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# Modified Masses and Parallaxes of Close Binary Systems: HD 39438

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## Abstract

We present the detailed fundamental stellar parameters of the close visual binary system HD 39438 for the first time. We used Al-Wardat's method for analyzing binary and multiple stellar systems. The method implements Kurucz's plane parallel model atmospheres to construct synthetic spectral energy distributions (SEDs) for both components of the system. It then combines the results of the spectroscopic analysis with the photometric analysis and compares them with the observed ones to construct the best synthetic SED for the combined system. The analysis gives the precise fundamental parameters of the individual components of the system. Based on the positions of the components of HD 39438 on the H-R diagram, and evolutionary and isochrone tracks, we found that the system belongs to the main sequence stars with masses of 1.24 and 0.98 solar masses for the components A and B, respectively, and age of 1.995 Gyr for both components. The main result of HD 39438 is new dynamical parallax, which is estimated to be $16.689 \pm 0.03$ mas.

*Key words:* methods: analytical – techniques: photometric – (stars:) binaries: visual – techniques: spectroscopic

## 1. Introduction

One of the most vital disciplines for contemporary stellar astronomy is having a reliable understanding of binary stars. Close binary systems can be used in precisely estimating the fundamental stellar parameters, especially stellar masses, because the majority of systems, up to 50%, are in the form of binary and multiple systems (Duquennoy et al. 1991).

The modern techniques of speckle interferometry (Balega et al. 2002a; Tokovinin et al. 2010; Köhler 2014) and adaptive optics (Roberts et al. 2005; Roberts 2011) have been instrumental in studying and analyzing close visual binary systems. The analysis of spectroscopic and astrometric data is of overriding significance in the time of speckle interferometry and adaptive optics (Lucy 2018). These techniques are also essential in improving the study of those binaries in terms of evolutionary status and relative motion.

Al-Wardat's method for analyzing binary and multiple stellar systems (BMSSs) involves merging the results of spectroscopic and photometric analyses with the observed measurements. This combination is regarded as the most effective method for analyzing such systems (Al-Wardat 2002, 2003, 2007). It consolidates the magnitude difference measurements of speckle interferometry, combined spectral energy distributions (SEDs) of the spectrophotometric analysis with the aid of the grids of ATLAS9 models (Kurucz 1994) and radial velocity measurements (once available) to estimate the individual fundamental stellar parameters of binary systems, thereby determining the precise spectrophotometric masses of such binary systems. The method has been utilized to compare synthetic stellar photometry with observed stellar photometry to estimate the fundamental parameters of solar-type stars (Al-Wardat 2009, 2012, 2014; Al-Wardat et al. 2014a, 2014b, 2014c, 2016, 2017, 2021a; Masda et al. 2016, 2018a, 2018b, 2019a, 2019b, 2021; Widyan & Aljboor 2021; Yousef et al. 2021).

On the one hand, synthetic stellar photometry is mainly utilized to obtain the fundamental stellar parameters more precisely through comparing their results with the observed ones (Al-Wardat et al. 2014a, 2014b, 2021a; Masda et al. 2018a, 2018b, 2019a, 2019b, 2021; Widyan & Aljboor 2021). Synthetic photometry is synthetic analysis of the results of the spectroscopic analysis (synthetic SED) of the binary system. This contributes to the improvement in the fundamental parameters of close binary systems.

In this work, the system HD 39438 (HIP 27758) is studied, a visual close binary in the solar neighborhood located at $\pi_{\rm H07} = 20.15 \pm 1.19$ mas (van Leeuwen 2007), also reported at $\pi_{\rm DR3} = 16.0508 \pm 0.264$ mas (Gaia Collaboration 2022), where the abbreviations of the astrometric measurements have been pointed out in Masda & Al-Wardat (2023). Since the renormalized unit weight error in $\pi_{\rm DR3}$ was very large, the solution of this parallax should not be used in this case.

The first orbital calculation for this binary was solved by Mason et al. (2010) with grade of three (G 3 = Reliable). Mason et al. (2010) found that the dynamical stellar mass was $M = 1.29 \pm 0.44\,M_\odot$ based on van Leeuwen (2007) (H07)'s parallax, and $2.56 \pm 0.34\,M_\odot$ based on the Gaia Data Release 3 (DR3)'s parallax. Then, the orbit was studied for a second time by Tokovinin et al. (2014) with grade of three and the dynamical stellar mass of the system was calculated as $M = 1.53 \pm 0.28\,M_\odot$ based on H07's parallax, and $M = 3.02 \pm 1.70\,M_\odot$ based on Gaia DR3's parallax. In 2017, Tokovinin (2017) revised the orbit of the system. In that case, Tokovinin (2017) found that the orbit has been graded as 2 (G 2 = Good), which should be adopted. According to this study, the individual dynamical masses were estimated to be $M = 1.29\,M_\odot$ and $M = 0.97\,M_\odot$ for the primary and secondary components, respectively. In this solution, the dynamical stellar mass of the system was $M = 1.50 \pm 0.27\,M_\odot$ based on H07's parallax, and $M = 2.97 \pm 0.15\,M_\odot$ based on Gaia DR3's parallax. Based on these results, Tokovinin (2017) indicated that H07's parallax is not accurate and should be revised to be more precise. As a result, Tokovinin (2017) suggested a new dynamical parallax of $\pi_{\rm dyn} = 17.6$ mas.

In this study, we proceed with the series of Masda & Al-Wardat (2023), which presents the modified masses and parallaxes for a selected sample of close binary systems. First, the key aim for this paper is to publish the fundamental stellar parameters of the binary system utilizing Al-Wardat's method for analyzing BMSSs. Second, we present the comparison between the observed photometry of the combined system with the combined synthetic photometry. Third, we report the spectrophotometric stellar masses and new dynamical parallax of the system.

In this study, we present the observational data of HD 39438 (HIP 27758), which will be compared to the synthetic analysis in Section 2. Section 3 contains the analysis method of the binary system. Section 4 describes the method to calculate the stellar masses of the binary system. In Section 5, the results and discussion of the close binary system are provided. Finally, in Section 6, we present the conclusion of this study.

## 2. Observed Data

The observed data are the backbone of the synthetic analysis. The observed photometric data, which are available from miscellaneous sources, are the key references to obtaining the stellar parameters. These are the Hipparcos (ESA 1997), Strömgren (Hauck & Mermilliod 1998) and Tycho catalogs (Høg et al. 2000), which will be compared with the synthetic photometric data to study details of the system. Table 1 lists the basic data and observed photometric data of HD 39438, while Table 2 contains the observed magnitude differences between the primary and secondary components of the binary system.

**Table 1**
Fundamental Data and Observed Photometry of HD 39438

| Property | HD 39438<br>HIP 27758 | Reference |
|---|---|---|
| $\alpha_{2000}$ | $05^{\rm h}52^{\rm m}29\overset{\rm s}{.}411$ | 1 |
| $\delta_{2000}$ | $-02°17'07\overset{''}{.}62$ | 1 |
| Sp. Typ. | G0V | 2 |
| Gaia DR2 | 3025640770239673216 | 1 |
| Gaia DR3 | 3025640770239673216 | 1 |
| $E(B-V)$ | 0.017 | 3 |
| $A_v$ (mag) | 0.053 | * |
| $\pi_{\rm H07}$ (mas) | $20.15 \pm 1.19$ | 4 |
| $\pi_{\rm DR2}$ (mas) | $11.906 \pm 0.37$ | 5 |
| $\pi_{\rm DR3}$ (mas) | $16.051 \pm 0.26$ | 5 |
| [Fe/H] | $-0.12 \pm 0.08$ | 6 |
| $V_J$ (mag) | 7.26 | 7 |
| $B_J$ (mag) | $7.79 \pm 0.02$ | 8 |
| $(B-V)_J$ (mag) | $0.56 \pm 0.015$ | 7 |
| $(b-y)_S$ (mag) | 0.35 | 9 |
| $(v-b)_S$ (mag) | 0.51 | 9 |
| $(u-v)_S$ (mag) | 0.88 | 9 |
| $B_{\rm T}$ (mag) | $7.89 \pm 0.012$ | 7 |
| $V_{\rm T}$ (mag) | $7.32 \pm 0.010$ | 7 |

**Note.** * means $A_v = 3.1E(B-V)$.
**References.** (1) Gaia Collaboration (2020), (2) Houk & Swift (1999), (3) Lallement et al. (2014), (4) H07's parallax (van Leeuwen 2007), (5) Gaia Data Release 2 (DR2) and Gaia DR3's parallax (Gaia Collaboration et al. 2016; Gaia Collaboration 2022), (6) Gáspár et al. (2016), (7) ESA (1997), (8) Høg et al. (2000), and (9) Hauck & Mermilliod (1998).

**Table 2**
The Observed Magnitude Difference between the Components of HD 39438 (HIP 27758)

| HD | $\Delta m$ | $\sigma_{\Delta m}$ | Filter ($\lambda/\Delta\lambda$) | Reference |
|---|---|---|---|---|
| 39438 | 0.87 | 0.89 | $V_H$: 511 nm/222 | ESA (1997) |
| | 1.34 | 0.03 | 545 nm/30 | Pluzhnik (2005) |
| | 1.31 | 0.03 | 545 nm/30 | Balega et al. (2002b) |
| | 1.65 | | 550 nm/40 | Horch et al. (2008) |
| | 1.26 | | 541 nm/88 | Horch et al. (2008) |
| | 1.33 | | 550 nm/40 | Horch et al. (2010) |
| | 1.40 | | 551 nm/22 | Tokovinin et al. (2010) |
| | 2.30 | | 543 nm/22 | Hartkopf et al. (2012) |
| | 1.60 | | 543 nm/22 | Tokovinin et al. (2014) |
| | 1.50 | | 543 nm/22 | Tokovinin et al. (2014) |
| | 1.60 | | 543 nm/22 | Tokovinin et al. (2015) |
| | 1.62 | 0.28 | 543 nm/22 | Tokovinin (2017) |
| | 1.60 | | 543 nm/22 | Tokovinin (2016) |

## 3. Method and Analysis

The spectrophotometric analysis is the most important step in Al-Wardat's method, which depends on two solutions to estimate the astrophysical parameters. The solutions are as follows:

### 3.1. Spectroscopic Solution

The spectroscopic solution is the most important key to produce the fundamental stellar parameters. In this solution, we are required to construct the synthetic SED for the combined and individual synthetic SED of the system. First of all, we need to know the observed magnitude difference of the system, which is estimated as follows: $\Delta m = 1.49 \pm 0.01$. This parameter is the average for all $\Delta m$ measurements given in Table 2 under the $V$-band filters. The observed magnitude difference of the system, combined with the visual magnitude, leads to the individual apparent and absolute magnitudes of the system as follows: $m_v^A = 8^{\rm m}.30 \pm 0.002$, $M_V^A = 4^{\rm m}.36 \pm 0.01$, and $m_v^B = 8^{\rm m}.64 \pm 0.12$, $M_V^B = 4^{\rm m}.70 \pm 0.13$ for the primary and secondary components, respectively, by using the following simple relationships:

$$m_v^A = m_v + 2.5\log(1 + 10^{-0.4\Delta m}), \tag{1}$$

$$m_v^B = m_v^A + \Delta\, m, \tag{2}$$

$$M_V - m_v = 5 - 5\log(d) - A_V. \tag{3}$$

Here, the distance of the system from Earth ($d$) is measured in parsecs (pc). Furthermore, since HD 39438 is a nearby system, the interstellar extinction is neglected.

The absolute magnitudes of HD 39438's components are employed for estimating the input parameters, together with some parameters taken as introductory values from the tables of Lang (1992) and Gray (2005). In addition, the following equations for the main sequence stars are used:

$$\log\frac{R}{R_\odot} = \frac{M_{\rm bol}^{\odot} - M_{\rm bol}}{5} - 2\log\frac{T_{\rm eff}}{T_\odot}, \tag{4}$$

$$\log g = \log\frac{M}{M_\odot} - 2\log\frac{R}{R_\odot} + \log g_\odot \tag{5}$$

where $T_\odot = 5777$ K, $\log\ g_\odot = 4.44$ and $M_{\rm bol}^{\odot} = 4^{\rm m}.75$. $M_{\rm bol} = M_V + {\rm BC}$, where BC is the bolometric correction.

The individual synthetic SED for each single star is built based on input parameters of the binary system. Therefore, the Kurucz ATLAS9 models, which are plane-parallel model atmospheres developed by Kurucz in 1994, are employed. These models are used to generate the synthetic fluxes for individual components of the system, and when combined with the parallax, they produce the synthetic SED for the combined close binary system. For this purpose, the specialized subroutines of Al-Wardat's method for analyzing BMSSs must be utilized. The combined synthetic SED of the binary system is determined using the following equation

$$F_{\lambda,s} = \left(\frac{R_A}{d}\right)^2\left(H_\lambda^A + H_\lambda^B\left(\frac{R_B}{R_A}\right)^2\right), \tag{6}$$

where $F_\lambda$ is the combined synthetic SED of the binary system, and $R_A$ and $R_B$ are the radii of components A and B of the system, respectively, in solar units. $H_\lambda^A$ and $H_\lambda^B$ are the corresponding fluxes of components A and B, respectively, in units of ergs cm$^{-2}$ s$^{-1}$ Å$^{-1}$. These individual fluxes are dependent on the $T_{\rm eff.}$ and log $g$. This equation accounts for the energy flux of the individual components located at a distance $d$ (in parsecs) from Earth, ensuring a reliable estimation.

In Equation (6), the values of the radii are dependent mainly on the accuracy of the parallax measurements. Tokovinin et al. (2000) showed that the parallax measurements of binary systems were probably distorted by orbital motion. That is why, employing Al-Wardat's method, significant problems started appearing in the parallax measurements of the binary systems and new dynamical parallax values were provided (Al-Wardat et al. 2021b; Masda & Al-Wardat 2023).

The results of the fundamental stellar parameters should be in keeping with those observed of the binary system. This is regarded as one of the best ways to ensure a certain accuracy for the parallax of the system. So, the synthetic photometric solution should be calculated to determine the best stellar parameters of the close visual binary system.

### 3.2. Photometric Solution

The synthetic photometric solution is the perfect complement to the spectroscopic solution, which is in turn instrumental in estimating the fundamental stellar parameters of close binary systems. The main aim of this solution is to calculate the magnitudes and color indices of the combined and individual synthetic SEDs and then compare with the observed ones in any photometric system. So, the synthetic magnitudes and color indices in different photometrical systems such as: Johnson: $U, B, V, R, U-B, B-V, V-R$; Strömgren: $u, v, b, y, u-v, v-b, b-y$ and Tycho: $B_T$, $V_T$, $B_T - V_T$ are calculated by using the following equation (Al-Wardat 2012)

$$m_p[F_{\lambda,s}(\lambda)] = -2.5\log\frac{\int P_p(\lambda)F_{\lambda,s}(\lambda)\lambda d\lambda}{\int P_p(\lambda)F_{\lambda,r}(\lambda)\lambda d\lambda} + {\rm ZP}_p, \tag{7}$$

where $m_p$ is the synthetic magnitude of the passband $p$, $P_p(\lambda)$ is the dimensionless sensitivity function of the passband $p$, $F_{\lambda,s}(\lambda)$ is the synthetic SED of the object and $F_{\lambda,r}(\lambda)$ is the SED of the reference star (Vega). Zero-point (ZP$_p$) values from Maíz Apellániz (2007) are adopted.

## 4. Mass and Dynamical Parallax

Stellar mass plays a vital role in understanding the formation and evolution of binary systems. Thus, its estimation should be accurate. There are two types of masses, which are the spectrophotometric mass $M_{\rm Sph}$ and dynamical stellar mass $M_d$. The former is estimated based on the evolutionary tracks by using Al-Wardat's method for analyzing BMSSs, while the latter is estimated by using the orbital solution of the system based on Kepler's third law as follows

$$M_d = M_A + M_B = \left(\frac{a^3}{\pi^3 P^2}\right) M_\odot. \quad (8)$$

The error in the dynamical mass is estimated as follows

$$\frac{\sigma_M}{M} = \sqrt{9\left(\frac{\sigma_\pi}{\pi}\right)^2 + 9\left(\frac{\sigma_a}{a}\right)^2 + 4\left(\frac{\sigma_P}{P}\right)^2}, \quad (9)$$

where $a''$ and $\pi$ are the semimajor axis and parallax (both in arcsec), respectively, $P$ is the orbital period (in years), and $M_A$ and $M_B$ are the masses (in solar mass).

The dynamical masses are dependent mainly on the grades of the orbits. We can adopt the best orbit if that orbit has grades of Grade 1 = Definitive, Grade 2 = Good and Grade 3 = Reliable. When the spectrophotometric mass is in keeping with the dynamical mass, the parallax of the system is adopted, otherwise it should be estimated by applying Al-Wardat's method as follows

$$\pi_{\rm dyn} = \frac{a}{P^{2/3}\left(\sum M_{\rm Sph}\right)^{1/3}}, \quad (10)$$

where $\sum M_{\rm Sph}$ are estimated by using Al-Wardat's method for analyzing BMSSs in solar mass and $\pi_{\rm dyn}$ is in arcsec. Its error is estimated as follows

$$\frac{\sigma_{\pi_{\rm dyn}}}{\pi_{\rm dyn}} = \sqrt{\frac{4}{9}\left(\frac{\sigma_P}{P}\right)^2 + \left(\frac{\sigma_a}{a}\right)^2 + \frac{1}{9}\left(\frac{\sigma_{\sum M_{\rm Sph}}}{\sum M_{\rm Sph}}\right)^2}. \quad (11)$$

## 5. Results and Discussions

The fundamental stellar properties of the close binary system HD 39438 are estimated using the complex analytical method (Al-Wardat's method for analyzing BMSSs) by Al-Wardat (2002). The method combines the spectroscopic solution with photometric solution to estimate the physical and geometrical stellar parameters of the system. These lead to a new value for the system's parallax.

The results of the calculated synthetic magnitudes and color indices of the individual components and combined synthetic SEDs of the binary system, HD 39438, are listed in Table 3. These are presented in different photometrical systems (Johnson: $U$, $B$, $V$, $R$, $U-B$, $B-V$, $V-R$; Strömgren: $u$, $v$, $b$, $y$, $u-v$, $v-b$, $b-y$ and Tycho: $B_T$, $V_T$, $B_T-V_T$).

Table 4 shows the best agreement between the synthetic and observed photometry of the binary system, HD 39438. This agreement demonstrates that the basic stellar characteristics of each element in the system listed in Table 5 are reliable. Table 3 indicates that the synthetic apparent magnitudes are completely in keeping with the observed apparent magnitudes of the system.

The stellar luminosities of the individual components of HD 39438 are estimated to be as follows: $L_A = 2.65 \pm 0.08\, L_\odot$ and $L_B = 0.76 \pm 0.09\, L_\odot$ for the primary and secondary components of the system, while the spectral types for them are F5.5V and G8V, respectively, which are in line with the spectral types of Mason et al. (2010) and Tokovinin (2017), and with the spectral type F5V given in the WDS and SIMBAD catalogs.

According to the results of the analysis, Figure 1 shows the adopted combined synthetic SED and the synthetic SEDs for the individual components of the binary system for the first time based on the best agreement between the observed and synthetic stellar photometry of the system.

**Table 3**
The Synthetic Stellar Photometry of HD 39438

| Sys. | Filter | Combined Synth. $\sigma = \pm 0.03$ | HD 39438 A | HD 39438 B |
|---|---|---|---|---|
| Joh-Cou. | $U$ | 7.90 | 8.06 | 10.06 |
| | $B$ | 7.82 | 8.02 | 9.76 |
| | $V$ | 7.26 | 7.51 | 9.00 |
| | $R$ | 6.95 | 7.22 | 8.59 |
| | $U-B$ | 0.08 | 0.04 | 0.31 |
| | $B-V$ | 0.56 | 0.51 | 0.76 |
| | $V-R$ | 0.31 | 0.29 | 0.40 |
| Ström. | $u$ | 9.07 | 9.23 | 11.21 |
| | $v$ | 8.14 | 8.32 | 10.16 |
| | $b$ | 7.58 | 7.80 | 9.41 |
| | $y$ | 7.23 | 7.48 | 8.96 |
| | $u-v$ | 0.93 | 0.91 | 1.05 |
| | $v-b$ | 0.56 | 0.52 | 0.675 |
| | $b-y$ | 0.35 | 0.32 | 0.45 |
| Tycho | $B_T$ | 7.96 | 8.14 | 9.95 |
| | $V_T$ | 7.33 | 7.57 | 9.08 |
| | $B_T-V_T$ | 0.63 | 0.57 | 0.87 |

**Table 4**
The Best Agreement between the Observed Photometry from Catalogs and the Synthetic Photometry from this Study of HD 39438

| Filter | HD 39438 Observed[a] (mag) | HD 39438 Synthetic[b] (This Work) (mag) |
|---|---|---|
| $V_J$ | 7.26 | $7.26 \pm 0.03$ |
| $B_J$ | $7.79 \pm 0.02$ | $7.82 \pm 0.03$ |
| $B_T$ | $7.93 \pm 0.012$ | $7.96 \pm 0.03$ |
| $V_T$ | $7.32 \pm 0.01$ | $7.33 \pm 0.03$ |
| $(B-V)_J$ | $0.56 \pm 0.02$ | $0.56 \pm 0.03$ |
| $(u-v)_S$ | 0.88 | $0.93 \pm 0.03$ |
| $(v-b)_S$ | 0.51 | $0.56 \pm 0.03$ |
| $(b-y)_S$ | 0.35 | $0.35 \pm 0.03$ |
| $\Delta m$ | 1.49[c] $\pm$ 0.01 | 1.49[d] $\pm$ 0.05 |

**Notes.**
[a] The observational data of HD 39438 (see Table 1).
[b] The synthetic photometry of HD 39438 (see Table 3).
[c] The observed magnitude difference of HD 39438 (see Table 2).
[d] The synthetic magnitude difference of HD 39438 (see Table 3).

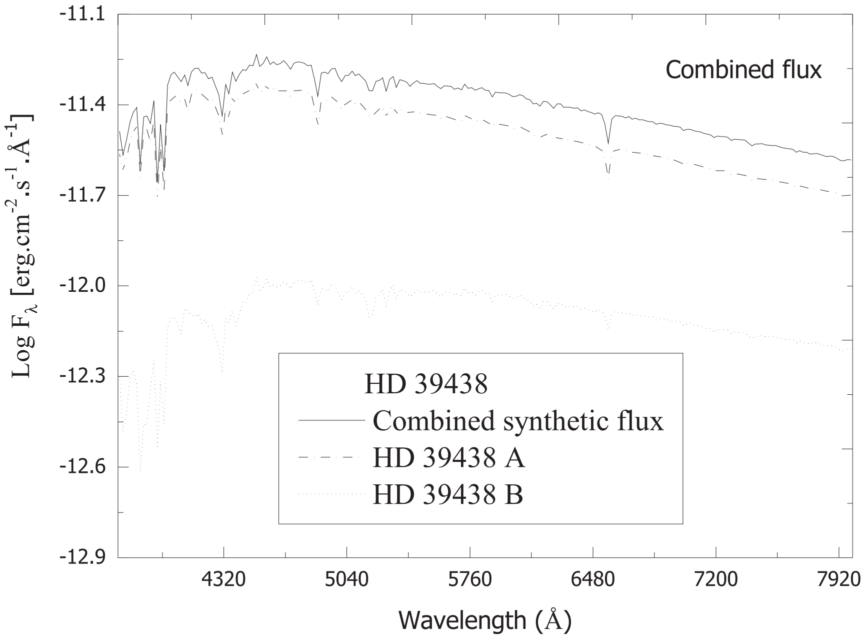


**Figure 1.** The combined synthetic SED and the corresponding individual components of HD 39438.

Figure 2 displays the spectrophotometric stellar masses of HD 39438, which are determined by using Al-Wardat's complex method for analyzing BMSSs based on the synthetic evolutionary tracks of Girardi et al. (2000b) and fundamental stellar parameters of the system. These are found to be $1.24 \pm 0.11\,M_\odot$ and $0.98 \pm 0.09\,M_\odot$ for the primary and secondary components of HD 39438 respectively. According to Tokovinin (2017), the total mass of the system is $2.26\,M_\odot$ by using the spectral types, which is in keeping with our results ($2.22\,M_\odot$).

The total dynamical mass obtained by the orbital solutions of Mason et al. (2010) ($2.56 \pm 0.32$) is consistent with the total mass achieved in this study within error margins, while there is no agreement between the results of Al-Wardat's method and dynamical mass obtained utilizing Tokovinin et al. (2014)'s orbit. However, Tokovinin (2017) revised the orbit and presented new orbital parameters; the new orbital solution was graded as two (G 2 = good), which is more accurate than the previous one. In his study, Tokovinin (2017) presented a new parallax of $\pi_{\rm dyn} = 17.6$ mas depending on the new orbital solution. This further supports our conclusion that the measured parallax for this system is not accurate enough and needs to be revised by observations.

In our analysis, we used the dynamical parallax and the good orbital solution by Tokovinin (2017) ($P = 11.963 \pm 0.036$ yr and $a = 0\farcs1207 \pm 0\farcs0007$) to calculate the dynamical mass sum as $\Sigma M = 2.25 \pm 0.05\,M_\odot$, which is well in line with the spectrophotometric mass sum ($\Sigma M = 2.22\,M_\odot$) using Al-Wardat's method. In our case, we say that the suggested dynamical parallax should be slightly larger than the dynamical parallax of Tokovinin (2017) based on our results. Consequently, we relied on the good orbital solution of Tokovinin (2017) and our spectrophotometric mass sum ($\Sigma M = 2.22\,M_\odot$) to compute the new dynamical parallax as $\pi_{\rm dyn} = 17.689 \pm 0.03$ mas, which is the closest estimate to the dynamical parallax of Tokovinin (2017). As a result, we expect that the Gaia data will perform well and provide improvement in terms of the trigonometric parallax in the near future.

**Table 5**
The Fundamental Stellar Parameters of the Individual Components of HD 39438

| Parameters | Units | HD 39438 A | HD 39438 B |
|---|---|---|---|
| | | HD 39438 | |
| $T_{\rm eff}$ | [K] | $6370 \pm 100$ | $5580 \pm 100$ |
| $R$ | [$R_\odot$] | $1.34 \pm 0.09$ | $0.935 \pm 0.09$ |
| log $g$ | [cgs] | $4.35 \pm 0.07$ | $4.50 \pm 0.07$ |
| $L$ | [$L_\odot$] | $2.65 \pm 0.08$ | $0.76 \pm 0.09$ |
| $M_{\rm bol}$ | [mag] | $3.69 \pm 0.08$ | $5.05 \pm 0.09$ |
| $M_V$ | [mag] | $4.03 \pm 0.12$ | $5.52 \pm 0.13$ |
| $M$[a] | [$M_\odot$] | $1.24 \pm 0.08$ | $0.98 \pm 0.07$ |
| Sp. Type | | F5.5V | G8V |
| Parallax[b] | [mas] | $20.15 \pm 1.19$ | |
| Age[c] | [Gyr] | 1.995 | |

**Notes.**
[a] Based on Al-Wardat's method.
[b] Based on H07's parallax.
[c] Based on the the isochrone tracks.

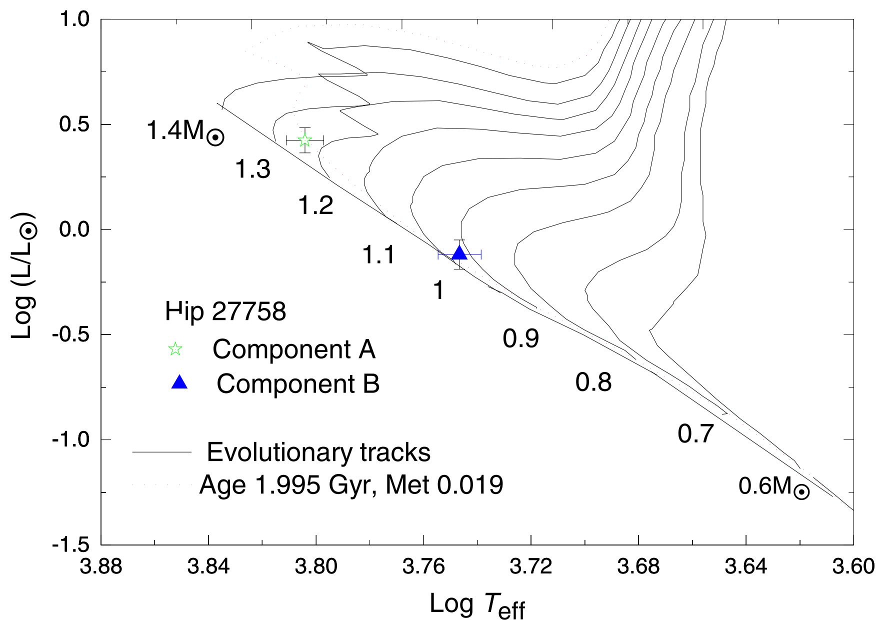


**Figure 2.** The synthetic evolutionary tracks of Girardi et al. (2000b) and isochrone tracks of Girardi et al. (2000a) of both components of the system on the Hertzsprung-Russell (H-R) diagram.

Figure 2 shows the positions of both components on the isochrone tracks of Girardi et al. (2000a). In that case, we can see that the metallicity of HD 39438 is [$Z = 0.019$, $Y = 0.27$], as affirmed in Figure 2.

Based on Figure 2, the age of the system is found to be 1.995 Gyr. The combined metallicity of the system is 0.015 based on the observed data (Gáspár et al. 2016), which corresponds well with the synthetic metallicity of 0.019, as shown in Figure 2.

## 6. Conclusions

We have presented the fundamental stellar parameters of the close binary system, HD 39438, using Al-Wardat's method for analyzing BMSSs. The method implements Kurucz's plane parallel model atmospheres to construct synthetic SEDs for both components of the system. It then combines the results of the spectroscopic analysis with the photometric analysis and compares them with the observed ones to construct the best synthetic SED for the combined system. The best match between the synthetic and observed magnitudes and color indices of the system for various photometrical systems, including Johnson: $U$, $B$, $V$, $R$, $U-B$, $B-V$, $V-R$; Strömgren: $u$, $v$, $b$, $y$, $u-v$, $v-b$, $b-y$ and Tycho: $B_T$, $V_T$, $B_T-V_T$, is showcased.

The results affirm that HD 39438 consists of two main sequence stars, a 1.24 solar mass F5.5V and a 0.98 solar mass G8V; both have the same age of around 2 Gyr. We revised the dynamical parallax of the system, which is estimated to be $16.689 \pm 0.03$ mas.

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