https://doi.org/10.18524/1810-4215.2025.38.340282

DETERMINATION OF THE EFFECTIVE TEMPERATURES AND SURFACE GRAVITIES OF SEVERAL A-TYPE STARS BASED ON PHOTOMETRIC PARAMETERS

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ABSTRACT. The fundamental parameters – effective temperatures (T_{eff}) and surface gravities (g) – have been determined for of A-type stars: HD 6364 (A5/7III), HD 6365 (A3III/IV), HD 6492 (A9V), HD 6723 (A8V), HD 25093 (A7II/III), HD 123798 (A8/9V), HD 129175 (A6V), HD 129433 (A0IV), HD 129660 (A7V), and HD 209124 (A0III-IV).

In order to determine the chemical composition of stars using the model or synthetic spectrum method, it is essential to know their fundamental parameters – effective temperatures (T_{eff}) and surface gravity (g). T_{eff} and log g are the basic parameters of stellar atmosphere models – determining these parameters is necessary to compute stellar atmosphere models. On the other hand, by knowing the effective temperature (T_{eff}) and surface gravity (g), it is possible to calculate the evolutionary parameters of stars – their masses (M), luminosities (L), radii (R), and ages (t). Thus, the accurate determination of the chemical composition of stars through the model or synthetic spectrum method depends on the precision of the T_{eff} and log g parameters.

The effective temperatures (T_{eff}) and surface gravities (log g) of stars were determined using photometric method. The method employed is based on comparing observed and theoretical values of the photometric indices [c_1], Q, and β. This method is a simple and accurate method. The Q index in the UBV photometric system is defined as Q = (U – B) - 0.72(B – V), while the [c_1] index in the uvby photometric system is defined as [c_1] = c_1 - 0.2 (b - y). These indices are free from the effects of absorption in the interstellar medium.

The following values of T_{eff} and log g were obtained for the studied stars: HD 6364: T_{eff} = 7,610 K, log g = 4.25; HD 6365: T_{eff} = 7,880 K, log g = 4.35; HD 6492: T_{eff} = 7,390 K, log g = 3.70; HD 6723: T_{eff} = 7,380 K, log g = 4.00; HD 25093: T_{eff} = 7,780 K, log g = 4.10; HD 123798: T_{eff} = 7,090 K, log g = 3.65; HD 129175: T_{eff} = 8,220 K, log g = 4.35; HD 129433: T_{eff} = 9,960 K, log g = 4.00; HD 129660: T_{eff} = 7,710 K, log g = 3.65; HD 209124: T_{eff} = 9,820 K, log g = 3.80.

Keywords: A-type stars, fundamental parameters.

АНОТАЦІЯ. Для зір типу A визначено фундаментальні параметри – ефективні температури (T_{eff}) та поверхневі гравітації (g): HD 6364 (A5/7III), HD 6365 (A3III/IV), HD 6492 (A9V), HD 6723 (A8V), HD 25093 (A7II/III), HD 123798 (A8/9V), HD 129175 (A6V), HD 129433 (A0IV), HD 129660 (A7V) та HD 209124 (A0III-IV). Для визначення хімічного складу зір за допомогою модельного методу або методу синтетичного спектру важливо знати їхні фундаментальні параметри – ефективні температури (T_{eff}) та поверхневу гравітацію (g). T_{eff} та log g є основними параметрами моделей зоряних атмосфер – визначення цих параметрів необхідне для обчислення моделей зоряних атмосфер. З іншого боку, знаючи ефективну температуру (T_{eff}) та поверхневу гравітацію (g), можна розрахувати еволюційні параметри зір – їхні маси (M), світності (L), радіуси (R) та вік (t). Таким чином, точне визначення хімічного складу зір за допомогою модельного або синтетичного спектрального методу залежить від точності параметрів T_{eff} та log g. Ефективні температури (T_{eff}) та поверхневі гравітації (log g) зір були визначені за допомогою фотометричного методу. Використаний метод базується на порівнянні спостережуваних та теоретичних значень фотометричних індексів [c_1], Q та β. Цей метод є простим та точним. Індекс Q у фотометричній системі UBV визначається як Q = (U – B) - 0,72(B – V), тоді як індекс [c_1] у фотометричній системі uvby визначається як [c_1] = c_1 -0,2(b - y). Ці індекси не залежать від впливу погли-нання в міжзоряному середовищі. Для досліджуваних зір було отримано такі значення T_{eff} та log g: HD 6364: T_{eff} = 7 610 K, log g = 4,25; HD 6365: T_{eff} = 7 880 K, log g = 4,35; HD 6492: T_{eff} = 7 390 K, log g = 3,70; HD 6723: T_{eff} = 7 380 K, log g = 4,00; HD 25093: T_{eff} = 7 780 K, log g = 4,10; HD 123798: T_{eff} = 7 090 K, log g = 3,65; HD 129175: T_{eff} = 8 220 K, log g = 4,35; HD 129433: T_{eff} = 9 960 K, log g = 4,00; HD 129660: T_{eff} = 7 710 K, log g = 3,65; HD 209124: T_{eff} = 9 820 K, log g = 3,80.

Ключові слова: зорі типу A, фундаментальні параметри.

1. Introduction

The determination of the chemical composition of stellar atmospheres is one of the key issues in astrophysics. Recently, the chemical composition of supergiant star atmospheres has attracted the attention of astrophysicists.

Table 1: Observational values of photometric quantities of stars

№	Names of stars	Spectral class	b-y	c_1	$[c_1]$	β	U-B	B-V	Q
1	HD 6364	A5/7III	0.169	0.730	0.696	2.772	0.047	0.291	-0.1625
2	HD 6365	A3III/IV	0.150	0.826	0.796	2.804	0.046	0.256	-0.1383
3	HD 6492	A9V	0.165	0.855	0.822	2.751	0.096	0.283	-0.1078
4	HD 6723	A8V	0.184	0.766	0.729	2.746	0.023	0.294	-0.1887
5	HD 25093	A7II/III	0.290	0.822	0.764	2.795	0.270	0.450	-0.054
6	HD 123798	A8/9V	0.205	0.661	0.620	2.712	0.020	0.300	-0.196
7	HD 129175	A6V	0.170	0.910	0.876	2.842	0.100	0.245	-0.0764
8	HD 129433	A0IV	0.011	1.054	1.052	2.833	-0.05	-0.002	-0.0506
9	HD 129660	A7V	0.172	0.983	0.949	2.790	0.160	0.272	-0.0358
10	HD 209124	A0III/IV	0.025	1.141	1.136	2.820	-0.020	0.030	-0.0416

This is because, during the evolutionary process, variations occur in the abundances of certain elements in the atmospheres of A-, F-, G-, and K-type supergiant stars. In particular, an excess of the nitrogen element and a deficiency of the carbon element are observed.

In giant and supergiant stars of spectral classes A, F, G, and K, a deep convective mixing process takes place. As a result, the products of thermonuclear reactions from the cores of such stars are transferred to their atmospheres. Therefore, the observational determination of the chemical composition of stellar atmospheres is crucial for verifying the predictions of modern theories of stellar chemical evolution.

We have studied the atmospheres of many A, F, and G spectral class stars, including supergiant stars (Lyubimkov & Samedov, 1985, 1987, 1990; Samedov, 2019; Samedov et al., 2023, 2024). The first step in studying the chemical composition of stars is determining the effective temperature (T_{eff}) and surface gravity (g). T_{eff} and g are the basic parameters of stellar atmosphere models. The accuracy of determining the chemical composition depends on the computational precision of the star's atmospheric model. Furthermore, by knowing the effective temperature (T_{eff}) and surface gravity (g) parameters, the evolutionary characteristics of stars – such as their masses, luminosities, radii, and ages can be determined. Accurate determination of the effective temperature (T_{eff}) and surface gravity (g) is one of the important problems in astrophysics.

2. Determination of effective temperatures (T_{eff}) and surface gravity (g)

In this work, the main atmospheric parameters – effective temperatures (T_{eff}) and surface gravity (g) of the A-type stars HD 6364 (A5/7III), HD 6365 (A3III/IV), HD 6492 (A9V), HD 6723 (A8V), HD 25093 (A7II/III), HD 123798 (A8/9V), HD 129175 (A6V), HD 129433 (A0IV), HD 129660 (A7V), and HD 209124 (A0III-IV) have been determined. The effective temperatures (T_{eff}) and surface gravity (g) of the examined stars were determined based on the comparison of observed and theoretically calculated values of $[c_1]$, Q, and β quantities. This method is a simple and accurate method. The application of this method allows for the determination of the effective temperatures (T_{eff}) and surface gravity (g) of a large number of stars. The method was proposed by L.S. Lyubimkov (Lyubimkov et al., 2010).

The Q index in the UBV photometric system is defined as Q = (U – B) – 0.72(B – V), while the $[c_1]$ index in the uvby photometric system is defined as $[c_1] = c_1 - 0.2(b - y)$. The β index is related to absorption in the Hβ line, it measures the intensity of this line relative to the surrounding continuum in the spectrum. These indices are free from the effects of absorption in the interstellar medium. The observed values of c_1, b – y, U – B, B – V, and β quantities were taken from the Hauck, B. & Mermilliod catalog (Hauck and Mermilliod 1998). Theoretical values for c_1, b – y, U – B, and B – V were calculated by (Castelli et al., 2003), while the theoretical value of the β quantity was calculated by Castelli F. and Kurucz R.L. (Castelli & Kurucz, 2006). The observed values of the photometric quantities for the studied stars are shown in Table 1.

The theoretical calculated values of the $[c_1]$, Q, and β quantities are overlaid with the observed measured values, and based on each quantity, pairs of T_{eff} and log g are determined. The determined T_{eff} and log g pairs are plotted on the log g ─ T_{eff} diagram, and lines are drawn in the log g ─ T_{eff} plane based on the [c], Q, and β indices. The intersection point of these lines determines T_{eff} and log g (Figure 1).

The effective temperature (T_{eff}) and surface gravity (log g) we determined are given in Table 2.

For the star HD 6364, other authors have determined T_{eff} = 7433 K, log g = 3.9 (Steinmetz et al., 2020), and T_{eff} = 7400 K (Paunzen, 2024); for HD 6365, T_{eff} = 7861 K (Paunzen, 2015); for HD 6492, T_{eff} = 7183 K (Masana, Jordi & Ribas, 2006); for HD 25093, T_{eff} = 7800 K (Paunzen, 2024); for HD 123798, T_{eff} = 6908 K (Deacon, Henning & Kossakowski, 2019), T_{eff} = 7047 K (Nascimbeni et al., 2016), and T_{eff} = 7112 K (Bai et al., 2020); for HD 129175, T_{eff} = 8200 K (Kharchenko et al., 2007) and T_{eff} = 8040 K (Brown et al., 2021); for HD 129433, T_{eff} = 9709 K, lo gg = 3.64 (Shokry et al., 2018) and T_{eff} = 9817 K (Zorec and Royer, 2012); and for HD 129660, T_{eff} = 7800 K Tkachenko, Johnston & Aerts, 2024).

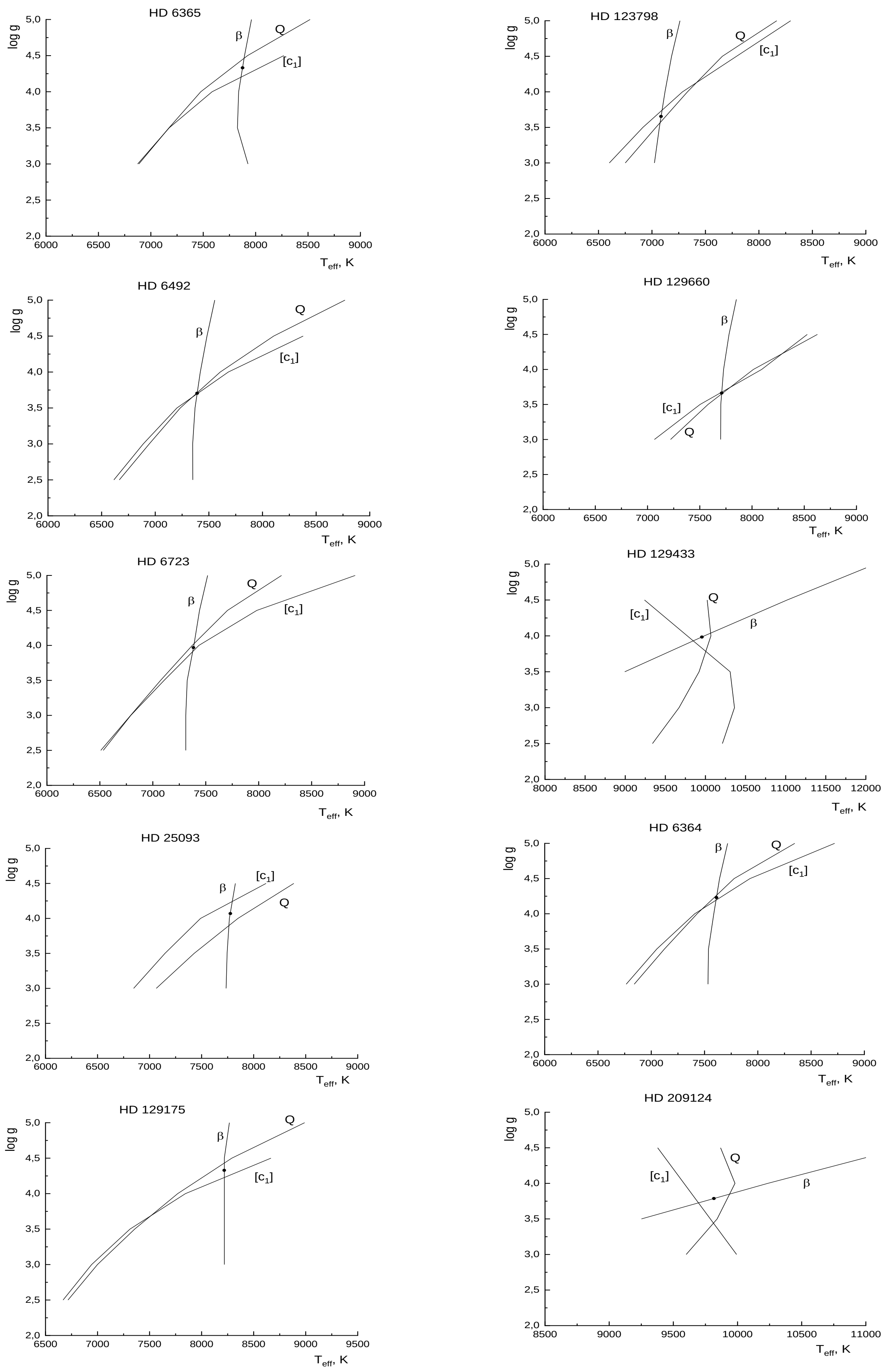

Figure 1: log g — T_{eff} diagrams

Table 2: Atmospheric parameters of stars (T_{eff}, log g)

№	Names of stars	Spectral class	T_{eff}, K	log g
1	HD 6364	A5/7III	7610 K	4.25
2	HD 6365	A3III/IV	7880 K	4.35
3	HD 6492	A9V	7390 K	3.70
4	HD 6723	A8V	7380 K	4.00
5	HD 25093	A7II/III	7780 K	4.10
6	HD 123798	A8/9V	7090 K	3.65
7	HD 129175	A6V	8220 K	4.35
8	HD 129433	A0IV	9960 K	4.00
9	HD 129660	A7V	7710 K	3.65
10	HD 209124	A0III/IV	9820 K	3.80

The differences between the effective temperatures (T_{eff}) and surface gravities (log g) determined in this study and those reported by other authors are as follows: for the star HD 6364, ΔT_{eff} = 193 K (mean value) and Δlog g = 0.35; for HD 6365, ΔT_{eff} = 19 K; for HD 6492, ΔT_{eff} = 207 K; for HD 25093, ΔT_{eff} = 20 K, for HD 25093, ΔT_{eff} = 68 K (mean value); for HD 129175, ΔT_{eff} = 100 K (mean value); for HD 129433, ΔT_{eff} = 197 K (mean value) and Δlog g = 0.36; and for HD 129660, ΔT_{eff} = 90 K.

The fundamental parameters of the stars were determined by various methods: spectral analysis and infrared photometry in Steinmetz et al. (2020); comparison of observed and theoretical values of the b photometric index in Paunzen (2015); spectral energy distribution fitting and infrared photometry in Masana, Jordi & Ribas (2006); Balmer jump in Shokry et al. (2018); broadband photometry in Nascimbeni et al. (2016); empirical or theoretical color–temperature relations in Deacon, Henning & Kossakowski (2019); photometric indices in Bai et al. (2020) and Tkachenko, Johnston & Aerts (2024); photometric and spectral indices in Kharchenko et al. (2007) and Brown et al. (2021); and hydrogen Balmer line profiles in Zorec and Royer (2012).

3. Conclusion

Based on the comparison of the observed and theoretically calculated values of the [c_1], Q, and β quantities, the main atmospheric parameters–effective temperatures (T_{eff}) and surface gravity (log g) – of the A spectral class stars HD 6364 (A5/7III), HD 6365 (A3III/IV), HD 6492 (A9V), HD 6723 (A8V), HD 25093 (A7II/III), HD 123798 (A8/9V), HD 129175 (A6V), HD 129433 (A0IV), HD 129660 (A7V), and HD 209124 (A0III-IV) have been determined.

The following values of T_{eff} and log g were obtained for the studied stars: HD 6364: T_{eff} = 7610 K, log g = 4.25; HD 6365: T_{eff} = 7880 K, log g = 4.35; HD 6492**:** T_{eff} = 7390 K, log g = 3.70; HD 6723: T_{eff} = 7380 K, log g = 4.00; HD 25093: T_{eff} = 7780 K, log g = 4.10; HD 123798: T_{eff} = 7090 K, log g = 3.65; HD 129175: T_{eff} = 8220 K, log g = 4.35; HD 129433: T_{eff} = 9960 K, log g = 4.00; HD 129660: T_{eff} = 7710 K, log g = 3.65; HD 209124: T_{eff} = 9820 K, log g = 3.80.

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