Contrib. Astron. Obs. Skalnaté Pleso **55/3**, 307 – 312, (2025)
https://doi.org/10.31577/caosp.2025.55.3.307

Period changes in low-mass eclipsing binaries:

V1828 Aql, NSVS 2676703, and NSVS 6507557

M. Wolf[1], **L. Šmecler**[2,3], **H. Kučáková**[1,3,4,5], **T. Hynek**[6], **P. Zasche**[1], **K. Hornoch**[5] **and R.F. Auer**[3,7]

[1] *Astronomical Institute, Faculty of Mathematics and Physics, Charles University, Praha 8, Czech Republic (E-mail: Marek.Wolf@mff.cuni.cz)*
[2] *Observatory Valašské Meziříčí, Czech Republic*
[3] *Variable Star and Exoplanet Section of the Czech Astronomical Society*
[4] *Research Centre for Theoretical Physics and Astrophysics, Institute of Physics, Silesian University in Opava, Czech Republic*
[5] *Astronomical Institute, Academy of Sciences, Ondřejov, Czech Republic*
[6] *DARK SKY Beskydy, Park tmavé oblohy, Czech Republic*
[7] *South Moravian Observatory, Veverská Bítýška, Czech Republic*

Received: November 5, 2024; Accepted: January 11, 2025

Abstract. Low-mass stars belong to the most numerous component of our Galaxy. We present the new results of our long-term observational project to detect small variations in the orbital periods of low-mass and short-period eclipsing binaries. Three known systems, namely V1828 Aql, NSVS 2676703, NSVS 6507557, and their period changes visible in the current $O-C$ diagrams, are briefly discussed.

Key words: binaries: eclipsing – binaries: close – stars: low-mass – stars: individual (V1828 Aql, NSVS 2676703, NSVS 6507557)

1. Introduction and observations

Low-mass binaries (LMB) and their multiple systems play an important role in stellar astrophysics. Their origin and evolution are still not fully understood questions in star formation theory. Moreover, observations of low-mass stars show a severe discrepancy between estimated and modeled parameters, where the models give some 10-15% smaller radii than the observations, while their effective temperatures are some 5% higher (Ribas et al., 2008; Morales et al., 2013). Here, we focus on three detached low-mass eclipsing binaries of different spectral types. In V1828 Aql the hot subdwarf star is present as a primary, and the other two contain K and M dwarf components. Our previous studies on LMB were presented in Wolf et al. (2018, 2020, 2021).

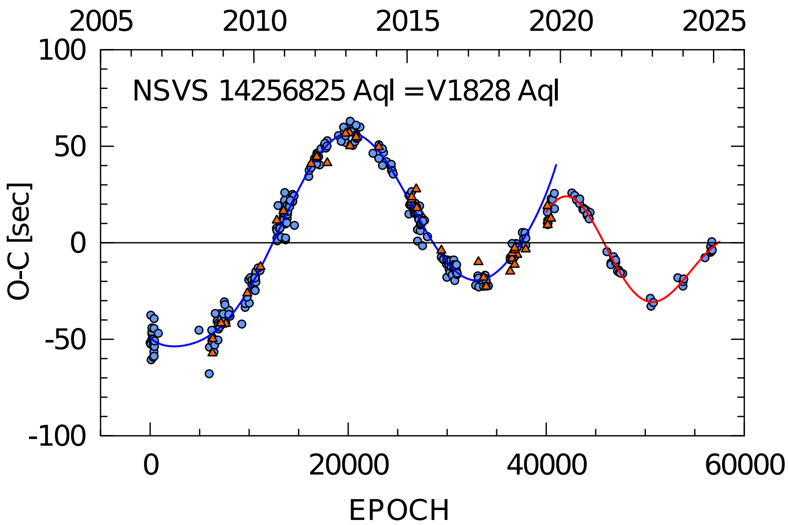

Figure 1. Period changes in the current $O-C$ diagram of NSVS 14256825 = V1828 Aql. Primary and secondary eclipses are plotted as blue circles and orange triangles, resp. The previous solution of LITE with the third body period $P_3 \simeq 9$ yr (blue curve) is no longer valid. Overall variations of $O-C$ values cannot be interpreted as a single LITE, sinusoidal oscillations of $O-C$ values are showing a decaying amplitude in recent years. Combination of several LITEs of additional bodies or a still unknown mechanism in binary systems can play a role.

LMBs are relatively faint objects with a short orbital period, rapid and deep eclipses, also interesting for amateur observers and their small telescopes with CCD techniques. Since 2006 systematic long-term light curve and eclipse monitoring of many eclipsing LMB has been made at several observatories:

- 65-cm Mayer telescope (D65) in Ondřejov observatory and CCD camera MII G2-3200 (Moravian Instruments, `https://www.gxccd.com`) with Johnson-Cousins BVRI filters in remote access,
- 40-cm Ritchey-Chrétien telescope at Dark Sky Beskydy observatory and CCD camera MII C3-Pro mono with Baader LRGB Halfa filters and remote access to the telescope, `https://www.darkskybeskydy.cz`
- 35-cm and 28-cm SCT Celestron telescopes at Valašské Meziříčí observatory with CCD camera G2-1600 and G2-4000, `https://www.astrovm.cz/cz/`
- 20-cm Newtonian telescope at South Moravian Observatory with CCD camera MII G2-1600, `https://south-moravian-observatory.jimdofree.com/`

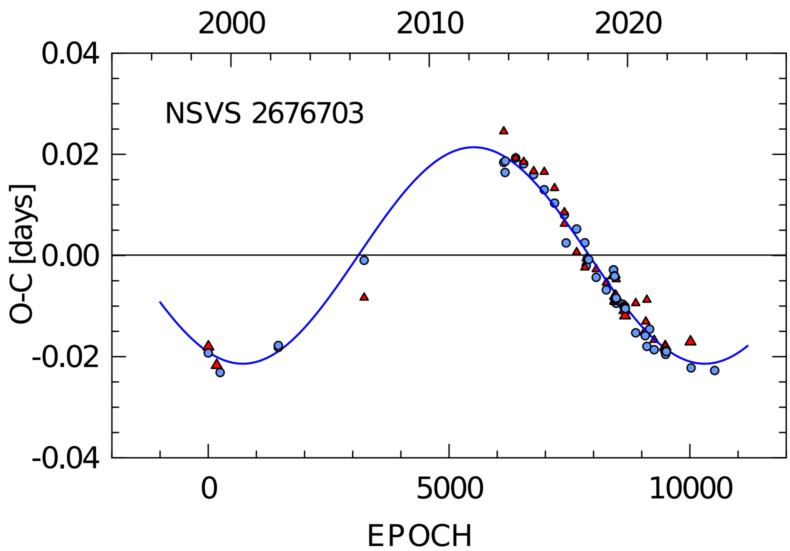

Figure 2. $O - C$ diagram for NSVS 2676703 for orbital period $P = 0.86743297$ days, where data from the TESS satellite (larger symbols) were also used. The blue sinusoidal curve represents our solution of LITE with the period of 22.8 yr and a relatively large semi-amplitude about 30 minutes. Assuming coplanar orbit and the masses of both components $M_1 = 1.2$ M$_\odot$ and $M_2 = 0.72$ M$_\odot$, the minimal mass of the third body follows $M_{3,\rm min} \simeq 0.9$ M$_\odot$. Unfortunately, such a bright third body is not visible in the TESS light curve solution.

2. Period variation and light time effect

The period analysis of three selected binaries was performed using all available mid-eclipse times found in the literature, as well as our newly measured times and those derived from TESS data. One of the best methods to detect the third body orbiting the eclipsing binary, in addition to astrometry and spectroscopy, is the light travel delay, or the so-called light time effect (LITE), associated with the orbital motion of the third body (Irwin, 1952; Mayer, 1990). Usually, this method is more sensitive to companions on a long-period orbit, and its semi-amplitude A is proportional to the mass and period of the third body as

$$A \sim M_3 \; P_3^{2/3}.$$

Moreover, low-mass binary components favor the detection of low-mass companions on short-period orbits (Pribulla et al., 2012). On the other hand, in the case of a shorter orbital period of the third body (usually less than one year), small dynamical perturbations of the inner orbit can occur that also create additional changes in the observed times; see Borkovits et al. (2011, 2016). In the

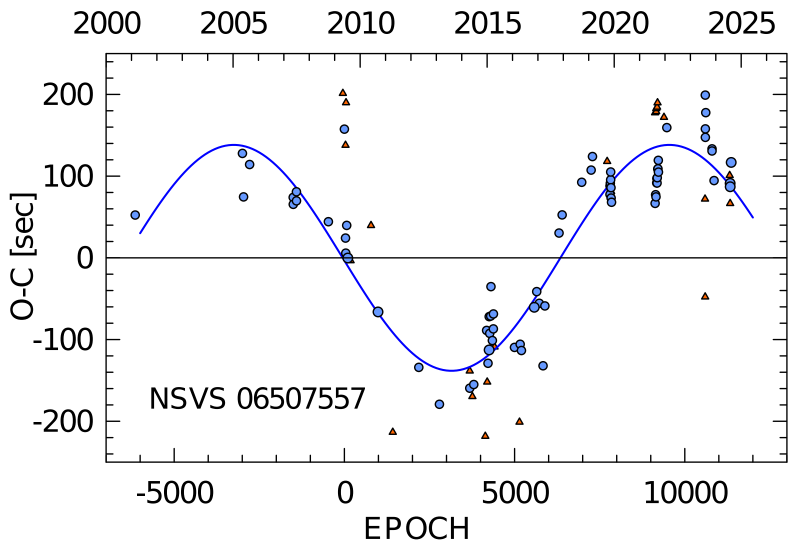

Figure 3. Current $O - C$ diagram for NSVS 6507557 with orbital period P = 0.515089155 days. See legend to Fig. 1. The blue sinusoidal curve represents possible LITE with a period of 15.3 yr and a semi amplitude of about 140 sec. Short time deviations from the overall sinusoidal course are clearly visible, esp. around the epochs 8000 – 9000 (larger symbols for TESS data). This points to another dynamical effect likely to occur in this system.

following, we present three examples of $O - C$ diagrams for systems in which the original solution of LITE turns out to be unsatisfactory or incomplete. They are discussed below and plotted in Figs. 1 – 3.

3. Discussion and conclusions

Just as among massive stars, we are also finding an increasing number of multiple systems among low-mass stars. This study provides accurate information on period changes and the possible multiplicity of three detached low-mass eclipsing binaries. Based on the presented analyses, we can conclude the following.

1. V1828 Aql = NSVS 14256825, one of the well-known PCEB HW Vir-type systems containing a very hot subdwarf B primary and M dwarf secondary. Several comprehensive period studies have been presented in the past. In the last one Zervas & Christopoulou (2024) suggest that the $O - C$ data can be well explained by the presence of two circumbinary planets. The inner planet with mass of 11 M_{Jup} revolves in a nearly circular orbit with the period of 7 yr. The outer orbiting body is unconstrained with a period range 20 – 50 yr and substellar mass 11 – 70 M_{Jup}. The authors also confirm the stability of

their solution for 100 Myr. We can conclude that this system belongs to several similar systems like HW Vir, HS0705+6700 and NN Ser, showing currently a decaying LITE amplitude in their $O - C$ diagrams.

2. In case of NSVS 2676703, only a part of the third-body orbital period is covered by precise and continuous timings. Further two decades of observations can bring more clarity to this interesting stellar object and to its period changes.

3. Concerning NSVS 6507557, there is a close faint object listed in the Gaia Archive (https://gea.esac.esa.int/archive/), about 2.5 mag fainter with a similar proper motion and distance. Its angular separation is 0.001145 deg = 4.122 arcsec and the parallax $\pi \simeq 8$ mas (distance 125 pc). This gives us a linear separation of a possible companion of 515 au. Simply, it is too far from being identified as an orbiting third body derived in this study with an orbital period of about 15 yr.

Unfortunately, to our knowledge, in the case of NSVS 2676703 and NSVS 6507557 no radial velocities have been published so far. Some presented results can therefore be considered preliminary. Further measurements of eclipses and radial velocities are desirable. The sample of well-known LMB needs to be increased, and observations of additional systems would be very useful. Multicolor photometry of individual systems and lists of mid-eclipse times are available upon request.

Acknowledgements. The research of MW and PZ was supported by the project Cooperatio-Physics of Charles University. HK and KH were supported by the RVO 67985815 project. The authors also thank Lenka Kotková, Ondřejov observatory, Jan Vraštil, Charles University Prague, and Marek Chrastina, Masaryk University Brno, for their important contribution to photometric observations. TH thanks Jan Zahajský (Supra Praha) and Martin Myslivec, who played a significant role in putting the whole set in the Beskydy observatory into operation. The following Internet-based resources were used: the SIMBAD database operated at CDS, Strasbourg, France, and the NASA Astrophysics Data System Bibliographic Services. This paper includes data collected by the Tess mission. The funding for the Tess mission is provided by the NASA Science Mission Directorate. This research is part of ongoing collaboration between professional astronomers and the Czech Astronomical Society, Variable Star and Exoplanet Section (https://var.astro.cz/en).

References

Borkovits, T., Csizmadia, S., Forgács-Dajka, E., & Hegedüs, T., Transit timing variations in eccentric hierarchical triple exoplanetary systems. I. Perturbations on the time scale of the orbital period of the perturber. 2011, *Astronomy and Astrophysics*, **528**, A53, DOI:10.1051/0004-6361/201015867

Borkovits, T., Hajdu, T., Sztakovics, J., et al., A comprehensive study of the Kepler triples via eclipse timing. 2016, *Monthly Notices of the RAS*, **455**, 4136, DOI:10.1093/mnras/stv2530

Irwin, J. B., The Determination of a Light-Time Orbit. 1952, *Astrophysical Journal*, **116**, 211, DOI:10.1086/145604

Mayer, P., Eclipsing Binaries with Light-time Effect. 1990, *Bulletin of the Astronomical Institutes of Czechoslovakia*, **41**, 231

Morales, J. C., Ribas, I., & Jordi, C., Fundamental properties of low-mass stars in eclipsing binary systems. 2013, in EAS Publications Series, Vol. **64**, *EAS Publications Series*, ed. K. Pavlovski, A. Tkachenko, & G. Torres, 103–110

Pribulla , T., Vaňko, M., Ammler-von Eiff, M., et al., The Dwarf project: Eclipsing binaries - precise clocks to discover exoplanets. 2012, *Astronomische Nachrichten*, **333**, 754, DOI:10.1002/asna.201211722

Ribas, I., Morales, J. C., Jordi, C., et al., Fundamental properties of low-mass stars. 2008, *Mem. Societa Astronomica Italiana*, **79**, 562, DOI:10.48550/arXiv.0711.4451

Wolf, M., Kučáková, H., Zasche, P., et al., Possible substellar companions in dwarf eclipsing binaries. SDSS J143547.87+373338.5, NSVS 7826147, and NSVS 14256825. 2021, *Astronomy and Astrophysics*, **647**, A65, DOI:10.1051/0004-6361/202039851

Wolf, M., Kučáková, H., Zasche, P., et al., Possible substellar companions in low-mass eclipsing binaries: GU Bootis and YY Geminorum. 2018, *Astronomy and Astrophysics*, **620**, A72, DOI:10.1051/0004-6361/201833708

Wolf, M., Kučáková, H., Zasche, P., et al., Possible companions in low-mass eclipsing binaries: V380 Dra, BX Tri, and V642 Vir. 2020, *Contributions of the Astronomical Observatory Skalnate Pleso*, **50**, 637, DOI:10.31577/caosp.2020.50.2.637

Zervas, K. & Christopoulou, P. E., NSVS 14256825: Period variation and orbital stability analysis of two possible substellar companions. 2024, *Astronomy and Astrophysics*, **691**, A115, DOI:10.1051/0004-6361/202450195