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SEARCH FOR VARIABLE STARS AND THEIR STUDY

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ABSTRACT. We search for variable stars and study them using our CCD observations, observations available in the CSS, NSVS, ASAS-3 and Super-WASP online public archives.

Our CCD observations were performed using the Zeiss-1000 telescope of the V.G. Fesenkov Astrophysical Institute's Tien-Shan Astronomical Observatory. Earlier, as a result of our search using CCD images, we detected 27 new variable stars; using the NSVS and SuperWASP databases, we detected 12 new red semiregular and irregular variable stars.

In this paper, we present our study of seven known variables based on the ASAS-3 and SuperWASP databases. All these stars remained poorly studied, their light elements were unknown, variability types were considered preliminary only. We studied two eclipsing variables (FY And and V2250 Sgr) and five Mira-stars (BZ Sco, CZ Sco, FK Sco, V880 Sco and V1818 Sgr).

Keywords: stars: variables: eclipsing binary, Mira-stars – stars: individual: FY And, V2250 Sgr, BZ Sco, CZ Sco, FK Sco, V880 Sco, V1818 Sgr

1. Introduction

We search for variable stars and study them using our CCD observations, observations available in the Catalina Surveys (Drake et al. 2009), Northern Sky Variability Survey (NSVS ,Woźniak et al. 2004), the All Sky Automated Survey (ASAS-3, Pojmanski 2002) and SuperWASP (Butters et al. 2010) online public archives.

Our CCD observations were performed using the Zeiss-1000 telescope of the V.G. Fesenkov Astrophysical Institute's Tien-Shan Astronomical Observatory (altitude 2759 meters above the sea level). The telescope has a 1000-mm mirror and the focal length of 6650 mm. The Apogee U9000 D9 CCD camera was used. The CCD observations were carried out in Johnson's *BVR* photometric system. We mainly observed moderate-density areas of the Milky Way. The images were subjected to photometric processing using MaxIm DL5 specialized software and to further interpretation of the data. The limiting magnitude of our search is about 20^m *V*; it is possible to separate star pairs with inter-component distances as small as 1–2 seconds of arc.

Using online archives, we not only search for new variables but also use them (especially the NSVS archive) to study known variable stars. The databases contain a large volume of information permitting to improve types of variable stars, their light elements, follow the behavior of variables during time intervals of long duration.

2. Search for new variables

As a result of our search using CCD images, we detected 27 new variable stars (Kusakin et al. 2013, Kusakin et al. 2014, Kusakin et al. 2015a, Kokumbaeva et al. 2016); among them there are 13 eclipsing variables (EW, EB types; classification according to the General Catalogue of Variable Stars, GCVS, Samus et al. 2007-2016), 5 red semiregular and irregular variables (M, SR, LB types), 5 δ Scuti variables, two RR Lyrae stars, 1 BY Draconis star and 1 ellipsoidal variable (ELL type). Some of them were earlier suspected from survey data. For several variables, the light elements were later improved (Khruslov & Kusakin 2014ab).

Using the NSVS and SuperWASP databases, we detected 12 new red semiregular and irregular variable stars (LB and SR types; Kusakin et al. 2015b).

3. Study of known variables

In this paper, we present our study of seven known variables based on the ASAS-3 and SuperWASP databases. All these stars remained poorly studied, their light elements were unknown, variability types were considered preliminary only. We studied two eclipsing variables and five Mira-stars.

3.1. FY And

The variability of FY And = S 10112 (RA = 23^h 23^m $28^s.65$; Dec = +50° 15' 57".9, J2000) was discovered by Hoffmeister (1967). The variable was classified as an Algol-type variable star without light elements, range 15^m – $16^m.5$. The discoverer used 64 photographic plates to detect 2 times of minima and 1 small fading. Later, Busch

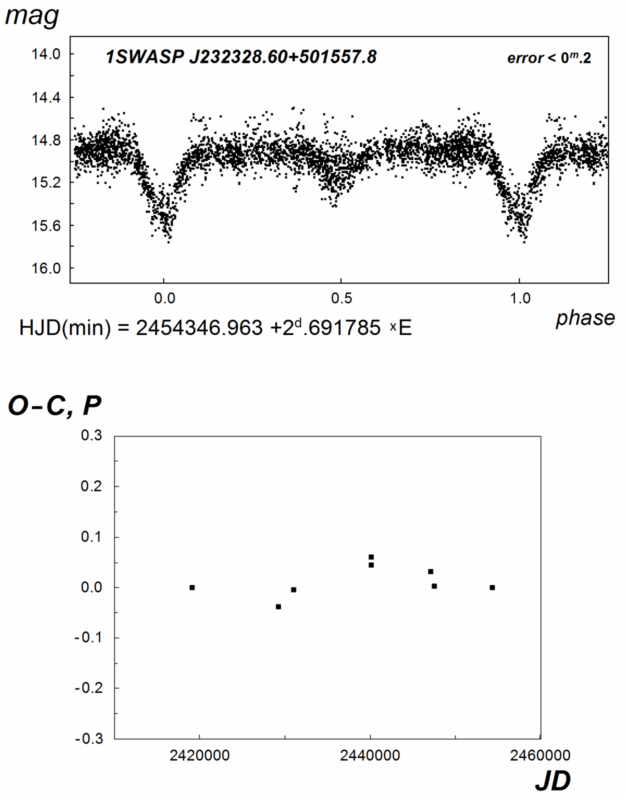

Figure 1: Light curve and O-C diagram for FY And.

& Häußler (1990) classified the variable as a possible eclipsing star, gave 5 moments of minima or fadings (the first of them coinciding with the latest by Hoffmeister) and a possible period P = 2.7 days. The photographic magnitude range is $15^{m}.55 – 16^{m}.40$. In the GCVS (Samus et al. 2007-2016), the variable was classified as an Algol-type variable with the magnitude range $15^{m}.6 – 16^{m}.4$; the variability period is not specified and the epoch of light minimum is given (the same as the latest one by Busch & Häußler).

We studied FY And using SuperWASPdata and all times of minima. We confirm the eclipsing nature of this variable (EA type). The light elements are:

$$\text{HJD (minI)} = 2454346.963 + 2^{d}.691785 \times E.$$

From the 1SWASP data, the magnitude range is $14^{m}.9 – 15^{m}.5$, MinII = $15^{m}.1$; the duration of the primary eclipse is D = 0.16 P.

The SuperWASP observations, available as FITS tables, were converted into ASCII tables using the OMC2ASCII program as described by Sokolovsky (2007). From the SuperWASP data, we removed observations with errors exceeding $0^{m}.20$.

Additionally, we present the O-C diagram and the table of the all known eclipsing minima.

Table 1. Times of minima for FY And.

JD	O-C	Publication
2419111.50	0.000	Hoffmeister (1967)
2429251.35	-0.038	Hoffmeister (1967)
2430998.410	-0.004	Hoffmeister (1967), Busch&Häußler (1990)
2440150.610	+0.045	Busch&Häußler (1990)
2440153.345	+0.061	Busch&Häußler (1990)
2447087.304	+0.032	Busch&Häußler (1990)
2447469.461	+0.003	Busch&Häußler (1990)
2454346.963	0.000	1SWASP data, this paper

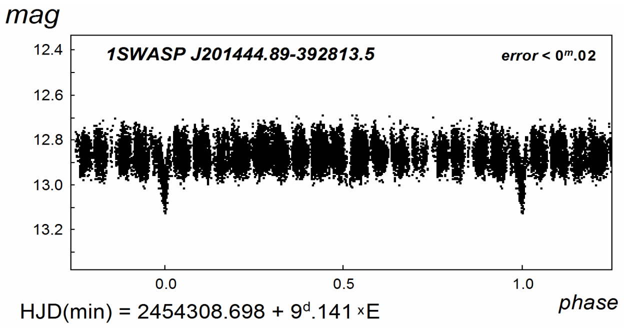

Figure 2: Light curve for V2250 Sgr.

3.2. V2250 Sgr

The variability of V2250 Sgr = S 7327 (RA = 20^{h} 14^{m} $44^{s}.90$; Dec = -39° 28' 13".9, J2000) was discovered by Hoffmeister (1963). Following this publication, the variable was classified in the GCVS as an Algol-type variable star without light elements, magnitude range $13^{m}.0 – 13^{m}.5$ (pg). We confirm the eclipsing nature of this variable according to data from SuperWASP. The light elements are:

$$\text{HJD (min)} = 2454308.698 + 9^{d}.141 \times E.$$

From the 1SWASP data, the magnitude range is $12^{m}.85 – 13^{m}.05$; the duration of the eclipse is D = 0.025 P. We removed observations with errors exceeding $0^{m}.02$.

3.3. Five southern Mira variables

We studied 5 red long-period variables, type M according to the GCVS, using ASAS-3 data. The results are presented in Table 2. In comments, we present the history of studies of these stars.

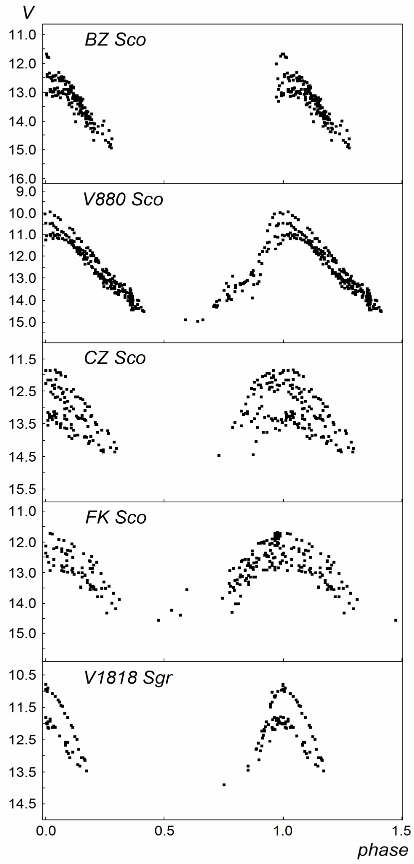

Figure 3: Light curves for five Mira stars.

Table 2. Light elements of the 5 southern Mira stars

No.	Variable	Coordinates (2000)	Type	V mag.	Period, days	Epoch, JD
1	BZ Sco	$16^h 30^m 11^s.29$ -36° 15' 06".7	M	$11^m.7$ – $<15^m.0$	369	2453769
2	V880 Sco	16 41 14.44 -34 07 32.8	M	10.0 – 15.0	389	2454528
3	CZ Sco	16 46 17.89 -31 02 06.8	M	11.9 – <14.4	216	2454615
4	FK Sco	17 01 54.07 -32 39 18.9	M	11.8 – <14.5	184	2453506
5	V1818 Sgr	18 06 57.91 -32 00 57.0	M	10.8 – <13.9	338	2454683

Comments:

1. The variability of BZ Sco (HV 4023) was discovered by Luyten (1927). The variable was classified as a long-period variable star without light elements, magnitude range $15^m.0$ – $<16^m.0$ (pg). The variable was classified in the GCVS as a possible Mira variable (M: type) without light elements. We confirm the Mira nature of this variable according to data from ASAS-3. The period is 369 days; a twice shorter period (184 days) is not excluded.

2. The variability of V880 Sco (AN 446.1935, HV 8933) was discovered by Luyten (1935); its magnitude range was $11^m.0$ – $15^m.0$ (pg). The variable was classified in the GCVS as a Mira variable (M type) without light elements. Sanduleak et al. (1995) give the spectral type M8e. We confirm the Mira nature of this variable according to data from ASAS-3.

3. The variability of CZ Sco (HV 4207) was discovered by Swope (1928). Following Swope (1928), the variable was not classified in the GCVS, with only the magnitude range ($14^m.8$ – $16^m.4$ pg) given. Actually, it is a Mira variable star according to ASAS-3 data.

4. The variability of FK Sco (HV 4327) was discovered by Swope (1928). Following Swope (1928), the variable was not classified in the GCVS, with only the magnitude range given ($14^m.4$ – $< 16^m.5$ pg). Actually, it is a Mira variable star according to ASAS-3 data.

5. The variability of V1818 Sgr (AN 591.1933, HV 9242) was discovered by Luyten (1933), who gave the magnitude range $14^m.8$ – $16^m.1$ (pg). Plaut (1958) classified the variable as a possible Mira variable, with the time of maximum JD 2427860. It was not possible to derive the period. The magnitude in maximum is $13^m.10$, with the detected full amplitude > $1^m.85$ (pg). The variable was classified in the GCVS as a possible Mira variable (M: type); the period is not specified, and the magnitude range is presented as $13^m.4$ – $16^m.1$ (pg). We confirm the Mira nature of this variable according to data from ASAS-3.

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