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Original scientific paper

IRON ABUNDANCE DETERMINATION FOR THE SOLAR-LIKE STARS HR4345 AND HR6573

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SUMMARY: Using the BLACKWELL software package written by R.O. Gray, the iron abundance of the solar-like stars HR 4345 and HR 6573 has been determined. The method is based on determination of the minimum dispersion (or the region of least confusion) of the iron abundance versus microturbulent velocity functions for some selected spectral lines of neutral iron. The input data used by BLACKWELL are the observed equivalent widths of several spectral lines of neutral iron. They are obtained from spectra observed at the Observatoire de Haute-Provence, France, with the 1.52-m telescope and Aurelie spectrograph. Reduction of the raw spectra and the measurement of the equivalent widths of spectral lines are carried out using IRAF and SPE software packages. The measured values of iron abundances of HR 4345 and HR 6573 are 7.72±0.03 and 7.63±0.05 respectively.

Key words. Stars: abundances - Techniques: spectroscopic - Line: profiles

1. INTRODUCTION

The determination of iron abundances of solar-like stars HR 4345 and HR 6573 was motivated by an unusually high variation of the Mn I 539.47 nm spectral line equivalent width and central depth during the solar activity cycle (Livingston 1992, Vince and Erkapic 1998). In order to solve this problem, the temperature sensitivity of the Mn I 539.47 nm spectral line parameters was determined using solar-like stars with different effective temperatures (Vince et al. 1998, Vince and Vince 2001). To get as accurate results as possible, a correction of the observed stellar spectra for metallicity was taken into account (Vince 2003). For some of the observed stars, the metallicity values could not be found in the existing catalogs so that they had to be derived from the observed spectra. For this purpose a suitable set of iron spectral lines was used.

The iron abundance of stars is very important in modeling the stellar atmospheres and determinating the stellar parameters.

2. METHOD

The iron abundances of HR 4345 and HR 6573 were determined using the BLACKWELL software package by R.O. Gray. The software calculates the abundance of the element in question (iron in our case), which yields the equivalent width for a given spectral line and for a range of microturbulent velocities. Different spectral lines of iron will give different slopes for plots of abundances against microturbulent velocity. The intersection of these curves (or the region of least confusion) will define the optimal microturbulent velocity for the star and the corresponding iron abundance.

As input parameters BLACKWELL uses the excitation potentials of the lower and higher energy levels of transition, oscillator strength (log(gf)), damping factor, type of transition and the observed equivalent widths of spectral lines used in calculation. All atomic parameters were taken from the NIST Atomic Spectra Database at

Table 1. List of spectral lines used for the iron abundance determination of HR 4345 and HR 6573 (wavelength (λ) in [Å], lower (E_l) and upper (E_u) energy levels in cm^{-1}, logarithm of oscillator strength (log (gf)) and excitation potential (χ) in eV).

λ[Å]	E_l [1/cm]	E_u [1/cm]	log (gf)	χ[eV]
5379.581	29799	48383	-1.58	3.6946
5386.340	33507	52067	-1.81	4.1544
5398.287	35856	54376	-0.68	4.4456
5417.072	35612	54067	-1.49	4.4154
6226.740	31323	47378	-2.16	3.8836
6232.648	29469	45509	-1.22	3.6537

Table 2. Right accession (α), declination (δ), magnitude (V) and spectral class (Sp) of the observed stars

Star	α_{2000}	δ_{2000}	V	Sp
HR 4345	11h 12m 32.1s	35^o 48' 49"	6.41	G0V
HR 6573	17h 34m 59.4s	61^o 52' 30"	5.23	G0Va

`http://physics.nist.gov`. The equivalent widths of spectral lines were obtained from the observed spectra. The raw spectra were reduced using IRAF and the parameters of spectral lines were measured with the SPE software package.

For the iron abundance determination of HR 4345 and HR 6573 we used the Kurucz's stellar atmosphere models (the models are found at `http://www.phys.appstate.edu`). Both stars have the same effective temperature ($T_{eff} \approx g000$ K) and the logarithm of surface gravity ($\log(g) = 4.37$). A stellar atmosphere model with these parameters could not be extracted directly from Kurucz's models, so that interpolation had to be made (a detailed description of the procedure is given in Vince and Vince (2003)).

In this study we used weaker iron spectral lines since their equivalent widths are almost independent of collisional damping. Furthermore, we have selected only the lines which are as free of blending with other spectral lines as possible and possess a clearly defined continuum on both sides of the line profile. As a source, the list of unblended spectral lines given by Rutten was used (Rutten and van der Zalm 1984). Since the curve of growth depends on the excitation potential, the lines were chosen to have similar excitation potentials of the lower energy level of transition. The spectral lines selected and some of their parameters are given in Table 1.

3. OBSERVATIONS AND REDUCTION

The observations of HR 4345 and HR 6573 were carried out at Observatoire de Haute-Provence (France) using the Coude telescope of 1.52 m and focal ratio of f/30, combined with Aurelie spectrograph with a "Thomson" TH 7832 detector (TH 7832 is a double linear array with 2048 photodiodes). The focal lengths of both the spectrograph collimator and camera mirrors were 1000 mm. The spectra were taken using two gratings, one with 1200 l/mm and the other with 3000 l/mm. The resolving power obtained with such configuration was about 35 000 and the signal-to-noise ratio was about 300.

The observations were carried out during the five nights from April 17 to April 21, 1998. Some relevant parameters for the observed stars are given in Table 2.

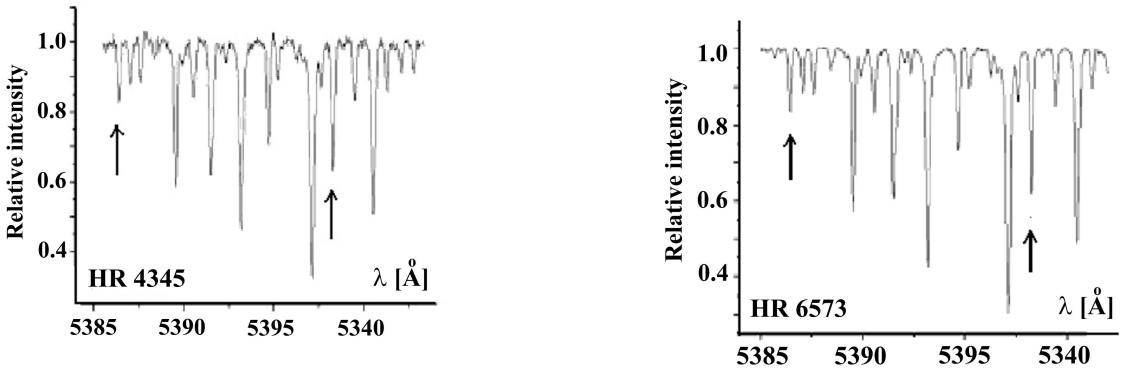

Fig. 1. *Examples of the reduced spectra of HR 4345 and HR 6573.*

Table 3. The measured equivalent widths of the neutral iron spectral line profiles utilized for stellar iron abundance determination.

λ[Å]	EW_{HR4345}[Å]	EW_{HR6573} [Å]
5379.581	0.063217	0.057176
5386.340	0.030482	0.022635
5398.287	0.078097	0.067875
5417.072	0.034372	0.031819
6226.740	0.036247	0.034412
6232.648	0.091667	0.083555

The reduction of the spectra, which includes dark subtraction, flat-field correction and wavelength calibration, was performed using the IRAF software package. Examples of the reduced spectra in the spectral range from 5384 Å to 5404 Å for both stars are given in Fig.1. The spectra of the two stars are very similar. Arrows mark the two spectral lines that were used for the abundance determination from this spectral range. As one can see, the line at 5386.34 Å is quite weak and the line at 5398.29 Å is of medium intensity. Both lines do not show any significant collisionally broadened wings, there are no important blends with other spectral lines and they have a clearly defined continuum on both sides of their profiles.

The spectral line profile parameters were measured with the SPE software package. The measured equivalent widths, which were used for the iron abundance determination, are presented in Table 3.

Using the appropriate Kurucz's atmosphere models and the iron spectral line parameters given in Tables 1 and 3 and the BLACKWELL software package we calculated the iron abundance for a range of microturbulent velocities. The results are illustrated in Fig. 2 which shows the iron abundances versus microturbulent velocity for both stars.

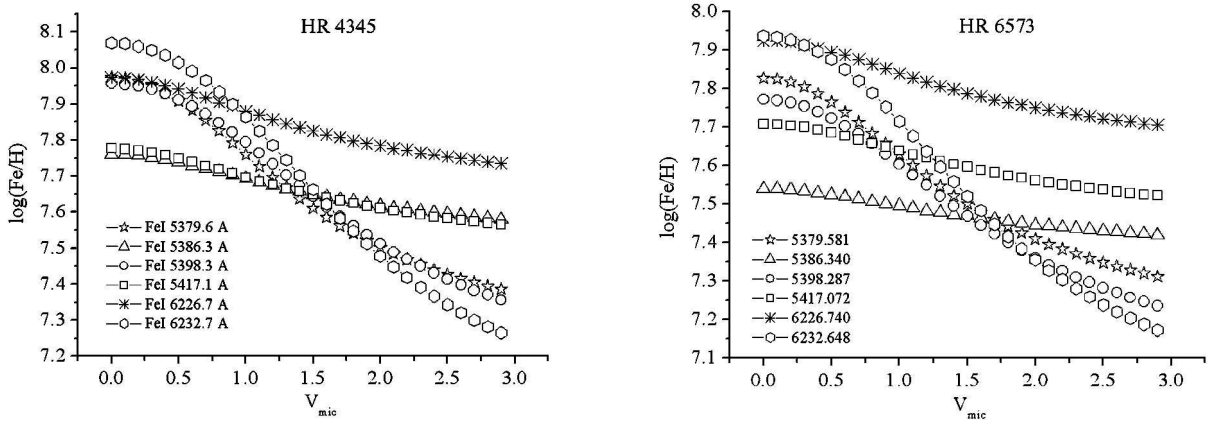

Fig. 2. *Iron abundance versus the microturbulent velocity for HR 4345 and HR 6573.*

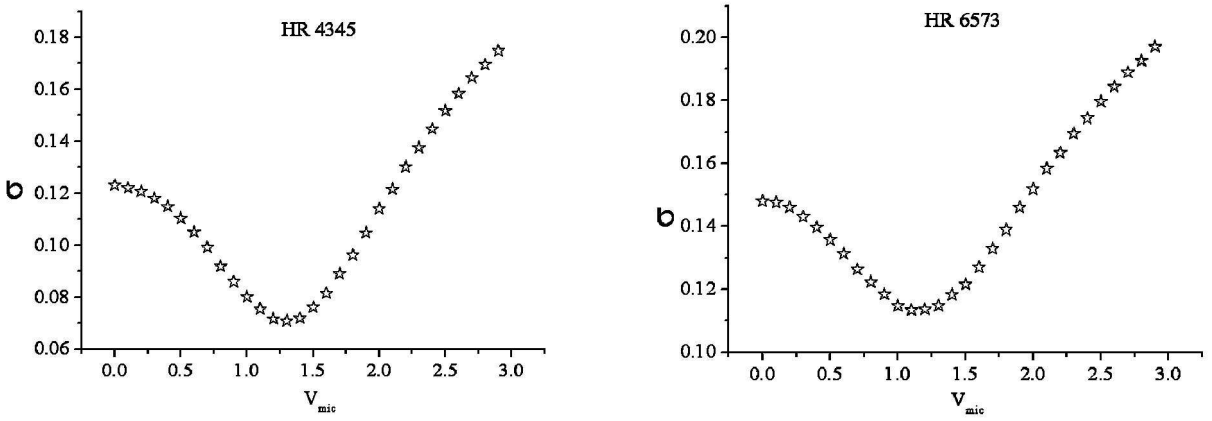

Fig. 3. *Standard deviation as a function of microturbulent velocity*

Table 4. Microturbulent velocities, iron abundances and metallicities of HR 4345 and HR 6573 obtained with the BLACKWELL software package.

Stars	V_{mic}[km/s]	log(Fe/H)	[Fe/H]
HR 4345	1.3	7.72±0.03	0.29±0.09
HR 6573	1.1	7.63±0.05	0.20±0.11

The common intersection (or the region of least confusion) of all curves defines the optimal microturbulent velocity and the iron abundance for each star. The intersection point can be determined by calculating the standard deviation in log(Fe/H) for every value of microturbulent velocity.

The dependence of standard deviation on microturbulent velocity is presented in Fig. 3. The minimum value ($\sigma_{\min}$) of this function gives the most probable value of the microturbulent velocity and the corresponding iron abundance. Dividing $\sigma_{\min}$ by $\sqrt{n}$, the standard error of iron abundance was estimated.

4. RESULTS

The microturbulent velocities and the iron abundances of the solar-like stars HR 4335 and HR 6573 obtained with the BLACKWELL software package are presented in Table 4. The obtained photospheric microturbulent velocity values of 1.3 km/s and 1.1 km/s are in agreement with values for other solar-like stars and of the sun. In order to compare the stellar iron abundances to the solar one, the metallicities were determined using the equation:

$$[Fe/H] = \log(Fe/H) - \log(Fe/H)_{\odot}$$

where $\log(Fe/H)$ is the determined stellar iron abundance and $\log(Fe/H)_{\odot}$ is the solar iron abundance. For the solar iron abundance, a value of 7.43±0.06 has been adopted. This value was inferred from neutral iron lines by Bellot, Rubio and Borrero (2002). The metallicities for both stars are presented in the last column of Table 4. As one can see, both stars considered have positive metallicity, i.e. they are slightly overabundant with metals in comparison to the sun. The star HR 4345 is almost twice, and the star HR 6573 is about 1.5 times more abundant in metals than the sun.

5. CONCLUSION

Spectral observations of high enough quality (signal to noise ratio approximately 300, spectral resolution about 35000) of HR 4345 and HR 6573 stars made with 1.52 m Coude telescope and Aurelie spectrograph, allowed us to derive precise equivalent width values for six neutral iron spectral lines. The spectral lines were selected to be as free of blend as possible and with well-known atomic parameters that are necessary in synthetic line profile calculations. To avoid the influence of saturation effect on linearity of equivalent width variation, we selected optically thin and moderately thick spectral lines.

Introducing a method based on determination of minimum dispersion in the iron abundance versus microturbulent velocity functions, the iron abundances of the HR 4345 and HR 6573 stars were found to be 7.72±0.03 and 7.63±0.05, and the corresponding microturbulent velocity values 1.3 km/s and 1.1 km/s, respectively. The abundance values are slightly greater than the iron abundance of the Sun. The derived microturbulent velocities are in agreement with typical values for solar-like stars and the corresponding value for the sun.

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ОДРЕЂИВАЊЕ ЗАСТУПЉЕНОСТИ ГВОЖЂА КОД СУНЦУ СЛИЧНИХ ЗВЕЗДА HR 4345 И HR 6573

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Оригинални научни рад

Користећи P.O. Грej-ев програмски пакет БЛЕКВЕЛ, одређена је заступљеност гвожђа код звезда HR 4345 и HR 6573 сличних Сунцу. Метода је заснована на одређивању минимума растурања (област најмањег растурања) функције зависности заступљености гвожђа од микротурбулентне брзине за неке изабране спектралне линије гвожђа. Улазни подаци које користи БЛЕКВЕЛ су посматране еквивалентне ширине неколико спектралних линија гвожђа. Оне су добијене из спектара посматраних на Опсерваторији Високе Провансе у Француској, телескопом пречника 1.52 m и спектрографом Аурелије. Редукција посматраних спектара и мерење еквивалентних ширина вршено је програмским пакетима ИРАФ и СПЕ. Мерене вредности заступљености гвожђа код звезда HR 4345 и HR 6573 су 7.72±0.03 и 7.63±0.05 респективно.