Applied Mathematics and Nonlinear Sciences

<http://journals.up4sciences.org>

Model atmosphere analysis of two new early-type O4 dwarfs stars

D.A. Fouda^{1 †}, M. Hamdy¹, M. Nouh¹, M. Beheary², Abdelaziz Bakrey², S. M. Saad^{1,3}.

1. National Research Institute of Astronomy and Geophysics (NRIAG),
Department of Astronomy, Stellar Lab., Helwan 11421, Cairo, EGYPT.

2. Department of Astronomy and Meteorology, Faculty of Science,
El Azhar University, Cairo, EGYPT.

3. Kottamia Centre of Scientific Excellence for Astronomy and Space Science,
Cairo, EGYPT.

Submission Info

Communicated by Elbaz I. Abouelmagd
Received 9th March 2017
Accepted 25th December 2017
Available 25th December 2017

Abstract

We present a synthetic spectra study of two new galactic early-type O4 dwarf stars (ALS 19618 and BD+50886) with high signal-to-noise ratio, typically $S/N \sim 300$, medium-resolution $R \sim 2500$ optical spectra of O4 dwarfs stars from Galactic O-Stars Spectroscopic Survey (GOSSS). The main stellar parameters (T_{eff} , surface gravity, rotational velocity) have been established using non-LTE, line-blanketed, atmospheric models calculated by TLUSTY204 and SYNSPEC49.

Keywords: Stars: early-type, Stars: dwarfs Stars: Model Atmosphere, Stars: physical parameters.

AMS 2010 codes: 85A04, 70F15.

1 Introduction

Early-type O stars play an excessively significant role in field of astrophysics. they have high effective temperatures ($T_{\text{eff}} > 30,000\text{K}$), strong ionizing radiation fields and display many times intense mass-loss over their stellar winds, making it very difficult to describe stellar evolution and the atmosphere models. It is known that these stars are the ancestors of the wonderful objects such as Wolf Wright Stars (W-Rs), the Red Giant (RSGs), luminous blue variables (LBVS), and As well as for some of the most active phenomena in the universe of the second type Supernovae and some gamma-ray bursts [11], [15]. As well they greatly affect their galaxies by

[†]Corresponding author.

Email address: diafouda@yahoo.com

transferring the momentum, energy and chemical elements enriched into the interstellar medium [1]; [3].

Many different studies have been dealing with O-type stars for many years, however their origin, properties and evolution are not completely clear and display many theoretical and observational challenges. their mass-loss rates ($\dot{M}$) depend on the metallicity (Z), For example, as well as effective temperatures, surface gravity and wind structure (e.g., clumping) have been constantly discussed in the literature over the last few years (see, e.g. [2], [9], [13], [14]).

For illustrate some of the questions mentioned earlier, and for further highlight into the problem, we have analyzed the spectra of two new early-type galaxy O4V stars (ALS 19618 and BD+50886) with optical medium-resolution. we used model atmosphere codes TLUSTY204 and SYNSPEC49 to achieve their stellar physical parameters [4].

The rest of the paper is arranged as follows. In Sect.2 we describe the optical observation of those two stars from GOSSS servay. In Sect.3 we give a specification for the atmosphere codes and the selected hypotheses. In sect.4. We provide analysis of (ALS19618) and (Bd + 50886). In Sect.5 The estimated physical parameters are given with comparisons to theoretical predictions/appreciation and epitomizes the main results found in this study.

2 Observational Material

Observations used in this work are retrieved from The Galactic O-Star Spectroscopic Survey (GOSSS) the third installment (see [8]) (GOSSS) is a large survey of Galactic O stars in spectroscopic, established on modern homogeneous, signal-to-noise ratio are very high, *typically* $S/N \sim 300$, moderate resolution ($R \sim 2500$), in a wavelength range $\sim 4000 - 5000$ of a considerable amount (1000+) of O stars in the our Galaxy and estimating precise and self-compatible spectral types for all of them . the selected digital observations are from the Galactic O-Star Catalog (GOSC) [7]. This study includes two new galactic O4 dwarfs stars from GOSSS, their Observational data are shown in Table. 1.

Table 1 Observational data of two new galagtic O4V stars from GOSSS.

Star	RA (hms)	dec (dms)	spectral type ^a	V	B-V
ALS 19618	18:20:34.493	-16:10:11.85	O4 V (n)((fc))	11.29	+1.11
BD+50886	04:03:20.736	+51:18:52.46	O4 V ((fc))	11.22	+1.05

^a Spectral type are taken from Maíz Apellániz, J. et al. 2016 [8]

3 Model Atmospheres and Synthetic Spectra

we used model atmosphere code TLUSTY204 [4] to determine the main stellar parameters of those two stars, TLUSTY code assumes the atmosphere is a plane-parallel layers, contains line-blanketing, NLTE, hydrostatic equilibrium, radiative equilibrium and present line formed only in photosphere layer.

We use to synthesis the spectra the code SYNSPEC 49 [5] which is a general spectrum synthesis program. The input model atmospheres to SYNSPEC could be taken from TLUSTY or from the literature, for instance from the Kurucz grid of models. Then the program solves the radiative transfer equation wavelength by wavelength in a specified wavelength range and with a specified wavelength resolution. In the present calculation

To start our analysis, we calculate a small grid of TLUSTY model based on the OSTAR2002 grid [6], with an effective temperature range between 40,000 K and 45,000 K, and surface gravity range between 3.80 and 4.20,

Our new model atmosphere grid uses small steps in effective temperature (1000 K) and surface gravity (0.1 dex). We use the helium lines He I $\lambda 4471$ and He II $\lambda 4542$ ratio to derive the effective temperatures, Typical errors for T_{eff} is 1 kK. Our deduction of $(\log g)$ was established on the fitting to the H γ wings, but fits other transitions such as H β wings and H δ wings were also checked for consistency. For this parameter, the uncertainty is 0.1 dex. After determining the effective temperatures and surface gravities for the target stars, we turn to determine the rotational velocities ($v \sin i$). For this purpose, we use the routine *rotin3* which is a part of the SYNSPEC package. To do that, a small grid of rotated spectra for a given effective temperature and surface gravity is calculated and The rotational velocities ($v \sin i$) were estimated from the fitting process.

4 Results

The results of our analysis and stellar modelling of ALS 19618 and BD +50886 are presented here. For each system a brief background is given, also the results of the analysis of their spectra and stellar modelling is discussed. The values of the effective temperature (T_{eff}), surface gravity ($\log g$) and the rotational velocity ($v \sin i$) is determined from the fitting process with the synthetic one. the variation between the best fit model achieved from the fitting process is small, so visual checking that make the final judgment of the reasonable model.

4.1 ALS 19618

ALS 19618 is located in the young open cluster NGC 6618 which embedded in the omega nebula (M 17), and it's the reason for the gases of the nebula to radiate because of radiation from these young, hot stars; It is considered one of the brightest and most massive star-forming regions of the galaxy.

No line blanketed stellar model atmosphere have been applied to study this star, in Fig.1 we show our best fit model to the optical spectrum, several spectral regions were displayed which include the diagnostic lines applied to estimate the stellar parameters. The effective temperature would be very well represented. The He I $\lambda 4471$ /He II $\lambda 4542$ ratio are well reproduced with $T_{eff} = (42.9 \pm 1)$ kK, from H γ we estimate surface gravity $\log g = 4.00 \pm 1.0$, and the best fit for rotation velocity $v \sin i = 210 \text{ km s}^{-1}$.

the most strong lines for hydrogen and helium in the wavelength range (4000 - 5000) show in Fig.1 are: He I $\lambda 4388$, He I $\lambda 4471$, He I $\lambda 4713$, He II $\lambda 4200$, He II $\lambda 4542$, He II $\lambda 4686$, H δ , H γ , and H β . These same transitions are easily identified in the objects of our sample.

4.2 BD+50886

BD+50 886 This object is the main ionizing source of the H II region Sh 2-206 (NGC 1491) and was classified by [12] as O5neb. The GOSSS spectral classification is O4V((fc)) [8] which agree with our calculations.

Also their is no line blanketed stellar model atmosphere have been applied to study this star. In Fig. 2 we display our best fit model atmosphere for the optical spectrum of BD+50 886. The He I and He II lines are well represented by a $T_{eff} = (44 \pm 1)$ kK. The best fit model to the H γ wings specifies a surface gravity ($\log g$) of 3.95 ± 0.1 , and the best fit for rotation velocity $v \sin i = 150 \text{ km s}^{-1}$.

5 Conclusion

In this study we provided a model atmosphere analysis of two new galactic early type O4 main-sequence stars. We established effective temperature (T_{eff}), surface gravities ($\log g$), and rotational velocities ($v \sin i$) for each star using NLTE model. The effective temperatures are 42,900 and 44,000 K. for ALS 19618 and BD+50886 respectively. BD+50886 has The lowest surface gravity 3.95 ± 0.1 and ALS 19618 has the higher

Fig. 1 Best fit (black dotted line) of the observed (gray line) of ALS 19618. The upper figure shows the whole fit to the blue-violet spectrum, The lower figure shows detailed fits for the standard diagnostic lines of He and H . The effective temperature is 42900 K, $\log g = 4.00$ and $v \sin i = 210 \text{ km s}^{-1}$.

surface gravity 4.0 ± 0.1 . the fit with the model performed higher rotational velocity for ALS 19618 ($v \sin i = 210$) and ($v \sin i = 150$) for BD+50886. The physical parameters of this study are displayed in Table 2. comparison of The derived stellar parameters with the recently calibration for Galactic O-type star properties of the O4 main-sequence shows a fair agreement (see [10]).

Acknowledgements. This research is supported by Kottamia Centre of Scientific Excellence for Astronomy and Space Science (Kosice) and the Science and Technology Development Fund (STDF N5217).

We would like to give thanks to A. Taki, A. Shukri, G. M. N. Hamed, and I. Zaid for their assistance and helpful discussions

Fig. 2 Best fit (black dotted line) of the observed (gray line) of BD+50886. The upper figure shows the whole fit to the blue-violet spectrum, The lower figure shows detailed fits for the standard diagnostic lines of He and H . The effective temperature is 44000 K, $\log g = 3.95$ and $v \sin i = 150 \text{ km s}^{-1}$.

References

- [1] Abbott, D. C. (1982), The theory of radiatively driven stellar winds. II - The line acceleration, *ApJ*, 259, 282 - 301. doi [10.1086/160166](https://doi.org/10.1086/160166)
- [2] Bouret, J.-C. Lanz, T. and Hillier, D. J. (2005), Lower mass loss rates in O-type stars: Spectral signatures of dense clumps in the wind of two Galactic O4 stars, *Astronomy & Astrophysics*, vol. 438, pp. 301-316. doi [10.1051/0004-6361:20042531](https://doi.org/10.1051/0004-6361:20042531)

Table 2 Stellar Parameters of the program stars.

Star	spectral type	Teff (kK)	Log (g)	$v \sin i (kms^{-1})$
ALS 19618	O4 V (n)((fc))	42.9 ± 1.0	4.00 ± 0.1	210
BD+50886	O4 V ((fc))	44.0 ± 1.0	3.95 ± 0.1	150

- [3] Freyer, T. Hensler, G. and Yorke, H. W. (2003), Massive Stars and the Energy Balance of the Interstellar Medium. I. The Impact of an Isolated 60 Msolar Star, *Astrophysical Journal*, vol. 594, pp. 888-910, doi [10.1086/376937](https://doi.org/10.1086/376937)
- [4] Hubeny, I. and Lanz, T. (1995), Non-LTE line-blanketed model atmospheres of hot stars. 1: Hybrid complete linearization/accelerated lambda iteration method, *Astrophysical Journal*, vol. 439, pp. 875-904, doi [10.1086/175226](https://doi.org/10.1086/175226)
- [5] Lanz, T. and Hubeny, I., (1995), Non-LTE line-blanketed model atmospheres of hot stars. 2: Hot, metal-rich white dwarfs, *Astrophysical Journal*, vol. 439, no. 2, p. 905-916, doi [10.1086/175227](https://doi.org/10.1086/175227)
- [6] Lanz, T. and Hubeny, I., (2003), A Grid of Non-LTE Line-blanketed Model Atmospheres of O-Type Stars, *Astrophysical Journal*, vol. 146, pp. 417-441, doi [10.1086/374373](https://doi.org/10.1086/374373)
- [7] Maíz-Apellániz, J., Walborn, N.R. and Galué, H. Á. and Wei, L. H., (2004), A Galactic O Star Catalog, *Astrophysical Journal*, vol. 151, pp. 103-148, doi [10.1086/381380](https://doi.org/10.1086/381380)
- [8] Maíz-Apellániz, J., Sota, A., Arias, J. I., Barbá, R. H., Walborn, N. R., Simón-Díaz, S., Negueruela, I., Marco, A., Leão, J. R. S., Herrero, A., Gamen, R. C. and Alfaro, E.J., (2016), The Galactic O-Star Spectroscopic Survey (GOSSS). III. 142 Additional O-type Systems., *Astrophysical Journal Supplement Series*, Volume 224, Issue 1, article id. 4, 42 pp, doi [10.3847/0067-0049/224/1/4](https://doi.org/10.3847/0067-0049/224/1/4)
- [9] Martins, F. Schaerer, D. and Hillier, D. J. (2002), On the effective temperature scale of O stars, *Astronomy & Astrophysics*, vol. 382, pp. 999-1004, doi [10.1051/0004-6361:20011703](https://doi.org/10.1051/0004-6361:20011703)
- [10] Martins, F., Schaerer, D. and Hillier, D. J., (2005), A new calibration of stellar parameters of Galactic O stars, *Astronomy & Astrophysics*, vol. 436, pp. 1049-1065, doi [10.1051/0004-6361:20042386](https://doi.org/10.1051/0004-6361:20042386)
- [11] Massey, P. (2003), Massive start in the local group: Implications for Stellar Evolution and Star Formation, *Annual Review of Astronomy and Astrophysics*, vol. 41, pp. 15-56, doi [10.1146/annurev.astro.41.071601.170033](https://doi.org/10.1146/annurev.astro.41.071601.170033)
- [12] Moffat, A.F.J., Jackson, P. D.; Fitzgerald, M. P., (1979), The rotation and structure of the galaxy beyond the solar circle. I - Photometry and spectroscopy of 276 stars in 45 H II regions and other young stellar groups toward the galactic anticentre, *Astronomy and Astrophysics Supplement Series*, vol. 38, p. 197-225.
- [13] Puls, J. Markova, N. Scuderi, S. Stanghellini, C. Taranova, O. G. Burnley, A. W. and Howarth, I. D. (2006), Bright OB stars in the Galaxy. III. Constraints on the radial stratification of the clumping factor in hot star winds from a combined H, IR and radio analysis, *Astronomy & Astrophysics*, vol. 454, pp. 625-651, doi [10.1051/0004-6361:20065073](https://doi.org/10.1051/0004-6361:20065073)
- [14] Vink, J. S. de Koter, A. Lamers, and H. J. G. L. M. (2001), Mass-loss predictions for O and B stars as a function of metallicity, *Astronomy & Astrophysics*, vol. 369, pp. 574-588, doi [10.1051/0004-6361:20010127](https://doi.org/10.1051/0004-6361:20010127)
- [15] Woosley, S. E. and Bloom, J. S. (2006), The Supernova Gamma-Ray Burst Connection, *Annual Review of Astronomy and Astrophysics*, vol. 44, pp. 507-556, doi [10.1146/annurev.astro.43.072103.150558](https://doi.org/10.1146/annurev.astro.43.072103.150558)

©UP4 Sciences. All rights reserved.