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Research Article

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New Data on the Eclipsing Binary V1848 Ori and Improved Orbital and Light Curve Solutions

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Abstract: New observations of the eclipsing binary system V1848 Ori were carried out using the V filter resulting in a determination of new times of minima and new ephemeris were obtained. We presented the first complete analysis of the system's orbital period behavior and analysis of O-C diagram done by the GA and MCMC approaches in OCFit code. The O-C diagram demonstrates a sinusoidal trend in the data; this trend suggests a cyclic change caused by the LITE effect with a period of 10.57 years and an amplitude of 7.182 minutes. It appears that there is a third body with mass function of $f(m_3) = 0.0058 \, M_\odot$ in this binary system. The light curves were analyzed using the Wilson-Devinney code to determine some geometrical and physical parameters of the system. These results show that V1848 Ori is a contact W UMa binary system with the mass ratio of q = 0.76 and a weak fillout factor of 5.8%. The O'Connell effect was not seen in the light curve and there is no need to add spot.

Keywords: photometry, ephemeris, sinusoidal, individual: V1848 Ori

1 Introduction

The system V1848 Orion (GSC 0107-0596) is classified as a W UMa type binary. The visual magnitude of this binary system changes from 11.3 to 11.5 with a period of 0.26635 day (Blättler and Diethelm 2007). The orbital period shows periodic changes which have not been investigated yet. It could be due to the presence of a third body. Therefore, we chose this system for the study.

This system's light curve solution has been studied once in the past and the mass ratio was reported as 0.7615, with a fillout factor of f = 13.14%. V1848 Ori belongs to the

A-type subclass of W UMa binaries (Kriwattanawong and Poojon 2014).

In our study, we provide the first complete analysis of the system's orbital period behavior in the light of new photometric data. We suggest a new model for the variations observed in the orbital period of the binary. We also present the new light curve solutions for this observation.

2 New photometry

The observation of V1848 Ori was carried out in January 2020 in two nights at the Bkaran Observatory, Kerman, Iran (Long. 57.0199; Lat. 32.2827) with a 10 inch Schmidt-Cassegrain F = 2500 mm telescope and the target was observed through a Nikon D5300 camera. In these observations, we used the *V* Standard Johnson filter with the estimated exposure time 30s and ISO of 6400. A total of 294 images were obtained during the two nights. We aligned, reduced, and plotted raw images with AstroImageJ (AIJ) software (Collins et al. 2017). AIJ is a graphical software package for astronomical image processing and data reduction. By using AIJ, the best fit of the data, by influencing parameters such as airmass, to the light curve is found. Ac-

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Table 1. Characteristics of the variable, comparison and reference stars (SIMBAD* query result V1848 Ori).1

Stars	Name	Magnitude (V)	RA. (2000)	Dec. (2000)
Variable	V1848 Ori	11.3	05 08 36.41	+05 12 22.05
Comparison	GSC 107-338	12.3	05 08 41.73	+05 13 29.64
Reference	GSC 107-046	11.7	05 08 30.64	+05 11 53.99

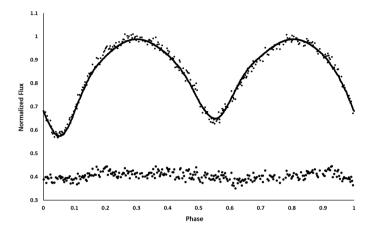


Figure 1. The observed, synthetic light curves, and residuals of V1848 Ori in *V* filter; with respect to orbital phase and flux for light curves, and shifted arbitrarily in the flux of residuals.

Table 2. The new times of minima for V1848 Ori in V filter.

Date (Y-M-D)	Filter	Min Type	Min (<i>BJD_{TDB}</i>)
2020-01-16	V	ı	2458865.2648 ± 0.0002
2020-01-16	V	II	2458865.3979 ± 0.0004

cording to this software, the data reduction was done for bias, dark, and flat fielding of each image.

Figure 1 shows the light curve in the *V* filter. The information and the coordinates of the variable, comparison, and reference stars are listed in Table 1. The new times of minima with their errors are listed in Table 2.

We used the Digital Single Lens Reflex camera (DSLR) method of observations. This is a common procedure these days. Many small observatories observe variable stars, and with the DSLR method, the number of these observations can be greater for ground-based data. The number of minima obtained by them, even without filters, can be useful in O-C analysis. There are a number of advantages and disadvantages of using DSLRs instead of CCDs (Zhang 2016); however nowadays, DSLR cameras have the precision to detect small magnitude changes due to events such as exoplanet transits (Davoudi et al. 2020); so DSLR cameras are a

Three features are necessary for a DSLR camera to be suitable for photometry; first, it must be able to record RAW format images; second, the exposure times must be controllable; and third, the camera's lens must be able to be focused manually or with a computer. There are some limitations; for example, high-quality CCDs are cooled to reduce thermal electronic noise. DSLR cameras generate more noise than CCDs, which increases the uncertainty of measurements and make it harder to measure faint objects without good observation skills.

3 Orbital Period Variations

We collected all mid-eclipse times from the literatures and obtained new individual mid-eclipse times from our observations using Gaussian fit on minimums; these are all listed in Table 3. Mid-eclipse times identified as Min (BJD $_{TDB}$) are in column 1; their uncertainties appear in column 2 (we calculated the average error amount for data points which other observers didn't compute their uncertainties); epochs of these minima times in column 3, O-C values in column 4, filters used in column 5; and the references of mid-eclipse times in the last column.

far less expensive method than using CCDs, and are easily adapted to the observation of variable stars.

¹ http://simbad.u-strasbg.fr/simbad/

Table 3. Times of minima of V1848 Ori obtained by CCD.

$\overline{\text{Min}\left(BJD_{TDB}\right)}$	Error	Epoch	O-C	Filter	Reference
2454066.4309	0.0003	0.0	0.0	R	IBVS 5781
2454066.5662	0.0008	0.5	0.0021	R	IBVS 5781
2454083.3484	0.0014	63.5	0.0042	R	IBVS 5781
2454083.4726	0.001	64	-0.0047	R	IBVS 5781
2454083.6129	0.001	64.5	0.0024	R	IBVS 5781
2454085.3382	0.0006	71	-0.0036	R	IBVS 5781
2454085.4769	0.0011	71.5	0.0019	R	IBVS 5781
2454085.6092	0.0012	72	0.0011	R	IBVS 5781
2454090.4024	0.0006	90	0.0	R	IBVS 5781
2454090.5360	0.0003	90.5	0.0004	R	IBVS 5781
2454097.3236	0.0008	116	-0.004	R	IBVS 5781
2454097.4633	0.0011	116.5	0.0025	R	IBVS 5781
2454097.5956	0.0015	117	0.0017	R	IBVS 5781
2454114.2427	0.0016	179.5	0.0019	R	IBVS 5781
2454114.3694	0.0006	180	-0.0046	R	IBVS 5781
2454114.5048	0.0005	180.5	-0.0024	R	IBVS 5781
2454474.3459		1531.5	-0.0008	Clear	IBVS 5837
2454783.8444	0.0005	2693.5	-0.0016	V	IBVS 5871
2455139.9523	0.0006	4030.5	-0.0043	V	IBVS 5920
2455522.8282	0.0002	5468	-0.0072	R	IBVS 5966
2455564.6454	0.0004	5625	-0.0071	V	IBVS 5992
2455564.7781	0.0008	5625.5	-0.0076	V	IBVS 5992
2455882.9310	0.0001	6820	-0.0103	Clear	IBVS 6011
2455904.7736	0.0007	6902	-0.0084	Clear	OEJV 160
2455905.8384	0.0007	6906	-0.009	Clear	OEJV 160
2455917.1598		6948.5	-0.0076	Clear	New Astronomy 28
2455917.2905		6949	-0.01	Clear	New Astronomy 28
2455918.0898		6952	-0.0098	Rc	VSOLJ 053
2455918.0901		6952	-0.0095	Clear	New Astronomy 28
2455918.2251		6952.5	-0.0077	Clear	New Astronomy 28
2455919.0246		6955.5	-0.0072	Rc	VSOLJ 053
2455919.9522		6959	-0.0118	Rc	VSOLJ 053
2455920.0896		6959.5	-0.0076	Rc	VSOLJ 053
2455921.9530		6966.5	-0.0087	Rc	VSOLJ 053
2455921.9532		6966.5	-0.0085	Ic	VSOLJ 053
2455922.0844		6967	-0.0104	Rc	VSOLJ 053
2455923.0192		6970.5	-0.0079	Rc	VSOLJ 053
2455933.9389		7011.5	-0.0086	Rc	VSOLJ 055
2455934.0706		7012	-0.01	Rc	VSOLJ 055
2455942.0610		7042	-0.0101	Clear	New Astronomy 28
2455942.1963		7042.5	-0.008	Clear	New Astronomy 28
2455944.0618		7049.5	-0.007	Clear	New Astronomy 28
2455944.1919		7050	-0.01	Clear	New Astronomy 28
2455960.3071	0.0002	7110.5	-0.0091	Clear	IBVS 6084
2456230.1197		8123.5	-0.0095	V	VSOLJ 055
2456232.1198		8131	-0.007	V	VSOLJ 055
2456233.0487		8134.5	-0.0104	V	VSOLJ 055
2456235.0473		8142	-0.0094	V	VSOLJ 055

2456238.9106	0.0002	8156.5	-0.0082	V	IBVS 6042
2456268.0744		8266	-0.0097	Ic	VSOLJ 055
2456268.0746		8266	-0.0095	V	VSOLJ 055
2456268.0754		8266	-0.0087	B	VSOLJ 055
2456272.0695		8281	-0.0099	B	VSOLJ 055
2456272.0700		8281	-0.0094	V	VSOLJ 055
2456274.0687		8288.5	-0.0083	V	VSOLJ 055
2456274.2005		8289	-0.0097	V	VSOLJ 055
2456296.9746		8374.5	-0.0086	Rc	VSOLJ 056
2456297.1070		8375	-0.0093	Rc	VSOLJ 056
2456541.6180	0.00007	9293	-0.0081	Clear	OEJV 165
2456638.9710		9658.5	-0.0062	Ic	VSOLJ 056
2456638.9712		9658.5	-0.006	V	VSOLJ 056
2456639.1034		9659	-0.007	B	VSOLJ 056
2456639.1037		9659	-0.0067	V	VSOLJ 056
2456639.1037		9659	-0.0067	Ic	VSOLJ 056
2456696.6353	0.0001	9875	-0.0068	Clear	IBVS 6131
2457029.9766		11126.5	-0.0032	V	VSOLJ 061
2457029.9767		11126.5	-0.0031	B	VSOLJ 061
2457029.9768		11126.5	-0.003	Ic	VSOLJ 061
2457035.0382		11145.5	-0.0022	B	VSOLJ 061
2457035.0391		11145.5	-0.0013	V	VSOLJ 061
2457035.0393		11145.5	-0.0011	Ic	VSOLJ 061
2457355.7244		12349.5	-0.0021	V	OEJV 179
2457355.7245		12349.5	-0.002	I	B.R.N.O.
2457355.7247		12349.5	-0.0019	R	OEJV 179
2457365.9789		12388	-0.0021	Ic	VSOLJ 061
2457365.9808		12388	-0.0002	B	VSOLJ 061
2457365.9819		12388	0.0009	V	VSOLJ 061
2457366.1111		12388.5	-0.0031	B	VSOLJ 061
2457366.1123		12388.5	-0.0019	Ic	VSOLJ 061
2457366.1125		12388.5	-0.0017	V	VSOLJ 061
2457389.6848	0.0002	12477	-0.0014	Clear	IBVS 6195
2457406.5979		12540.5	-0.0016	V	JAAVSO 47
2457406.5979		12540.5	-0.0016	B	JAAVSO 47
2457406.5986		12540.5	-0.0009	Ic	JAAVSO 47
2457417.6513		12582	-0.0017	Ic	JAAVSO 47
2457417.6523		12582	-0.0007	V	JAAVSO 47
2457417.6533		12582	0.0003	B	JAAVSO 47
2457433.4997		12641.5	-0.0012	Ic	JAAVSO 47
2457433.5001		12641.5	-0.0008	B	JAAVSO 47
2457433.5005		12641.5	-0.0004	V	JAAVSO 47
2457751.9208		13837	-0.0021	V	VSOLJ 63
2457751.9213		13837	-0.0016	Ic	VSOLJ 63
2457751.9218		13837	-0.0011	B	VSOLJ 63
2457752.0548		13837.5	-0.0013	B	VSOLJ 63
2457752.0553		13837.5	-0.0008	Ic	VSOLJ 63
2457752.0562		13837.5	0.0001	V	VSOLJ 63
2458865.2647	0.0002	18017	-0.0024	V	This study
2458865.3979	0.0004	18017.5	-0.0024	V	This study

We used the following light elements as the reference ephemeris (Blättler and Diethelm 2007), for computing epoch and initial O-C values,

$$Min\ I\ (BJD_{TDB}) = 2454066.4309 + 0.266349 \times E \quad (1)$$

The initial O-C diagram was shown in Figure 2. We fitted all mid-transit timings with a line, using the Robust regression. We determined a new ephemeris for primary minimum as,

$$Min\ I\ (BJD_{TDB}) = (2454066.4249 \pm 0.0083)$$
 (2)
+ $(0.266350 \pm 0.0000009) \times Edays$

where *E* is an integer of orbital cycles after the reference epoch.

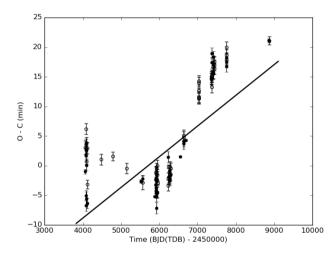


Figure 2. The O-C diagram of V1848 Ori with a linear trend on the data with $\chi_r^2 = 89.64$ and BIC = 8615.

The residual O-C diagram with respect to the linear ephemeris (Equation 2) is shown in Figure 3. As it's obvious from this figure, there may exist a cyclic variation. The parameters of Light-Time Effect (LITE) induced by the presence of third companion in the system (Table 4) were derived with the Genetic Algorithm (GA) and the Monte Carlo Markov Chain (MCMC) approach in OCFit code². The GA removes the necessity of any input values of the model's parameters. Final values together with their statistically significant uncertainties are obtained using MCMC fitting. The combination of these two algorithms allows us to analyze the exact physical model of the observed variations. The number of generations and the size of one generation were both regarded 2500 as parameters of GA. Also employing 1000000 iterations for the O-C diagram in our MCMC

runs (1000000 MC steps); and burn-in = 20000 (Gajdoš & Parimucha 2019). Confidence interval graphs for fitted parameters and histograms of parameters determined by the MCMC simulation and done in our code based on the result of OCFit code were displayed in Figure 4 and Figure 5, respectively.

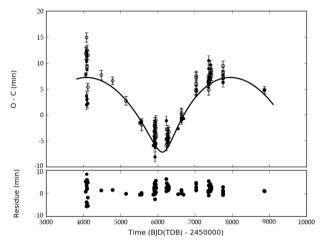


Figure 3. The residue O-C diagram of V1848 Ori showing a sinusoidal trend on the data and the residual curve (residue between (new values of O-C) calculated from values of fitted parameters to file) with $\chi_r^2 = 11.62$, and BIC = 1104.

Table 4. Results from the O-C analysis of V1848 Ori.

Parameter	Value	Error
P ₃ (d)	3863.1	43.5
P ₃ (year)	10.57	0.11
a ₁₂ sini ₃ (a.u.)	0.868	0.011
e ₃	0.55	0.01
tO_3 (BJD _{TDB})	2456174	24
ω ₃ (degree)	281	3
$f(m_3)$ (M_{\odot})	0.0058	0.0002
K ₃ (minutes)	7.182	0.097

The sinusoidal term in the equation suggests a cyclic change with a period of 10.57 years and an amplitude of 7.182 minutes. The analytical formula for O-C changes caused by LITE, which semi-amplitude of changes on O-C diagram generated by LITE is given by the equation,

$$K_3 = \frac{a_{12}\sin i_3\sqrt{1 - e_3^2\cos\omega_3}}{c} \tag{3}$$

Where $a_{12} \sin i_3$ is the projected semi-major axis of the binary star around the barycenter of a triple system, i_3 (assuming that $i_3 = 90$) is the inclination of the third body's

² https://github.com/pavolgaj/OCFit

Figure 4. Confidence interval graphs for fitted parameters determined by the MCMC simulation for the LITE model. Red point is solution and regions displayed 1σ , 2σ .

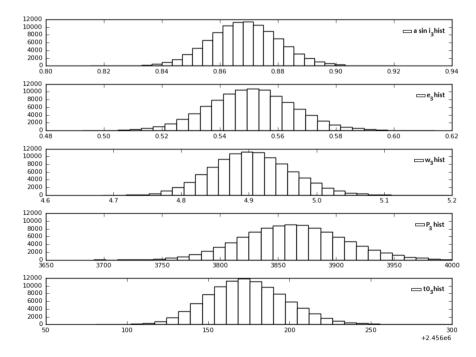


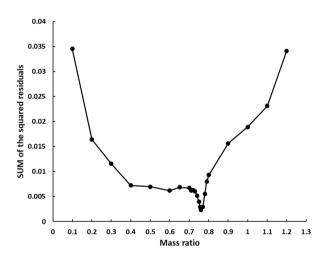
Figure 5. Histograms of parameters resulting from the MCMC chain for the LITE model.

orbit, e_3 is the eccentricity and ω_3 is the longitude of periapsis. A computation with the following equation yields a large mass function of $f(m_3) = 0.0058 \ M_{\odot}$ for the third companion (Irwin 1952),

$$f(m_3) = \frac{(a_{12}sini_3)^3}{P_3^2} \tag{4}$$

4 Light curve analysis

To analyse the light curves, we used PHOEBE (PHysics Of Eclipsing BinariEs) legacy 0.32 version. This program is designed based on the Wilson-Devinney code (Prsa and Zwitter 2005). At first we did the q search method to obtain the mass ratio of the binary system with PHOEBE software (Figure 6). As a result, a minimum value of $\sum (O - C)^2$ was initially achieved at q = 0.76.



 $\label{figure 6.} \textbf{Figure 6.} \ \textbf{Sum of the squared residuals as a function of the mass ratio.}$

We used Gaia DR2³ to find the temperature of components and also fixed it as the temperature of the hot component. We assumed gravity-darkening coefficients $g_1 = g_2 = 0.32$ (Lucy 1967), bolometric albedo $A_1 = A_2 = 0.5$ (Rucinski 1969), and linear limb darkening coefficients taken from tables published by Van Hamme (1993).

Based on the light curve and the main minimum which occurs near the 0 point of the phase curve, we could detect that the primary star is hotter than the secondary. So given that the depths of the minima are not the same, we ran the program in the 'overcontact binary system, not in thermal

contact' mode. Derived parameters from the light curve solutions are given in Table 5.

Table 5. Photometric solutions of V1848 Ori.

Parameter	Results
T ₁ (K)	4959
T ₂ (K)	4690(30)
$\Omega_1 = \Omega_2$	3.323(1)
i (deg)	75.76(2)
q	0.76(2)
$l_1/(l_1+l_2)$	0.641(5)
$l_2/(l_1+l_2)$	0.358
$A_1=A_2$	0.50
g_1 = g_2	0.32
f	0.058
$r_{1(back)}$	0.453
$r_{1(side)}$	0.422
$r_{1(pole)}$	0.400
$r_{2(back)}$	0.385
$r_{2(side)}$	0.351
$r_{2(pole)}$	0.335
$r_{1(mean)}$	0.424(4)
r _{2(mean)}	0.356(3)
$\sum (O-C)^2$	0.002
Phase shift	0.05

The mean fractional radii of components were calculated with the formula, $r_{mean} = (r_{back} \times r_{side} \times r_{pole})^{1/3}$.

This system appears not to demonstrate the O'Connell effect (O'Connell 1951) because there is no difference in both maxima. So we don't need to consider any spot for light curve solutions.

We calculated a fillout factor of 5.8% from the output parameters of the PHOEBE solutions from,

$$f = \frac{\Omega(L_1) - \Omega}{\Omega(L_1) - \Omega(L_2)} \tag{5}$$

The absolute parameters of V1848 Ori are shown in Table 6. The $M_{(primary)}$ is derived from a study by Eker et al. (2018), and $M_{(secondary)}$ is calculated by,

$$q = \frac{M_2}{M_1} \tag{6}$$

Table 6. Estimated absolute parameters of V1848 Ori.

Parameter	Primary	Secondary
Mass (M_{\odot})	0.848	0.645(23)
Radius (R_{\odot})	0.83(8)	0.69(6)
Luminosity (L $_{\odot}$)	0.37(13)	0.21(11)
M_{bol}	5.82(30)	6.44(46)
log g	4.53(1)	4.57(2)
a/R _☉	1.956	

³ https://www.cosmos.esa.int/web/gaia/dr2

Figure 7. The 3D view of the stars.

According to the estimated absolute parameters of this binary system, the distance was calculated. We obtained $m_V = 11.78(25)$ and $M_V = 6.14(30)$ for primary component ($BC_1 = -0.32$ from Eker et al. (2018)). So the distance to the binary system compute from the equation,

$$d_{(pc)} = 10^{\left(\frac{m_{pri} - M_{pri} + 5 - A_V}{5}\right)}$$
 (7)

Therefore, an estimate of the distance of this binary system is 128 \pm 18 parsec (using with $A_V = 0.11$ (Schlafly and Finkbeiner 2011)).

The 3D view of this binary system is shown in Figure 7.

5 Discussion and conclusion

We suggest a new ephemeris for determining the times of primary minima. The sinusoidal term in the O-C diagram suggests a cyclic change with a period of 10.57 years and an amplitude of 7.182 minutes. After estimating the quality of the statistical model, it is realized that the LITE signals have lower values of the Bayesian Information Criterion (BIC) compared to the linear trend. We concluded maybe there is a third component with a mass function of $f(m_3) = 0.0058 \ M_{\odot}$; where the parameters of the third body were derived as $a_{12} \sin i_3 = 0.868 \ a.u.$, $e_3 = 0.55$, $\omega_3 = 281^{\circ}$ and $t_{03}(BJD_{TDB}) = 2456174$.

The photometric solutions of the short period binary V1848 Ori were determined by analyzing the light curve in a V filter suggesting that V1848 Ori is a weak-contact binary with a fillout factor of 5.8% and the mass ratio of 0.76. These results show that V1848 Ori is a contact W UMa binary system and according to this study, we measured a distance of 128 \pm 18 pc, which is in agreement with the Gaia DR2 value 127.27 \pm 0.80 pc (Gaia Collaboration et al. 2018).

This binary system's light curve solution has been studied by Kriwattanawong and Poojon (2014) and they calculated the mass ratio as 0.7615 which is near the value obtained in this study. The temperature of the companions in that study was not consistent with Gaia DR2's results. In addition, the temperature they presented is very different from the temperature we calculated in this paper. For the fillout factor, they calculated f = 13.14% and in our study, it is reduced. Other parameters in the two studies are somewhat similar, except that we don't need to add any spot because the maximums are at the same level. However, in this paper, our main goal was to study orbital period variations in the system, which have not been studied before, and have merely been presented with the new ephemeris.

The positions of both components of V1848 Ori are shown in the H-R diagram in Figure 8. It can be seen that both components are Main Sequence stars.

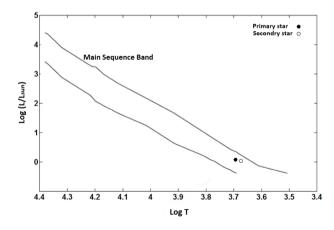


Figure 8. Position of both components of V1848 Ori on the H-R diagram, in which the theoretical ZAMS and TAMS curves are indicated.

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References

- Alton KB, Stepień K. 2019. CCD Photometry, Light Curve Deconvolution, Period Analysis, Kinematics, and Evolutionary Status of the HADS Variable V460 Andromedae. Journal of the American Association of Variable Star Observers. 47:53. [JAAVSO].
- Blattler, E. and Diethelm, R., 2007. Observations of variables. Information Bulletin On Variable Stars, 5799.
- B.R.N.O. 2015. Project-Variable Star and Exoplanet Section of the Czech Astronomical Society. http://var2.astro.cz/EN/brno/index.php>.
- Collins KA, Kielkopf JF, Stassun KG, Hessman FV. 2017. AstroImageJ: image processing and photometric extraction for ultra-precise astronomical light curves. AJ. 153(2):77.
- Davoudi F, Jafarzadeh SJ, Poro A, Basturk O, Mesforoush S, Harandi AF, et al. 2020. Light curve analysis of ground-based data from exoplanets transit database. New Astron. 76:101305.
- Diethelm, R., 2007. List of timings of minima eclipsing binaries by BBSAG observers. Information Bulletin on Variable Stars, 5781.
- Diethelm, R., 2008. List of timings of minima eclipsing binaries by BBSAG observers. Information Bulletin on Variable Stars, 5837.
- Diethelm, R., 2009. Timings of minima of eclipsing binaries. Information Bulletin on Variable Stars, 5871.
- Diethelm, R., 2010. Timings of minima of eclipsing binaries. Information Bulletin on Variable Stars, 5920.
- Diethelm, R., 2011. Timings of minima of eclipsing binaries. Information Bulletin on Variable Stars, 5992.
- Diethelm, R., 2012. Timings of minima of eclipsing binaries. Information Bulletin on Variable Stars, 6011.
- Diethelm, R., 2013. Timings of minima of eclipsing binaries. Information Bulletin on Variable Stars, 6042.
- Eker Z, Bakış V, Bilir S, Soydugan F, Steer I, Soydugan E, et al. 2018. Interrelated main-sequence mass-luminosity, massradius, and mass-effective temperature relations. MNRAS. 479(4):5491-5511.

- Gaia C. Brown AGA, Vallenari A. Prusti T. de Bruiine IHI. Babusiaux C. et al. 2018. Gaia Data Release 2 Summary of the contents and survey properties. A&A. 616(1):A1.
- Gajdoš P, Parimucha S. 2019. New tool with GUI for fitting OC diagrams. Open European Journal on Variable Stars. 197:71.
- Hoňková, K., Juryšek, J., Lehký, M., Šmelcer, L., Trnka, J., Colazo, C., Guzzo, P., Mina, F.D., Quinones, C., Taormina, M. and Melia, R., 2013. BRNO Contributions# 38 Times of minima. Open Eur J Var Stars 0160.
- Hübscher, J., 2013. Timings of minima of eclipsing binaries. Information Bulletin on Variable Stars, 6084.
- Hoňkova, K., Juryšek, J., et al., 2014. BRNO Contributions# 38 Times of minima. Open Eur J Var Stars 0165.
- Irwin JB. 1952. The Determination of a Light-Time Orbit. ApJ. 116:211-
- Juryšek J, Hoňkova K, Šmelcer L, Mašek M, Lehký M, Bílek F, et al. 2017. BRNO Contributions# 40 Times of minima. Open Eur J Var Stars. 179:1.
- Kriwattanawong W, Poojon P. 2014. First BVR light curves and preliminary results of a recently discovered W UMa-type binary: V1848 Ori. New Astron. 28:23-26.
- Lucy LB. 1967. Gravity-darkening for stars with convective envelopes. Z Astrophys. 65:89-92.
- Nagai K. 2012. Visual and CCD minima of eclipsing binaries during 2011. VSB. 53:1-10.
- Nagai K. 2013. Visual and CCD minima of eclipsing binaries during 2012. VSB. 55:1:10.
- Nagai K. 2014. Visual and CCD minima of eclipsing binaries during 2013. VSB. 56:1-9.
- Nagai K. 2016. Visual and CCD minima of eclipsing binaries during 2015. VSB. 61:1-9.
- Nagai K. 2017. Visual and CCD minima of eclipsing binaries during 2016, VSB, 63:1-9,
- Nelson RH. 2011. CCD minima for selected eclipsing binaries in 2010. IBVS. 1(5966).
- Nelson RH. 2015. CCD Minima for Selected Eclipsing Binaries in 2014. IBVS. 1(6131).
- Nelson RH. 2017. Timings of minima of eclipsing binaries. IBVS. 1(6195).
- O'Connell DJK. 1951. The so-called periastron effect in eclipsing binaries. MNRAS. 111(6):642-642.
- Prša A, Zwitter T. 2005. A computational guide to physics of eclipsing binaries. I. Demonstrations and perspectives. ApJ. 628(1):426-438.
- Rucinski SM. 1969. The proximity effects in close binary systems. II. The bolometric reflection effect for stars with deep convective envelopes. Acta Astron. 19:245-255.
- Schlafly EF, Finkbeiner DP. 2011. Measuring reddening with Sloan Digital Sky Survey stellar spectra and recalibrating SFD. ApJ. 737(2):103.
- Van Hamme W. 1993. New limb-darkening coefficients for modeling binary star light curves. AJ. 106:2096-2117.
- Zhang M, Bakos GÁ, Penev K, Csubry Z, Hartman JD, Bhatti W, et al. 2016. Precision multiband photometry with a DSLR camera. PASP. 128(961):035001.