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TIMES OF MINIMA FOR THE CLOSE ECLIPSING BINARY V405 DRACONIS

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Abstract: We present times of minima for an eclipsing binary V405 Dra of EW type. We used the MAVKA software to derive times of minima from observations conducted by one of the authors (Pyatnytskyy) (18 minima), from TESS data (816 minima), and from ASAS-SN, SuperWASP, and NSVS observations (15 minima). The O-C diagram built using the mentioned times of minima shows a complex period variation in the system.

1 Introduction

V405 Dra (= 2MASS J18311337+5247075 = GSC 03905-00060) is a close eclipsing binary star of EW type. It is one of 368 close binary systems discovered in the ROTSE-I experiment (Akerlof et al., 2000). The authors of the current paper previously found that the system's period changes considerably over time (Pyatnytskyy & Andronov, 2022). The period change includes a monotonous increase and a periodic component. Since then, additional observations conducted by one of the authors (Pyatnytskyy) and new data from the TESS space observatory revealed even more complex period changes. Further analysis of the system's behavior requires precise timing of the eclipsing minima, which we have provided in the current paper.

2 Observation and data analysis

The authors' observations were carried out at the private observatory "Osokorky" in Kyiv, Ukraine, using a 150/750-mm Newtonian telescope and a CMOS camera ZWO ASI183MM Pro. A Johnson *V* photometric filter was used. Light frames were treated with a standard procedure using dark, flat, and dark-flat frames. The dark, flat, and dark-flat frames were taken every observing night immediately after the observing session; for flat frames, a white paper screen placed about 2 meters from the telescope illuminated by an LED lamp was used. The differential aperture photometry of the light frames was conducted using the AstroImageJ software (Collins et al., 2017). All the observations are available via the AAVSO International Database (Kloppenborg, 2023), observer code PMAK.

We also used observations from other sources. The most plentiful and precise source was the TESS space observatory (Ricker et al., 2014). We used TESS light curves with a cadence of 2 min. Other sources were NSVS (Woźniak et al., 2004), SuperWASP (Butters et al., 2010), and ASAS-SN (Kochanek et al., 2017) surveys. The last three sources contained sparsed observations, so we created the "folded" light curves for each observation

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year. This means that times of minima derived from these surveys are "averaged" and cannot be used for analysis at a short time scale.

The system of V405 Dra demonstrates total eclipses with flat minima. For the precise timing of such flat minima, we used the Wall-Supported line (WSL) method (Andrych, Andronov & Chinarova, 2017). This method is realized in the MAVKA software (Andrych, Andronov & Chinarova, 2020), https://uavso.org.ua/mavka/ . Examples of the WSL approximation are shown in Fig. 1.

Times of minima for non-TESS observations were converted to BJD_{TDB} time system using the 'HJD2BJD' Time Utility of the Ohio State University (Eastman, Siverd & Gaudi, 2010).

An O-C diagram created using obtained times of minima is shown in Fig. 2. The diagram was built using the period of 0.4130518 days and the initial epoch BJD_{TDB} 2 459 763.3895. Several points in the diagram, labeled IBVS, correspond to minima taken from (Diethelm, 2006) and (Diethelm, 2007); they were added for completeness. A parabolic trend shown in Fig. 2 corresponds to the following ephemeris:

$$T_{min}(BJD_{TDB}) = 2\,459\,763.3895(1) + 0.4130518(1)E + 6.44(5)^{-10}E^2 \qquad (1)$$

where T_{min} is the time of a minimum for a cycle number E.

As it is seen from the O-C diagram, the period had been monotonously increasing until about JD 2459763. The O-C data also show a periodic pattern, which can indicate the presence of the third body in the system (Pyatnytskyy & Andronov, 2022). After Julian Day 2459763, though, the O-C diagram demonstrates an apparent decrease in the period. Additional observations are needed to interpret this phenomenon.

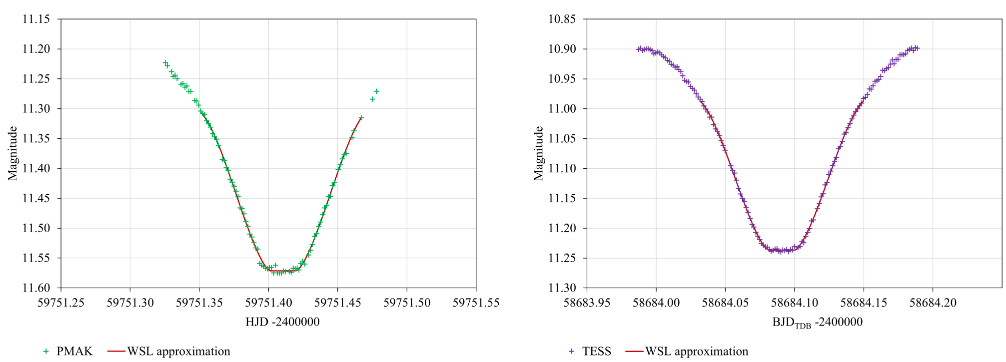
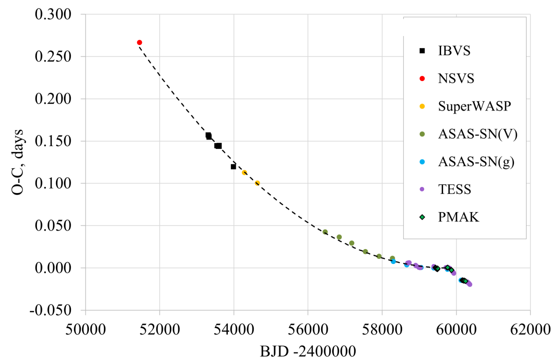


Figure 1: Example of the WSL approximation for the PMAK data (left) and TESS (right).

3 Times of minima

The times of minima obtained from the observation conducted by one of the authors (Pyatnytskyy) are listed in Tab. 1.

Since the number of minima derived from other sources (TESS, NSVS, SuperWASP, and ASAS-SN) is quite large, the entire table is provided in the Appendix to this article.



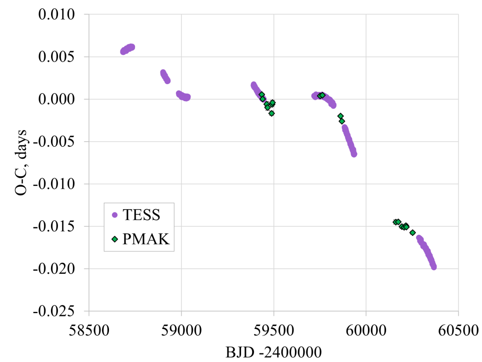


Figure 2: O-C diagram for V405 Dra.

Table 1: Times of minima for V405 Dra derived from PMAK observations

$BJD_{TDB} - 2400000$	Error [d]	Eclipse type	Epoch (cycle number)	O-C [d]	Source
59435.42692	0.00014	p	-794	0.00055	PMAK
59440.38300	0.00013	p	-782	0.00000	PMAK
59462.27415	0.00029	p	-729	-0.00058	PMAK
59466.40426	0.00031	p	-719	-0.00099	PMAK
59488.29533	0.00025	p	-666	-0.00167	PMAK
59490.36164	0.00025	p	-661	-0.00062	PMAK
59493.25321	0.00027	p	-654	-0.00042	PMAK
59751.41138	0.00009	p	-29	0.00039	PMAK
59763.38997	0.00013	p	0	0.00047	PMAK
59861.28078	0.00010	p	237	-0.00200	PMAK
59868.30206	0.00012	p	254	-0.00260	PMAK
60160.31779	0.00025	p	961	-0.01449	PMAK
60174.36157	0.00012	p	995	-0.01447	PMAK
60193.36140	0.00021	p	1041	-0.01503	PMAK
60205.33981	0.00011	p	1070	-0.01512	PMAK
60215.25324	0.00021	p	1094	-0.01493	PMAK
60217.31836	0.00012	p	1099	-0.01507	PMAK
60251.18792	0.00018	p	1181	-0.01576	PMAK

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4 Conclusions

We present times of minima for a close eclipsing binary V405 Dra derived from the authors' observations, TESS data, and NSVS, SuperWASP, and ASAS-SN surveys. The O-C diagram built using these data shows a complex period change over time. To gain a better understanding of the system's behavior, additional observations are required.

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References

Akerlof, C., Amrose, S., Balsano, R. et al. 2000, *AJ*, **119**, 1901, 2000AJ....119.1901A

Andrych, K. D., Andronov, I. L., Chinarova, L. L. 2017, *Odessa Astronomical Publications*, **30**, 57, 2017OAP....30...57A

Andrych, K. D., Andronov, I. L., Chinarova, L. L. 2020, *Journal of Physical Studies*, **24**, 1902, 2020JPhSt..24.1902A

Butters, O. W., West, R. G., Anderson, D. R. et al. 2010, *A&A*, **520**, L10, 2010A&A...520L..10B

Collins, K. A., Kielkopf, J. F., Stassun, K. G., and Hessman, F. V. 2017, *AJ*, **153**, 77, 2017AJ....153...77C

Diethelm, R. 2006, *IBVS*, **5713**, 1, 2006IBVS.5713....1D

Diethelm, R. 2007, *IBVS*, **5781**, 1, 2007IBVS.5781....1D

Eastman, J., Siverd, R., Gaudi, B. S. 2010, *PASP*, **122**, 935, 2010PASP..122..935E , https://astroutils.astronomy.osu.edu/time/

Kloppenborg, B. K. 2023, Observations from the AAVSO International Database, https://www.aavso.org

Kochanek, C. S., Shappee, B. J., Stanek, K. Z. et al. 2017, *PASP*, **129**, 104502, 2017PASP..129j4502K

Pyatnytskyy, M. Yu., Andronov, I. L. 2022, *RNAAS*, **6**, 149, 2022RNAAS...6..149P

Ricker, G. R., Winn, J. N., Vanderspek, R. et al. 2014, *Proceedings of the SPIE*, **9143**, 914320, 2014SPIE.9143E..20R

May 2024 DOI: 10.5817/OEJV2024-0251 ISSN 1801–5964

Woźniak, P. R., Vestrand, W. T., Akerlof, C. W. et al. 2004, *AJ*, **127**, 2436, 2004AJ....127.2436W