Determination of microturbulent velocity in the atmosphere of the HD217944 (G8IV) star

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In the atmosphere of the HD217944 (G8IV) star, the microturbulent velocity is determined for the odd-even and even-odd transitions. Thus, the microturbulent velocity of iron atoms determined on low levels of odd term lines (ξ_t = 3.5 km/s) is less than the microturbulent velocity (ξ_t = 4.2 km/s) determined on low levels of even term lines. This indicates that the microturbulent velocity increases towards the upper layers of atmosphere.

Keywords: *stellar atmospheres, microturbulent velocity*

Introduction

As it is known, besides the thermal motion of the atoms in the stellar atmospheres, the motion of large masses of gas also takes place. These motions are called turbulent motions. There are two types of turbulent motion:

1. *Microturbulent motions, and*
2. *Macroturbulent motions.*

If the optical thickness of the turbulent element satisfies condition τ>>1, then the beam of light intersects an element or part of it. In this case, we talk about the macroturbulent motions. The macroturbulent motions cause the sliding of the Fraunhofer lines and the change of the shape of the profile. Macroturbulation does not affect the equivalent widths of the profiles of the spectral lines.

If the optical thickness of the turbulent element satisfies condition τ<<1, then the beam of light intersects several elements. In this case, we talk about the microturbulent motions. Microturbulence affects the equivalent width of absorption lines, more specifically, increases it. Therefore, when determining the chemical composition of stellar atmospheres, it is necessary to determine the microturbulent velocities in advance.

The most accurate way to determine the microturbulent velocity in stellar atmospheres is to analyze the profiles of individual Fraunhofer lines. Only weak absorption lines should be used for this purpose. It is very difficult to specify their exact profiles. However, the recent introduction of new types of devices into stellar spectroscopy: the digital double monochromators and Fourier transform spectrometers greatly simplifies the solution to this problem.

Goldberg [1] proposed a new method to determine the microturbulent velocity in stellar atmospheres caused by strong lines. The essence of this method is as follows:

Two spectral lines are used that belong to the same multiple line of a given chemical element. If we assume that the profiles of these lines can be taken as a Doppler profile, the absorption coefficient in their nuclei can be written as follows

$$\varepsilon = \varepsilon_1 e^{-\left(\Delta\lambda/\Delta\lambda_D\right)^2},$$

$$\varepsilon = \varepsilon_2 e^{-\left(\Delta\lambda/\Delta\lambda_D\right)^2}$$

It can be assumed that this is the ratio of the absorption coefficients

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{g_1 f_1}{g_2 f_2}.$$

Here g is the statistical weight of the energy level and f is the power of the oscillator. Then we can write as follows

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{g_1 f_1}{g_2 f_2} = \frac{e^{-(\Delta\lambda_1/\Delta\lambda_2)^2}}{e^{-(\Delta\lambda_2/\Delta\lambda_1)^2}}.$$

Further, the intervals of Δλ1 and Δλ2 are chosen so that the condition

$$\varepsilon_1 e^{-(\Delta\chi_1/\Delta\chi_2)} = \varepsilon_2 e^{-(\Delta\lambda_2/\Delta\lambda_D)}$$

is satisfied.

Obviously, in this case, the radiation intensity at Δλ1 and Δλ2 wavelengths will be the same, i.e.

$$J(\Delta\lambda_1, \cos\vartheta) = J(\Delta\lambda_2, \cos\vartheta) .$$

Then, based on the above expression, for the Doppler profile width, we can write as follows

$$\Delta\lambda_D = \sqrt{\frac{(\Delta\lambda_1)^2 - (\Delta\lambda_2)^2}{\ln\left[\frac{gf_1}{gf_2}\right]}} .$$

Then from the expression

$$\Delta\lambda = \frac{\lambda}{c}\left(\frac{2kT}{m} + \vartheta_t^2\right)^2$$

we can calculate ϑ_t .

Recently, the microturbulent velocity has been determined by a more accurate method - the atmospheric models method. The necessary condition to calculate the microturbulent velocity in stellar atmospheres by the model method is the presence of a large number of lines, including weak lines within the star observation spectrum, varying over a wide range of the equivalent widths of any element. The theoretical equivalent widths of each of these lines are calculated and compared to the observed equivalent widths. By giving different values to the microturbulent velocity ξ_t, the abundance of the corresponding element $\log\varepsilon$ is calculated for each line according to its measured equivalent W_λ, and a certain value is selected for ξ_t. Thus, for this selected value of ξ_t, no systematic changes are observed with increasing $\log\varepsilon$ and W_λ. For this purpose, many observatories have special computer softwares. For instance, one of the most widely used softwares is the WIDTH program created by Kurucz. Its analogue at the Crimean Astrophysical Observatory is the DASA program.

As it is shown by Lyubimkov and Samadov, the microturbulent velocity increases with an increasing altitude in the atmospheres of *F* supergiant stars.The effect is stronger as the lines are stronger.

Observation material

Our aim is to determine the microturbulent velocity in the atmosphere of the star HD217944 (G8IV) and to study its dependence on even terms.The spectrum of the star HD217944 (G8IV) was obtained in 2013 by CCD installed in the Kassegren focus of a 2 meter telescope of the Shamakhi Astrophysics Observatory of ANAS [3]. The spectral material covers the range of λλ4700-6700Å.

2-3 spectra were obtained for the studied star a night. Since there is no strong variability in the spectrum of the star during the night, the spectra are averaged. The dispersion in the H_α region is 10.5 Å/mm, and it is 6 Å/mm in the H_γ region. The spectrum of the daytime sky was used to construct the dispersion curve. The spectra were processed using the DECH software package suggested by Galazutdinov [4-5]. All observed lines were identified, and their equivalent width (W) and center depths (R) were determined.

HD217944 is one of the subgiant stars in our galaxy. The spectral class - G8, luminosity class - IV, visible star size - $m_v=6^m.40$, parallax $-\pi=0''.00044$ [6] and absolute star size is $M_v = -5^m.38$. Balmer hydrogen. In our previous work [7-8], the effective temperature and acceleration of gravity on the surface of stars were determined by applying the parallax and based on a comparison of the observed and theoretically calculated values of the quantities Q, $[c_1]$ and equivalent widths of lines H_α and H_β of the Balmer hydrogen series

$$T_{eff}=5200\pm200 \text{ K}, \log g=3.1\pm0.2.$$

For comparison, we can say that Massarottin [9] found T_{eff} = 4898K, logg = 3.1 for the fundamental parameters of this star.

Dependence of the microturbulent velocity in the atmospheres of the star HD217944 (G8IV) on evenness of terms

T_{eff} = 5200 K, logg = 3.1 model parameter is selected from Kurucz models [10]. Using the model, the abundance of the *FeI* element is calculated at different values of the microtubulent velocity. In the absence of the correlation between the abundance of the element and the equivalent widht, the corresponding microturbulent velocity is taken as the microturbulent velocity in the atmosphere of this star.

In [11], it was shown that the excitation temperature in the solar photosphere depends on the evenness of terms. In this work, it was demonstrated that the excitation temperature determined for odd lines with low levels is much higher than the excitation temperature determined for even lines with low levels. It is believed that this is due to the efficient formation of spectral lines in different layers of the photosphere that corresponds to even-odd and odd-even transitions. The studies show that the odd lines with lower terms are efficiently formed in deeper layers of the photosphere.

To determine the microturbulent velocity in the atmosphere of HD217944 star, we divide the studied FeI lines into two groups - low-levels of odd term and low-levels of even term groups and in these cases, we determine the microturbulent velocity. Thus, the dependence of microturbulent velocity on evenness of terms was considered (Figure 1 and Figure 2).

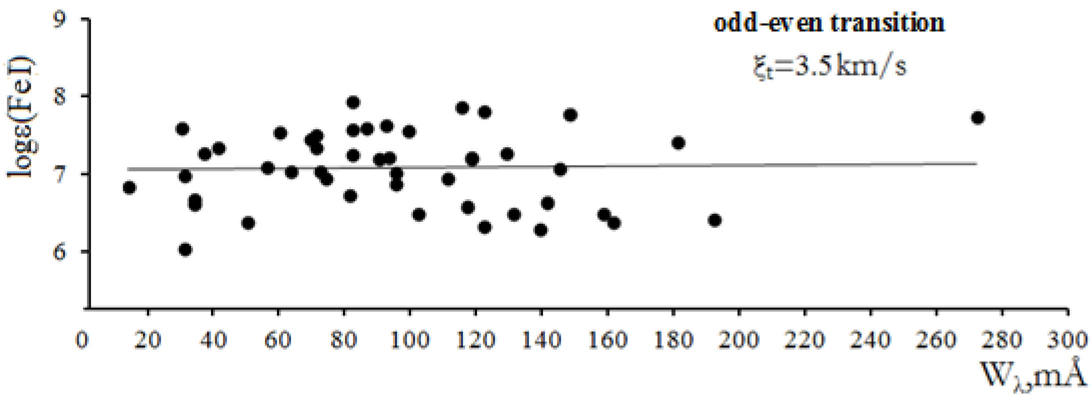

Fig. 1. Dependence of logε(*FeI*) on W_λ at ξ_t=3.5 km/s for the odd-even transition

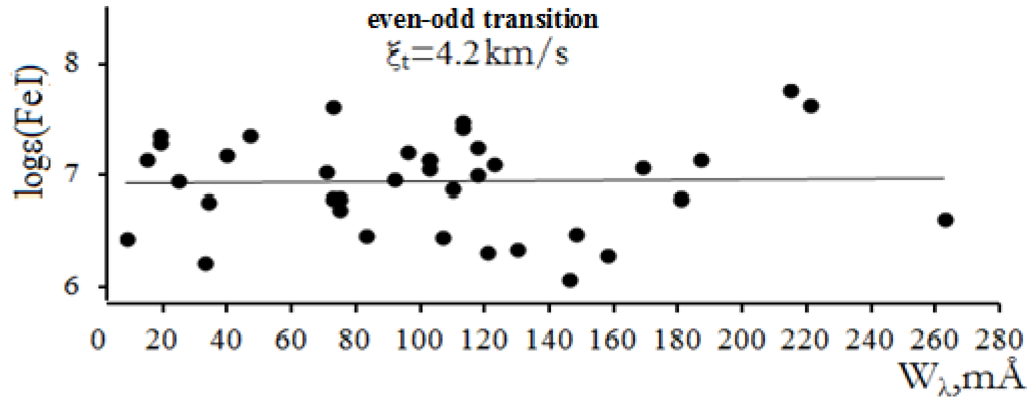

Fig. 2. Dependence of logε(*FeI*) on W_λ at ξ_t=4.2 km/s for the even-odd transition

The microturbulent velocity determined for odd-even transitions is ξ_t=3.5 km/s, and the microturbulent velocity determined for even-odd transitions is ξ_t=4.2 km/s, respectively. It was clarified that the microturbulent velocity determined according to odd-even transitions is less than the microturbulent velocity determined according to even-odd transitions. This is due to the fact that the turbulent velocities in the atmosphere of this star vary depending on the depth of the atmosphere.

The lines corresponding to the studied transitions are shown in Tables 1 and 2. The wavelengths of the spectral lines of the neutral iron atom selected for the corresponding transitions is indcated in column I, the corresponding statistical weight is shown in column II, the excitation potential of low lewel is given in column III, the equivalent widths of the profiles of the spectral lines determined by the DECH software package are given in column IV, and the abundance of elements corresponding to the values of 3.5 and 4.2 km/s of microturbulent velocity is shown in column V.

Conclusion

In the atmosphere of the HD217944 (G8IV) star, the microturbulent velocity was determined for odd-even and even-odd transitions. The microturbulent velocity of iron atoms determined on low levels of odd term lines is ξ_t = 3.5 km/s, and the microturbulent velocity determined on low levels of even term lines is ξ_t = 4.2 km/s. This evidences that the turbulent velocity increases towards the upper layers of atmosphere.

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Table 1. FeI (odd-even transitions) at a value 3.5 km/s of microturbulent velocity

λ, Å	loggf	ε (eV)	W, mÅ	lgε
4807,71	3,35	-2,17	32	6,64
4862,60	4,14	-2,03	12	6,85
4973,11	3,94	-1,01	109	6,96
4988,95	4,14	-0,97	116	7,21
5002,80	3,32	-1,68	29	6,05
5004,03	4,19	-1,49	120	7,82
5022,24	3,97	-0,67	179	7,43
5044,21	2,84	-2,31	93	6,89
5074,76	4,2	-0,32	115	6,60
5121,64	4,26	-0,91	93	7,03
5383,38	4,29	0,42	159	6,40
5393,17	3,23	-0,90	137	6,31
5410,92	4,45	0,12	139	6,65
5415,21	4,37	0,36	156	6,51
5417,03	4,4	-1,69	58	7,56
5424,08	4,3	-0,34	232	
5546,51	4,35	-1,35	97	7,57
5557,98	4,45	-1,32	69	7,36
5560,23	4,42	-1,26	54	7,10
5563,61	4,17	-1,70	113	7,88
5586,76	3,35	-0,31	190	6,43
5619,60	4,37	-1,77	39	7,35
5620,53	4,14	-1,83	29	7,00
5701,55	2,55	-2,22	100	6,50
5705,47	4,28	-1,62	80	7,59
5717,84	4,27	-1,19	70	7,05
5731,77	4,24	-1,33	80	7,26
5762,99	4,19	-0,58	143	7,08
5775,09	4,2	-1,37	61	7,05
5827,89	3,27	-3,40	28	7,61
5859,23	4,29	-1,65	69	7,51
5905,68	4,63	-0,79	88	7,21
5914,16	4,59	-0,52	127	7,28
5934,66	3,91	-1,20	79	6,75
5983,69	4,53	-0,89	91	7,23
6079,02	4,63	-1,21	90	7,64
6093,66	4,59	-1,55	35	7,28
6188,04	3,93	-1,71	32	6,68
6338,90	4,77	-1,10	84	7,61
6364,37	4,77	-1,47	80	7,94
6411,66	3,64	-0,81	129	6,51
6419,98	4,71	-0,36	48	6,40
6496,47	4,77	-0,69	146	7,79
6569,22	4,71	-0,49	116	7,23

Table 2. FeI (even-odd transitions) at a value 4.2 km/s of microturbulent velocity

λ, Å	loggf	ε (eV)	W, mÅ	lgg ε
4834,51	2,41	-3,35	31	6,76
4889,01	2,19	-2,85	212	7,76
5027,23	3,62	-1,55	30	6,22
5028,13	3,56	-1,17	218	7,63
5029,62	3,40	-2,08	93	7,21
5141,75	2,41	-2,33	184	7,14
5151,92	1,01	-3,32	155	6,28
5225,53	0,11	-4,79	178	6,80
5242,50	3,62	-1,00	104	6,45
5280,36	3,63	-1,98	110	7,48
5294,60	3,62	-2,89	12	7,14
5307,37	1,60	-2,99	118	6,31
5320,04	3,63	-2,51	44	7,36
5322,05	2,27	-3,02	72	6,70
5341,03	1,60	-2,05	260	6,61
5365,40	3,56	-1,18	166	7,07
5379,58	3,68	-1,58	72	6,79
5491,84	4,17	-2,43	16	7,35
5641,45	4,27	-1,25	110	7,42
5760,35	3,63	-2,49	70	7,61
5778,50	2,58	-3,57	37	7,18
5916,25	2,44	-2,99	70	6,80
5956,70	0,86	-4,60	115	7,00
6027,06	4,06	-1,22	89	6,96
6180,21	2,72	-2,77	100	7,14
6240,65	2,21	-3,34	100	7,14
6335,34	2,19	-2,38	145	6,48
6344,15	2,42	-2,92	120	7,09
6380,75	4,17	-1,36	68	7,02
6430,86	2,17	-2,01	143	6,06
6475,63	2,58	-2,90	213	
6481,88	2,27	-2,98	107	6,87
6498,95	0,95	-4,70	100	7,05
6518,37	2,82	-2,67	115	7,24
6546,25	2,75	-1,76	127	6,34
5020,82	3,53	-2,55	6	6,44
5617,22	3,24	-2,88	22	6,95
5536,60	2,82	-3,80	16	7,29
6322,69	2,58	-2,43	80	6,47

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