0.3735416	12.9 –13.3 V	13.3	1	2
42	21 59 05.4	+17 44 32	EW	0.407	EW	0.395357	13.00–13.26CV	13.22		7
43	22 01 42.5	+17 28 45	?	0.407	EB	1.794670	12.72–13.38CV	12.90		7
44	21 50 25.4	+14 51 06	?	0.414	EB	0.878990	12.05–12.50V	12.35		2
46	22 03 30.2	+19 39 13	EW?	0.433	EA	1.136793	13.11–14.83CV	13.60:	4	7
47	21 57 11.2	+22 40 11	EW	0.435	EW	0.422024	9.55– 9.95V	9.90	1	9
48	22 07 53.8	+22 43 59	EW	0.440	EW	0.469433	12.50–13.00V	12.95		1
51	22 01 49.3	+17 59 42	EW	0.456	EW	0.415211	11.77–12.08V	12.0		6
52	21 55 25.4	+19 37 17	EB	0.487	EA	1.285180	9.81–10.5 V	9.9	5	10
53	22 13 03.9	+18 27 04	RR	0.488	RRAB	0.4883871	11.13–12.31V		6	11
54	21 52 02.8	+22 34 29	RR	0.502	RRAB	0.3903814	9.93–10.99V		7	12
56	22 06 00.1	+19 35 50	EB	0.515	EB	0.57983	11.45–12.6 V	11.65		1
57	21 53 21.2	+22 37 11	EA	0.524	SR	43.5	11.5 –11.8 V		1	2
58	22 12 51.8	+17 20 16	RR	0.556	EW	0.960564	12.27–12.64V	12.64		13
60	21 54 29.8	+19 03 52	EW	0.566	EW	0.59057	12.7 –13.3 V	13.2		2
61	21 53 45.3	+18 31 59	EW	0.587	EA	0.9382	11.18–11.33R	11.31		4
62	22 03 28.0	+18 19 23	EW	0.596	EB	0.475533	11.24–11.41V	11.33		2
63	22 04 51.5	+14 46 19	EW	0.603	EB	0.659481	12.68–13.25V	13.0		5
64	22 17 40.0	+17 10 17	EW	0.647	EB	0.677572	12.77–13.15R	13.04		4
69	21 50 08.2	+19 25 26	DSCT?	1.041	ELL+ DSCTC	1.4708	7.40– 7.49B		8	14
71	21 53 12.0	+22 23 38	EA	1.187	EA	1.62394	12.50–13.0 R	12.60	1	4
72	22 03 11.0	+22 32 07	E?	1.212	EB:	0.714821	11.96–12.45V	12.10		1
73	21 52 43.7	+21 44 53	E?	1.741	EA:	3.05174:	8.54– 8.62V	8.57	2	2

Remarks. 1. SuperWASP data are available and agree with the tabulated results. 2. Sp F2. 3. CY Peg. 4. $D = 0.09P$. 5. Sp A2. 6. VV Peg. Sp A9–F4. 7. AV Peg. Sp A7–F6. 8. NSV 25772. The orbital period is tabulated; δ Scuti periods: $0^{\mathrm{d}}.06479$ and $0^{\mathrm{d}}.06337$. Sp A8+F7V:.

References. 1. ASAS catalog (Pojmanski et al. 2005). 2. This paper, ASAS-3 data. 3. Wils et al. (2011). 4. This paper, ROTSE-I/NSVS data. 5. S. Otero (VSX), ASAS-3 data. 6. Otero et al. (2006). 7. This paper, Catalina data. 8. Diethelm (2010). 9. Diethelm (2011). 10. Szczygieł et al. (2008). 11. Samus et al. (2012). 12. Szczygieł et al. (2009). 13. Otero (2008). 14. Henry et al. (2004).

3 Conclusions

It appears from the Table that we suggested types for all stars given in Kane et al. (2005) without a type. Types were found different, often absolutely different (for example,

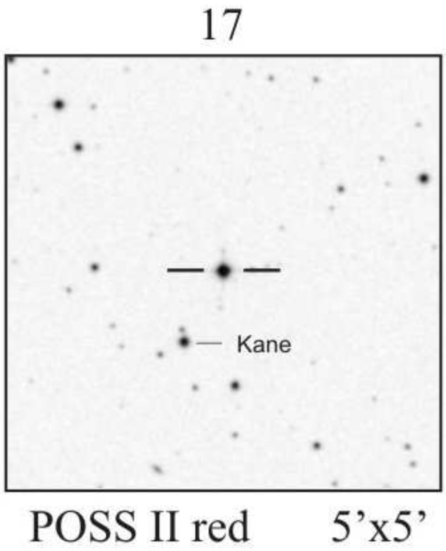

Figure 1. The finding chart for the variable star No. 17.

pulsating variables instead of eclipsing stars or *vice versa*), for a large fraction of the stars. More than half of all stars in the Table have unacceptably wrong periods in Kane et al. (2005). The data now tabulated permits us to include the stars into the NL80 with sufficiently reliable information.

In the era of data-intensive astronomy, it is important that researchers present data on their new variable-star discoveries satisfying, as completely as possible, needs of future variable-star catalogs. In particular, it is important to present sufficiently accurate coordinates. Surely, star numbers from known positional catalogs permit to find the coordinates but, if not accompanied with coordinates, make the task of catalog compilers more difficult. Researchers working with small telescopes and large pixel sizes should remember that, with the exception of cases of still undetected serious mistakes, the GCVS electronic catalog currently presents coordinates accurate to approximately one second of arc. We do not want to deteriorate this level of positional accuracy, achieved by large effort of GCVS compilers. Thus, stars with poorly determined coordinates will remain outside the GCVS for a long time period.

It is preferable to arrange photometric observations of new variable stars so that the time distribution of the observations would permit to avoid spurious period determinations. We are currently preparing a complete GCVS-format version of the NL80, like that we prepared for the 79th Name-List (Kazarovets et al. 2009). Knowledge of correct periods greatly contributes to such work.

Finally, it is important to provide access to raw data, in order to make it possible to verify the results (or re-reduce them) using the same information that was used by the authors.

Meeting these requirements will strongly facilitate the transition to more automatic methods of variable-star-catalog compilation.

Acknowledgments: We have used data from the WASP public archive in this research. This study made use of the ASAS and ROTSE-I/NSVS data bases, USNO Image and Catalog Archive, and Aladin Sky Atlas. Thanks are due to Dr. S.V. Antipin for his assistance. We gratefully acknowledge financial support from the program "Origin and

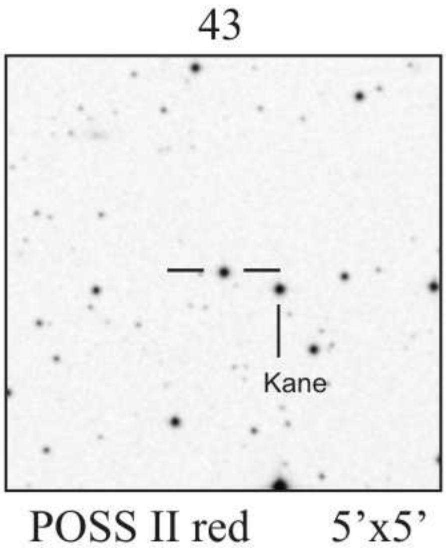

Figure 2. The finding chart for the variable star No. 43.

Evolution of Stars and Galaxies" of the Presidium of Russian Academy of Sciences.

References:

Butters, O. W., West, R. G., Anderson, D. R., et al., 2010, *Astron. & Astrophys.*, **520**, L10

Diethelm, R., 2010, *Inform. Bull. Var. Stars*, No. 5920

Diethelm, R., 2011, *Inform. Bull. Var. Stars*, No. 5960

Henry, G. W., Fekel, F. C., Henry, S. M., 2004, *Astron. J.*, **127**, 1720

Kane, S. R., Lister, T. A., Collier Cameron, A., et al., 2005, *Monthly Notices Roy. Astron. Soc.*, **362**, 117

Kazarovets, E. V., Samus, N. N., Durlevich, O. V., et al., 2009, *Astronomy Reports*, **53**, 1013

Kazarovets, E. V., Samus, N. N., Durlevich, O. V., et al., 2011a, *Inform. Bull. Var. Stars*, No. 5969

Kazarovets, E. V., Samus, N. N., Durlevich, O. V., et al., 2011b, *Inform. Bull. Var. Stars*, No. 6006

Otero, S. A., 2008, *Open Europ. J. Var. Stars*, No. 91

Otero, S. A., Hoogeveen, G.J., Wils, P., 2006, *Inform. Bull. Var. Stars*, No. 5674

Pojmanski, G., 2002, *Acta Astron.*, **52**, 397

Pojmanski, G., Pilecki, B., Szczygiel, D., 2005, *Acta Astron.*, **55**, 275

Samus, N. N., Durlevich, O. V., Kazarovets, E. V., et al., 2012, *General Catalogue of Variable Stars*, Version 2012 March

Samus, N. N., Durlevich, O. V., Zharova, A. V., et al., 2006, *Astronomy Letters*, **32**, 263

Szczygieł, D. M., Socrates, A., Paczyński, B., et al., 2008, *Acta Astron.*, **58**, 405

Szczygieł, D. M., Pojmański, G., Pilecki, B., 2009, *Acta Astron.*, **59**, 137

Wils, P., Hambsch, F.-J., Robertson, C. W., et al., 2011, *Inform. Bull. Var. Stars*, No. 5977

Woźniak, P. R., Vestrand, W. T., Akerlof, C. W., et al., 2004, *Astron. J.*, **127**, 2436

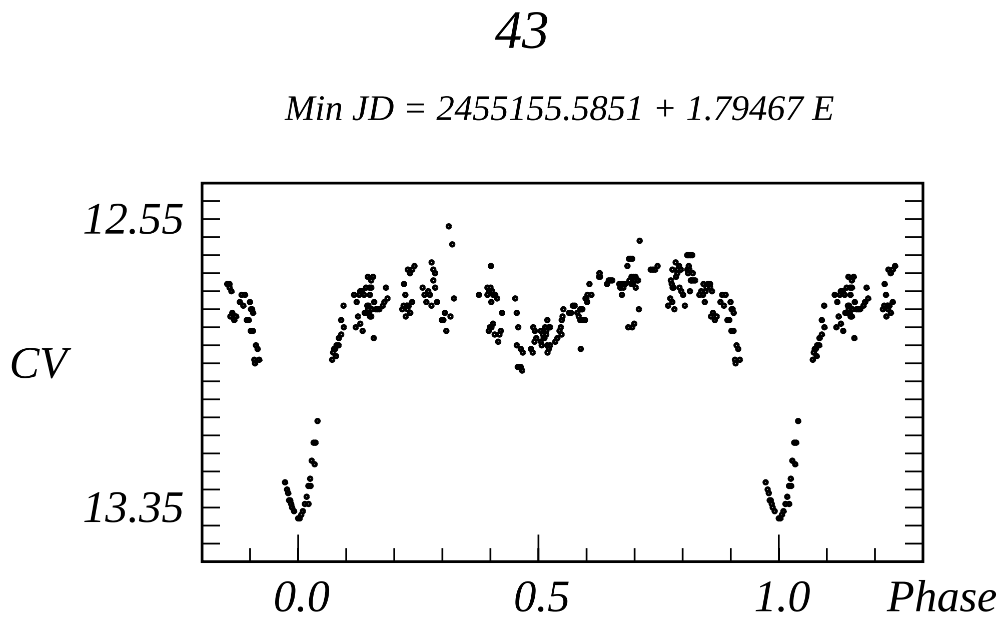

Figure 3. The light curve of the variable star No. 43 based on Catalina data.

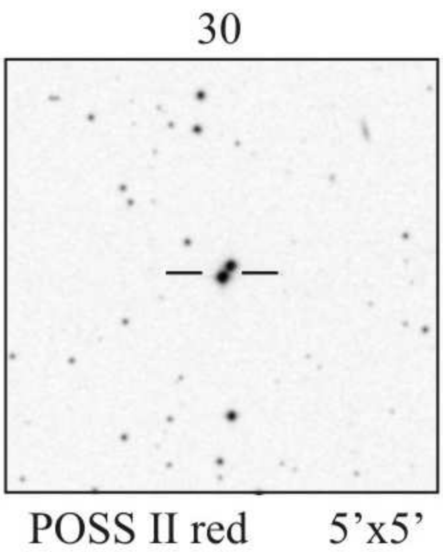

Figure 4. The finding chart for the variable star No. 30.

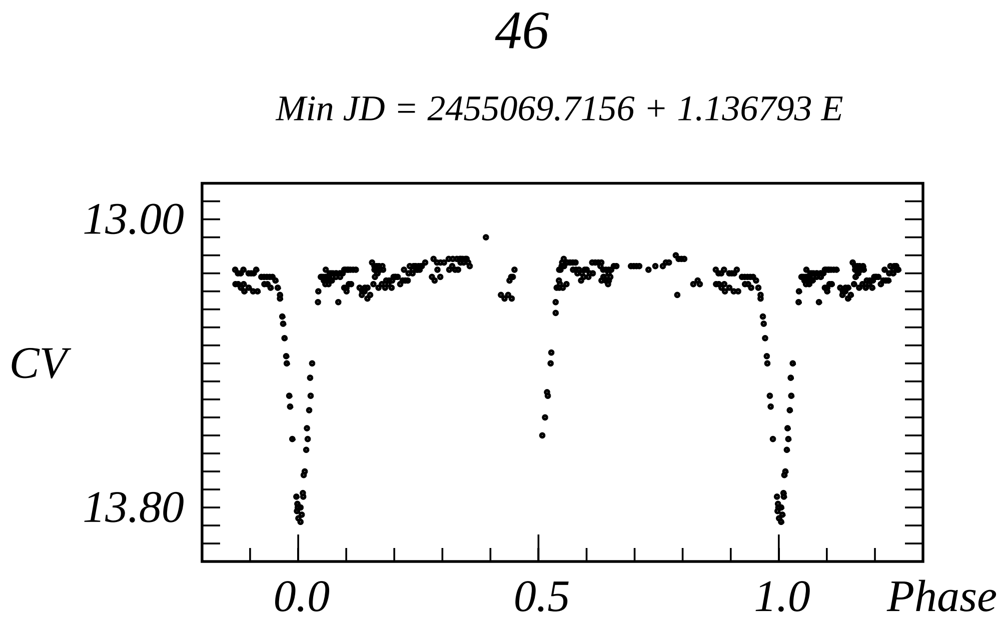

Figure 5. The light curve of the variable star No. 46 based on Catalina data.