The Astronomical Reports, vol.IX (2019), 33-44

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The discovery of eleven nova-like VY *Scl* type stars

Abstract

I present the discovery of eleven previously unknown NL/VY type variables found via data-mining method around hot sub-luminous blue stars. The survey is meant to increase the number of nova-like targets showing deep fadings for further investigation via photometric and spectroscopic follow-up observations.

Introduction

The progenitor of nova-like variables (NL) with deep fadings is VY *Sculptoris* (Burrell et al. 1973). Variable Star Index (VSX) currently lists 102 of NL/VY stars and 32 candidates. Nova-like variables can be found around hot sub-luminous blue stars. Photometric and astrometric observations by Gaia revealed about 39 thousands of such stars brighter than V=19 magnitude, as presented in the recent catalog (Geier et al. 2019). New variable stars can be found via data mining method, by checking the most promising targets. With archival data, it is possible to find many previously unknown variables that have been missed by automatic processes. Current algorithms work best on periodic changes of brightness, but are often inaccurate on irregular and occasional phenomena, which are skipped. In the next section I describe the method used to find new variables. In subsequent section I describe each NL/VY variable that has been found.

Searching method

I used ASAS-SN Sky Patrol (Shappee et al. 2014 and Kochanek et al. 2017) and CRTS (Drake et al. 2009) survey data to retrieve photometric observations of targets presented in the catalog of sub-luminous stars (Geier et al. 2019). Only targets with magnitude errors higher than 0.005 magnitude in Gaia G band were checked, as it's an indication of possible high amplitude variability. There have been 938 stars to be analysed. ASAS-SN is an all-sky survey and light curves only of objects G<17 mag were manually requested through ASAS-SN Sky

Patrol. CRTS has photometric data unavailable for low galactic latitude regions, and in result, not every target could be checked. NL/VY stars show high amplitude variability, thus archive POSS-II plates were also used for the analysis (Lasker et al. 1996). After having all the data downloaded, with visual inspection I marked thirteen stars as possible NL/VY type objects. It is possible that many other found nova-like stars show fading phenomena, but no such events happened in available ASAS-SN and CRTS timespan. After rejection of other variable types and known stars already listed in the Variable Star Index database, the survey revealed nine new NL/VY stars and two with uncertain classification. Two other candidates have too low amplitudes to apply such classification (nova-like stars without deep dimmings of amplitude above 1 mag in V-band or CV-band), so they are not included in the paper. All these variable stars have been published to the VSX database with main identification names starting from MGAB-V195 to MGAB-V197 (in January 2019) and MGAB-V201 to MGAB-V208 (in August 2019).

If photometric data is available from both surveys, CV measurements by CRTS are shifted to V-band values from ASAS-SN data by difference of average values during maxima. In addition, I used ASAS-SN g-band photometry data only in case when it's necessary to present VY Scl-like fading that was observed through this filter. Some stars however, especially in Milky Way region, might be blended with several faint stars in the background. Deblending was not applied in any case, as CRTS and ASAS-SN magnitudes are not contaminated by any bright objects inside their photometric aperture. Names, positions, magnitudes and color indexes are presented in Tab. 1. It also shows J-K values from 2MASS (Cutri et al. 2003), B-V from APASS (Henden et al. 2015) and BP-G from Gaia DR2 release (Gaia Collaboration, Brown et al. 2018). If NL/VY classification of a specified target is uncertain, it is explained in the next section.

Tab. 1. Literature and variability ranges of nova-like VY Scl stars presented in this paper. Indexes marked as bold are uncertain.

Target name from literature	MGAB name	Gaia DR2 position	Magnitude range	Uncertain classification	J-K (2MASS)	B-V (APASS)	BP-G (Gaia DR2)
GSC 07196-00489	MGAB-V195	10 22 05.25 −35 37 56.0	13.8 (V) – <18.8 (CV)	No	0.23	0.03	0.00
CD-35 9665	MGAB-V196	14 37 39.71 −36 13 25.8	12.3 (V) – 18.5 (CV)	No	0.09	0.02	−0.05
GSC 06742-00051	MGAB-V197	14 13 50.22 −29 53 23.1	14.3 (V) – 17.5: (V)	No	0.41	0.07	−0.02
2MASS J06275107-5345181	MGAB-V201	06 27 51.08 −53 45 17.7	16.7 (CV) – 18.8 (CV)	Yes	**0.80**	0.02	−0.05

Target name from literature	MGAB name	Gaia DR2 position	Magnitude range	Uncertain classification	J-K (2MASS)	B-V (APASS)	BP-G (Gaia DR2)
GSC 07668-01706	MGAB-V202	08 18 08.73 −42 34 16.8	13.9 (V) – 17.2 (R)	Yes	0.34	0.07	0.00
2MASS J06141482-2504359	MGAB-V203	06 14 14.83 −25 04 36.2	16.3 (V) – 19.5 (V)	No	**−0.05**	0.18	0.03
2MASS J21490305+3459055	MGAB-V204	21 49 03.08 +34 59 05.7	15.8 (V) – <17.6 (g)	No	0.48	**0.28**	0.05
2MASS J17301973+1202522	MGAB-V205	17 30 19.74 +12 02 52.3	15.4 (V) – 18.5 (V)	No	0.33	**0.21**	−0.13
2MASS J16272354-6233286	MGAB-V206	16 27 23.55 −62 33 28.7	14.4 (V) – 19.4 (B)	No	0.22	N/A	0.03
2MASS J03582954-5446411	MGAB-V207	03 58 29.55 −54 46 41.2	15.8 (V) – 18.0 (CV)	No	**0.97**	−0.09	−0.04
2MASS J15060334-7355303	MGAB-V208	15 06 03.36 −73 55 30.4	15.3 (V) – 16.9 (V)	No	0.21	N/A	0.05

Photometric results

GSC 07196-00489 = MGAB-V195

The first identified new nova-like VY Scl variable, located in Antlia constellation. Three fadings have been observed – a single one by ASAS-SN and two by CRTS (Fig. 1). Based on POSS-II survey in 1993–1995, the star looks faded on red plate compared to blue one, suggesting a fourth event. The largest decrease of brightness was observed by CRTS, based on four measurements at the same night. The target could be fainter, which makes the magnitude range uncertain.

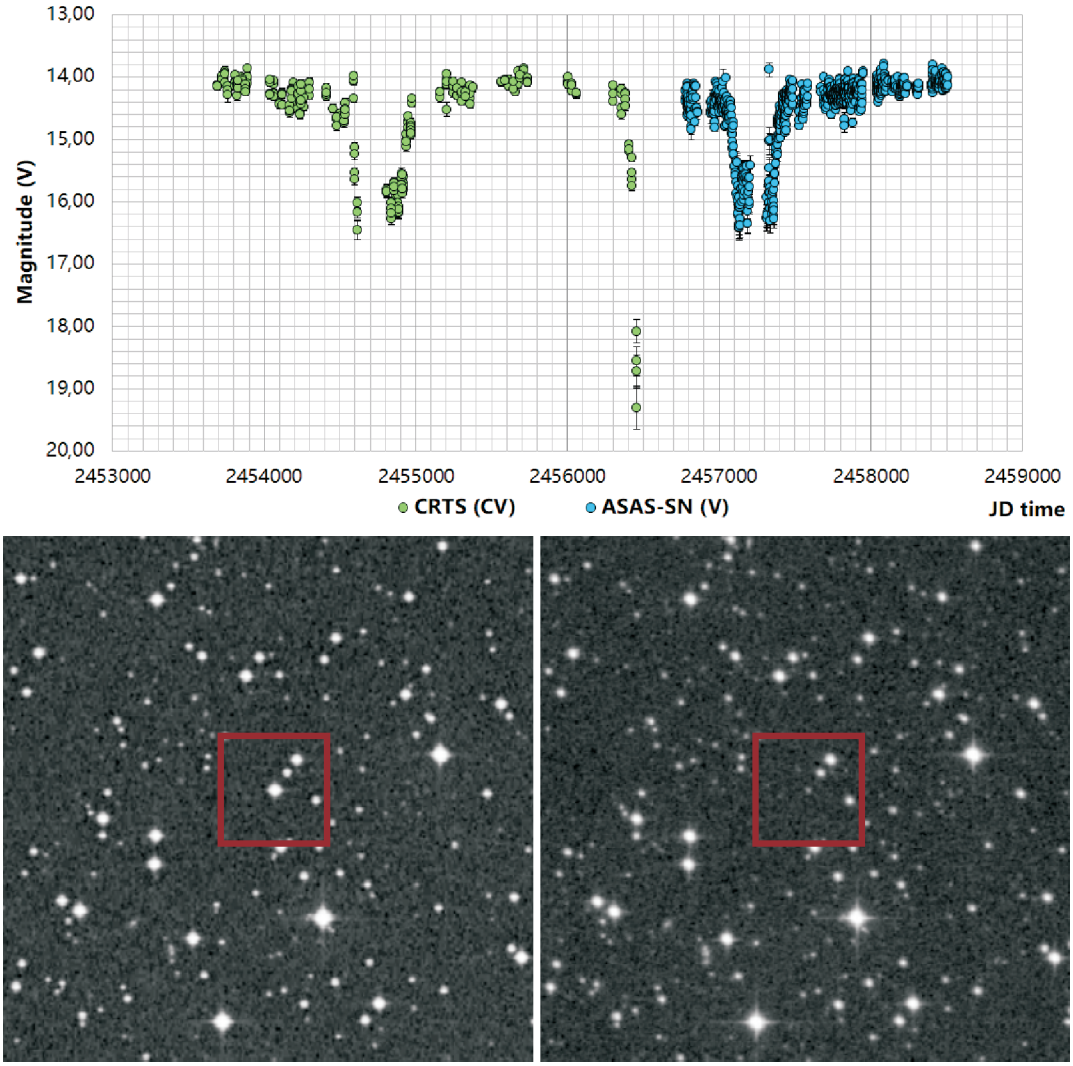

Fig. 1. Light curve with CRTS and ASAS-SN data. Three VY *Scl*-like fadings observed at JD=2454700, 2456450 and 2457250. Archive POSS-II plates showing high variability of GSC 07196-00489 when compared blue (left) and red (right) plates.

CD-35 9665 = MGAB-V196

The brightest target out of all six NL/VY variables, also with the largest amplitude of Δ=6.2 magnitude in CV. Only one dimming event was observed so far, in the beginning of CRTS timespan (Fig. 2). For the next 13 years, MGAB-V196 kept varying with amplitude up to 0.4 mag. Target has been spectroscopically identified as an OB+ star (Drilling et al. 1995) and ROSAT X-ray source (Voges et al. 2000).

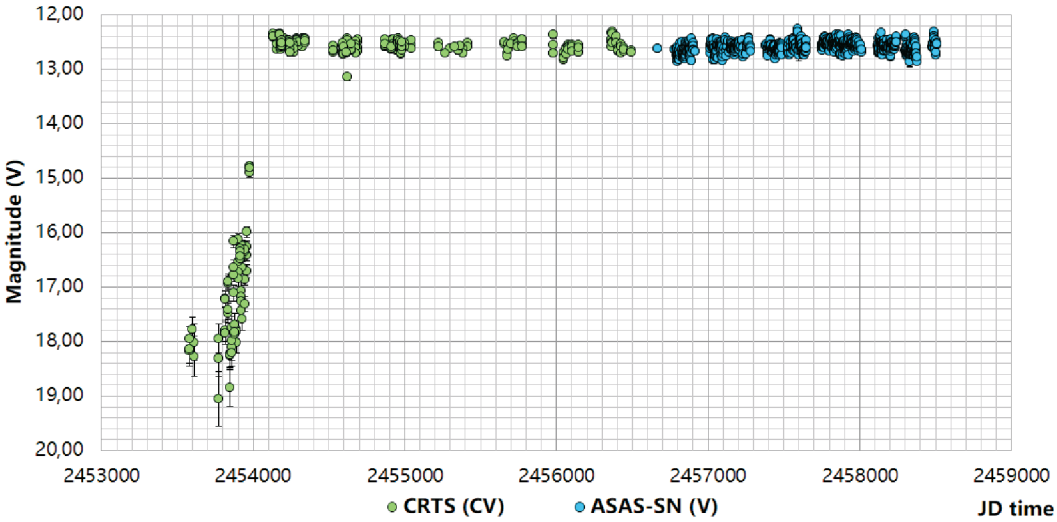

Fig. 2. JD plot with CRTS and ASAS-SN data. Single VY *Scl*-like fading observed at JD=2453700.

GSC 06742-00051 = MGAB-V197

Target identified as NL/VY type variable in Milky Way region, thus only ASAS-SN data is available. A single U-shaped fading was seen through both V and g filters (Fig. 3).

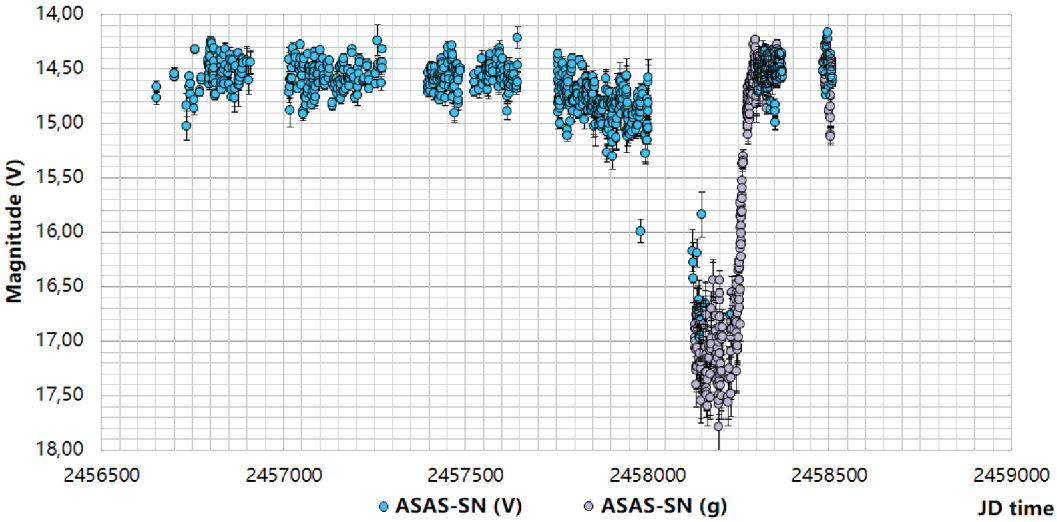

Fig. 3. JD plot with CRTS and ASAS-SN data. Single VY *Scl*-like fading observed at JD=2453700.

2MASS J06275107-5345181 = MGAB-V201

Target is too faint for ASAS-SN, but several fading phenomena were observed by CRTS with depth up to 1.5 magnitude in CV (Fig. 4). I used *Period04* software (Lenz and Berger 2005) to check if these have an eclipsing binary origin. Periodogram output shows no clear peak, however the most significant one (at 0.373095d) gives a hint of data points concentrating

nearly at the same phase (Fig. 5). The value is much above 3–4 hours orbital period seen around NL/VY stars (Warner 1999) and ETV-like behaviour is too large to suggest an eclipsing body, thus dimmings are related to VY *Scl* variability. The target is close to *Canopus*, separated by 73 arcminutes.

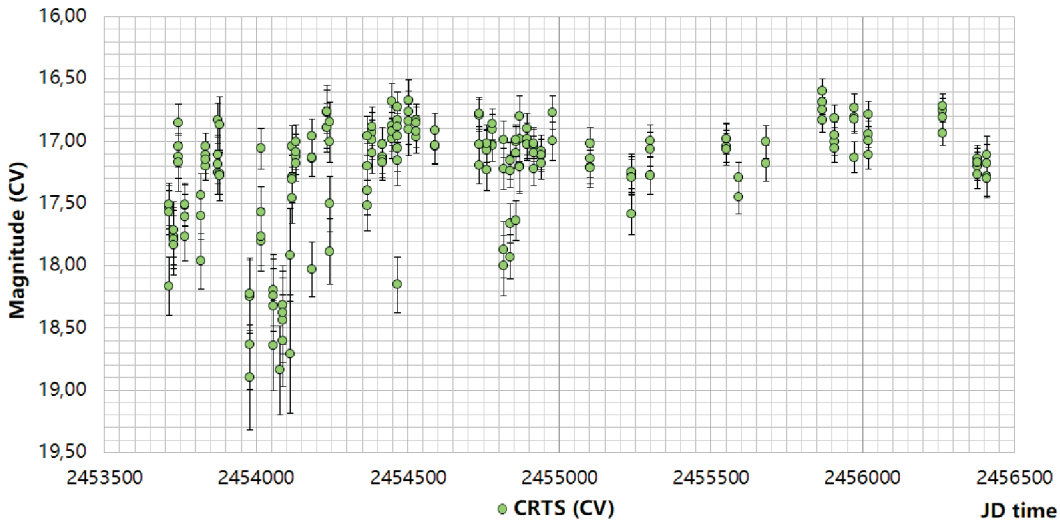

Fig. 4. JD plot with CRTS data. Possible VY *Scl*-like fading observed at JD=2454000.

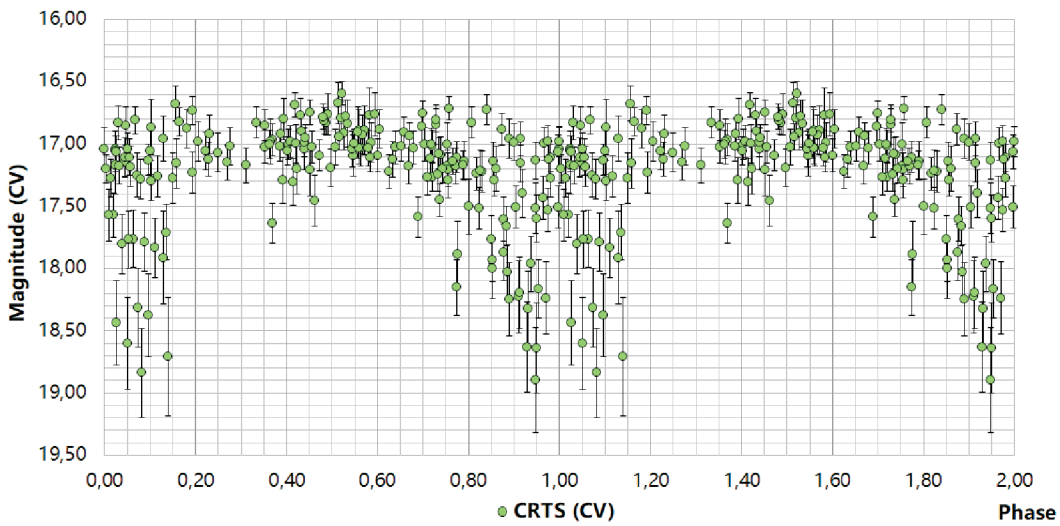

Fig. 5. Phase plot with CRTS data for potential 0.373095d period.

GSC 07668-01706 = MGAB-V202

Target with only ASAS-SN data available. No fadings have been observed, but high variability is seen (Fig. 6), similar to MGAB-V195 or MGAB-V196 during maximum. Archive

POSS-II images show a clear magnitude drop on red plate compared to blue one, indicating possible VY *Scl*-like variability. Minimum magnitude in Tab. 1 given from the USNO-A2.0 catalog (Monet 1998).

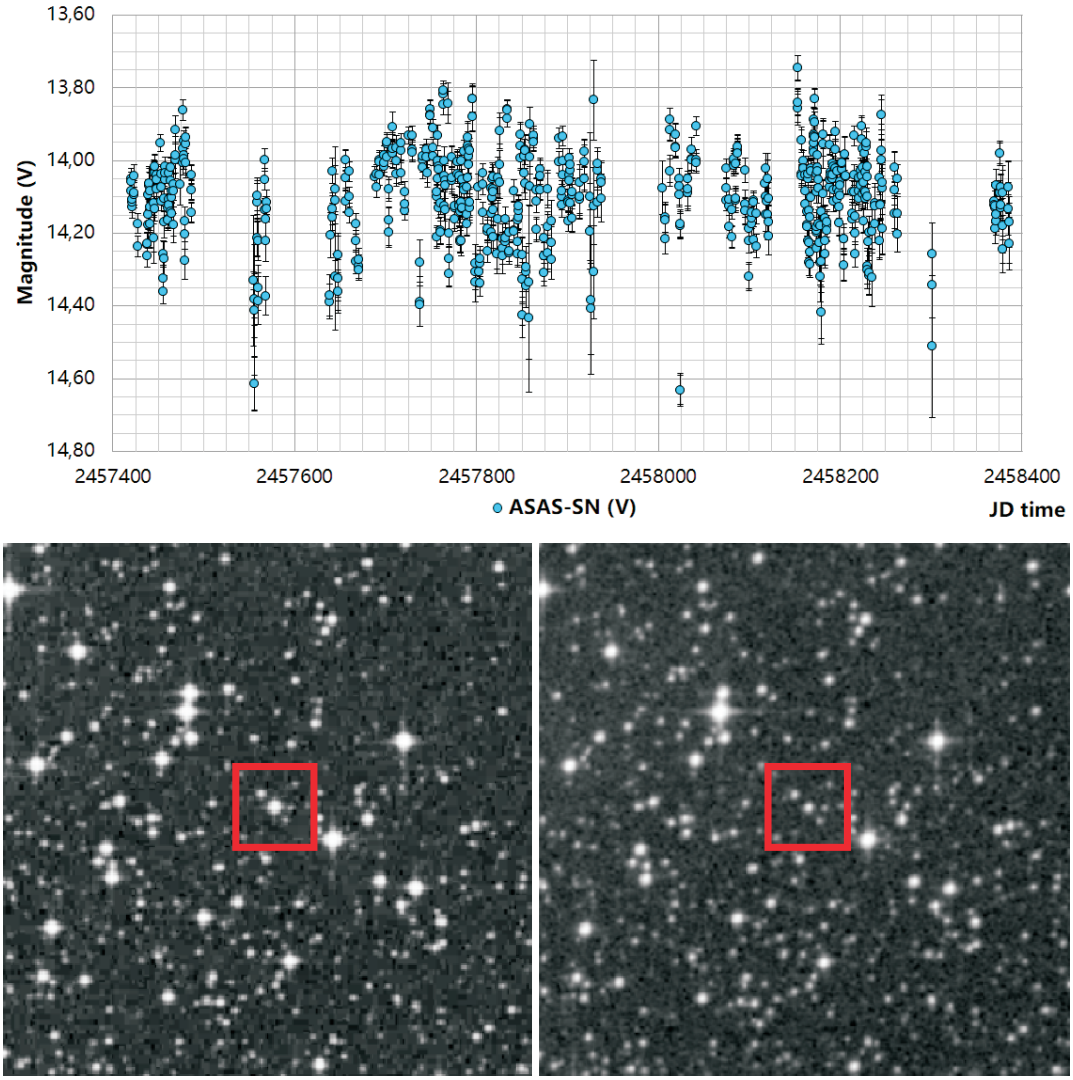

Fig. 6. Light curve with ASAS-SN data in V band. Nova-like variability is seen without any deep fadings. Archive POSS-II plates showing high variability (left: blue, right: red).

2MASS J06141482-2504359 = MGAB-V203

This object shows highly repetitive fading events lasting for days (based on ASAS-SN in 2018) and months (CRTS data), as seen in Fig. 7. Such cases require a period check for an eclipsing binary test. However, in this object, there are no periodic events found.

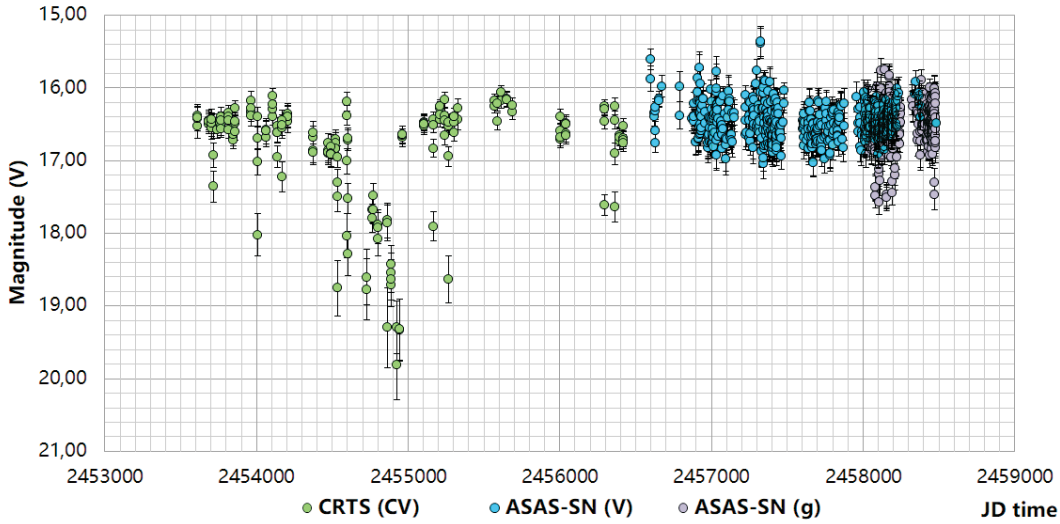

Fig. 7. JD plot with ASAS-SN and CRTS data. High amplitude fading seen around JD=2454800.

2MASS J21490305+3459055 = MGAB-V204

Target remained at maximum brightness until 2018, when a deep fading appeared (Fig. 8). Additionally, 'fainter than' observations were added to the plot, as ASAS-SN did not detect during its minimum. CRTS data are unavailable.

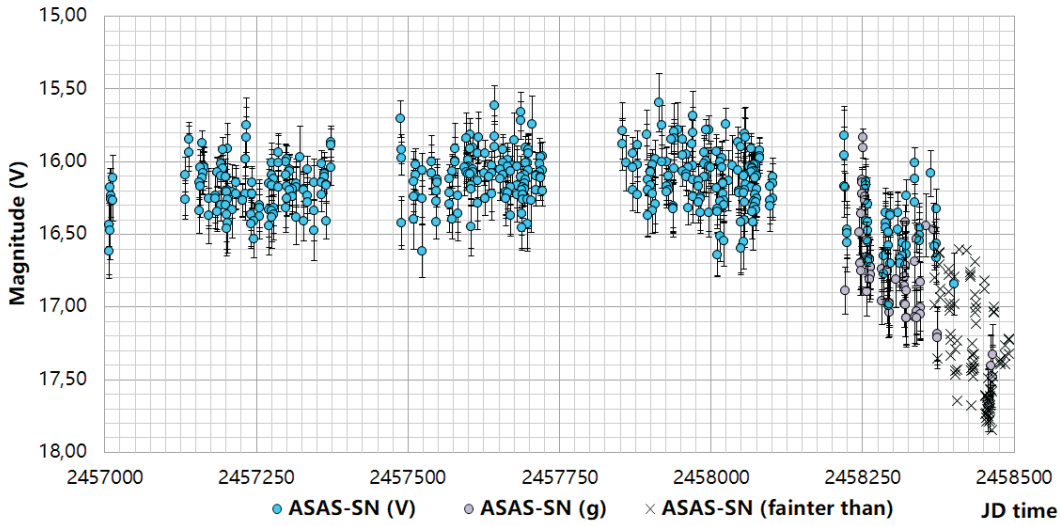

Fig. 8. JD plot with ASAS-SN data. Given 'fainter than' observations in 2018 are for V and g band.

2MASS J17301973+1202522 = MGAB-V205

Rapid fading and rising with amplitude higher than 1 magnitude was observed by ASAS-SN in 2017 and 2018 (Fig. 9). 'Fainter than' measurements from 2017 and 2018 were added to

the plot. During the deep fade, a single series of observations taken at JD=2457495 by CRTS were done, showing a fade down to V=18.5 magnitude. Object identified as ROSAT X-ray source.

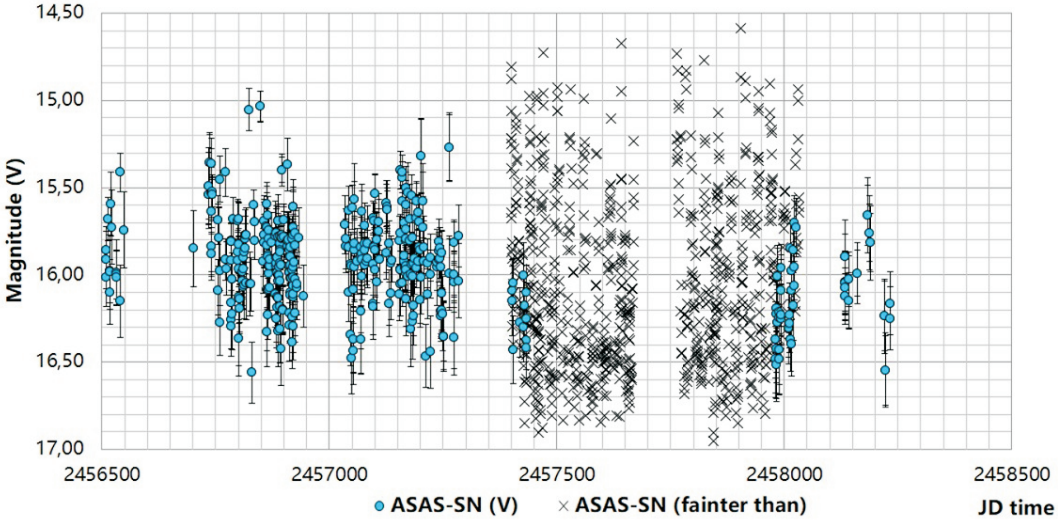

Fig. 9. JD plot with ASAS-SN data. 'Fainter than' observations from 2017 and 2018 have been added.

2MASS J16272354-6233286 = MGAB-V206

First noticed on 23rd of January 2019; independently found by Mariusz Bajer two days later. This object shows a deep fading in the beginning of ASAS-SN data (Fig. 10). Archive POSS-II images also show a deep magnitude drop on blue plate compared to red one, which is a result of VY *Scl*-like variability. During maximum, MGAB-V206 varies with amplitude of 0.8 mag in V band, but occasional little drops may appear, as seen around JD=2457950. Minimum magnitude given from USNO-A2.0 catalog.

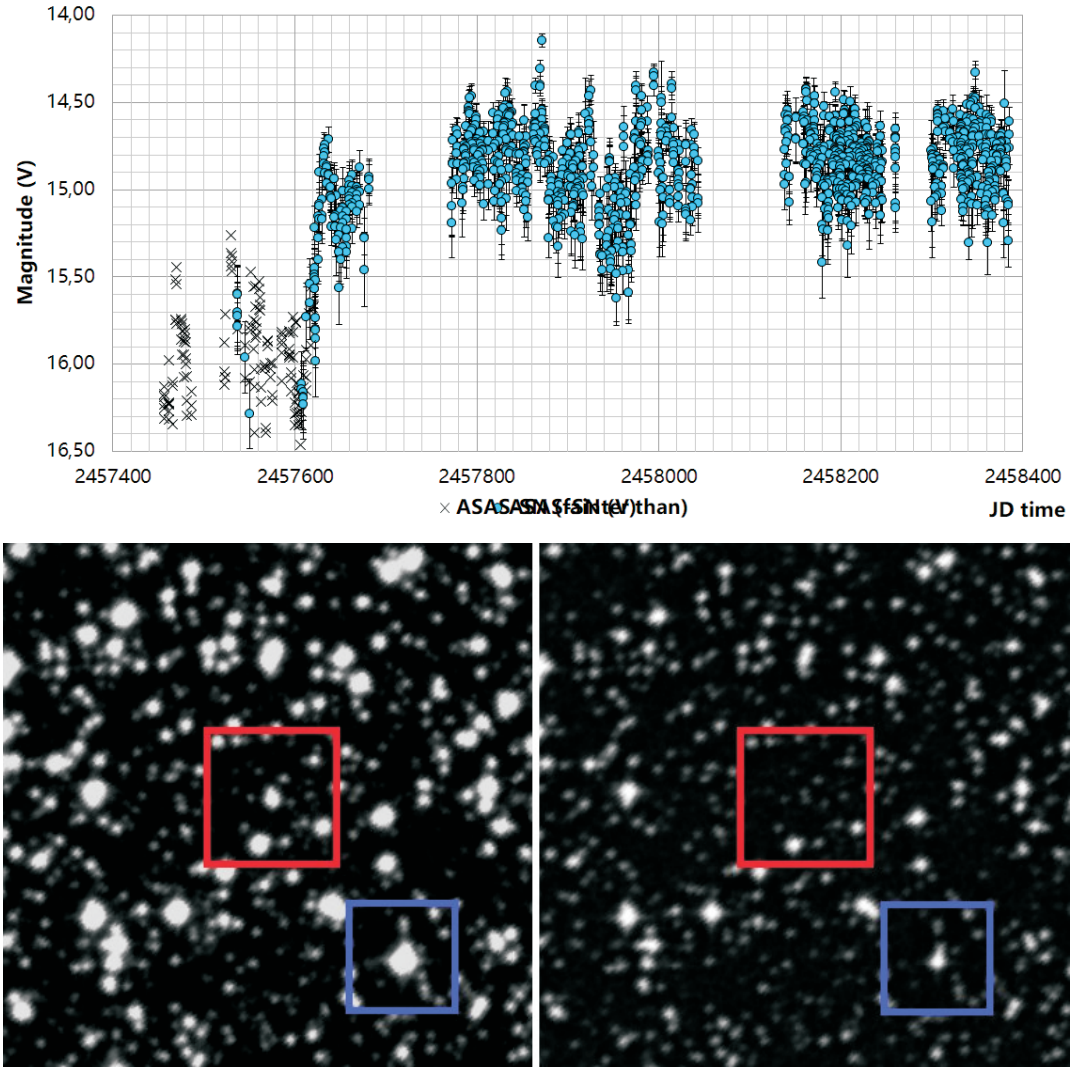

Fig. 10. JD plot with ASAS-SN data. A deep fading with amplitude larger than 1.2 mag (V) was observed in 2016. Archive POSS-II plates showing large variability (left: red, right: blue). Target marked by smaller square is a known long period variable KL *TrA*.

2MASS J03582954-5446411 = MGAB-V207

Short-lasting fade with depth of ~1.5 mag (CV) observed by CRTS. At maximum, object varies with amplitude up to 1 mag (V), as seen in Fig. 11. A dimming event is clearly seen in the plot, with high amplitude variations of NL-type variability. Target is spectroscopically confirmed as sdB type (Kilkenny et al. 2015).

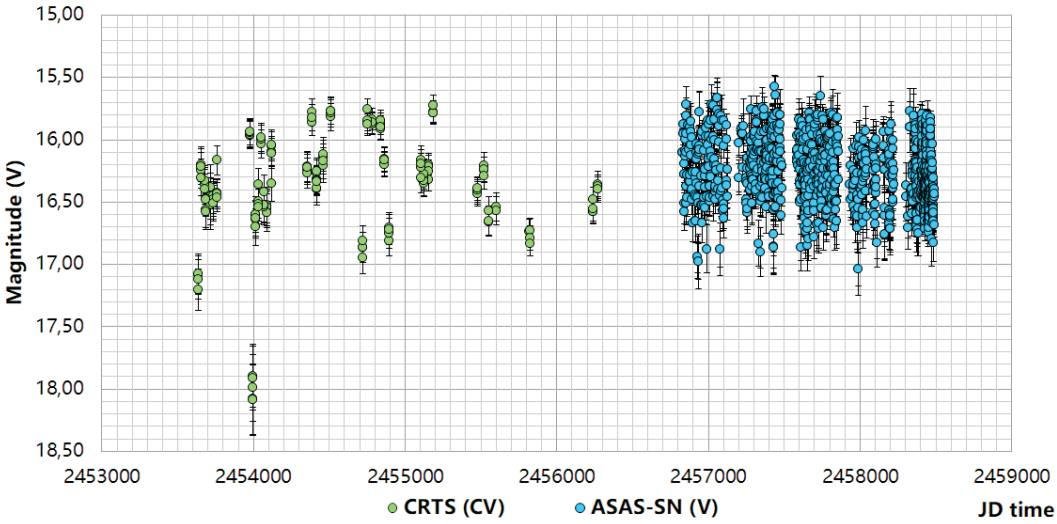

Fig. 11. JD plot with CRTS ASAS-SN data. Target appears to fade near JD=2454000.

2MASS J15060334-7355303 = MGAB-V208

Nova-like variable that undergone a series of fadings in mid-2015. ASAS-SN detected brightness drop with amplitude up to 1 mag in V band (Fig. 12).

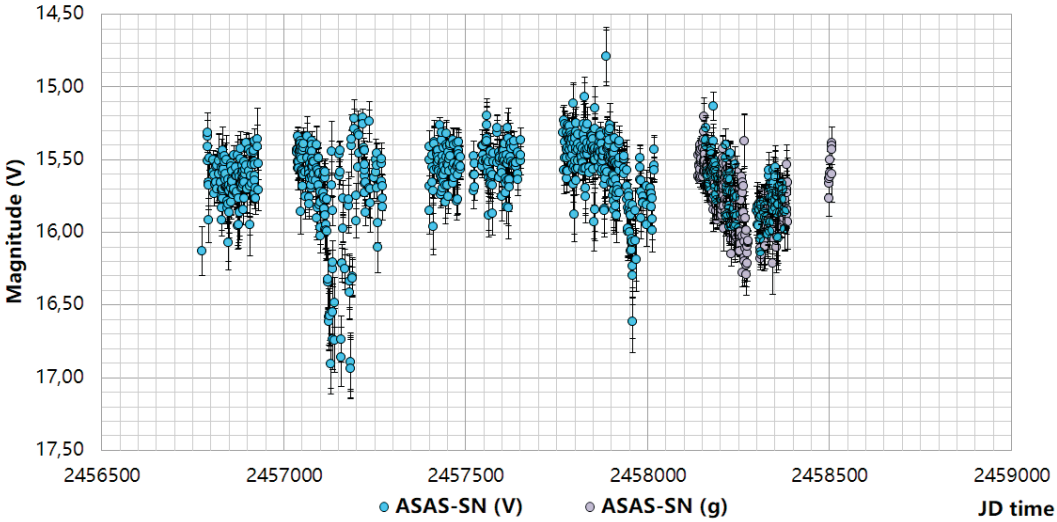

Fig. 12. JD plot with ASAS-SN data. Fadings up to 1 magnitude (V) visible near JD=2457150.

Conclusion

The survey has revealed more than 100 hundred variables, where eleven objects were classified as nova-like VY *Scl* stars based on photometric data. After rejection of known variables from the VSX database, I found that most of new NL/VY stars are located in the southern

hemisphere. This concludes that hot subluminous stars in northern hemisphere had already been well studied and discovered earlier. Many targets in the catalog of hot sub-luminous stars show significant scatter on their light curves, indicating good NL/VY candidates during quiescence, but no dimming events had been observed yet. Follow-up photometric and spectroscopic observations for all presented targets are encouraged to confirm NL/VY nature of MGAB-V201 and MGAB-V202, as well as monitor all objects for more VY *Scl*-like phenomena.

References

Burrell, J.F., Mould, J.R., 1973, Publications of the Astronomical Society of the Pacific, vol. 85, p. 627.

Cutri, R.M. et al., 2003, The IRSA 2MASS All-Sky Point Source Catalog, NASA/IPAC Infrared Science Archive. http://irsa.ipac.caltech.edu/applications/Gator/

Drake, A.J. et al., 2009, The Astrophysical Journal, vol. 696, is. 1, pp. 870-884.

Drilling, J.S., Bergeron, L.E., 1995, Publications of the Astronomical Society of the Pacific, vol. 107, p. 846.

Gaia Collaboration, Brown, A.G.A., et al., 2018, Astronomy & Astrophysics, vol. 616, id. A1, 22 pp.

Geier, S. et al., 2018, Astronomy & Astrophysics, vol. 621, id.A38, 13 pp.

Henden, A.A. et al., 2015, American Astronomical Society, AAS Meeting #225, id.336.16.

Kilkenny, D. et al, 2015, Monthly Notices of the Royal Astronomical Society, vol. 453, is. 2, pp. 1879-1887.

Kochanek, C.S. et al., 2017, Publications of the Astronomical Society of the Pacific, Volume 129, Issue 980, pp. 104502

Lasker, B.M. et al., 1996, Astronomical Data Analysis Software and Systems V, A.S.P. Conference Series, vol. 101, 1996, Jacoby G.H. and Barnes J. eds., p. 88.

Lenz, P., Breger, M., 2005, Comm. in Asteroseismology, 146, 53.

Monet, D.G., 1998, American Astronomical Society, 193rd AAS Meeting, id.120.03; Bulletin of the American Astronomical Society, vol. 30, p. 1427.

Shappee, B.J. et al., 2014, The Astrophysical Journal, vol. 788, is. 1, article id. 48, 13 pp.

Voges, W. et al., 2000, IAU Circ., no. 7432, #3 (2000). Edited by Green, D. W. E.

Warner, B., 1999, Annapolis Workshop on Magnetic Cataclysmic Variables, ASP Conference Series, vol. 157, Hellier C. and Mukai K. eds., p. 63.