Determination of Fe I abundance of HD26574

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ABSTRACT

Many characteristics of a star can be calculated using the method of curve of growth including its chemical abundances of the atmosphere which is able to describe the chemical composition of a star. Analysis of Fe I abundances was conducted using the method of curve of growth (COG). The spectrum of star HD26574 (Beid), in the wavelength region of 4200 Å to 5000 Å was obtained from the 45 cm Cassegrain telescope at Arthur C Clarke Institute for Modern Technologies in Sri Lanka. Identification of Fe I line profiles of the spectrum of Beid was carried out by generating a synthetic spectrum using Kurucz model atmospheres. Blended lines were neglected and 12 identified Fe I peaks were used for the analysis. List of oscillator strength values, effective temperature of the star, metallicity, ionization temperature, logarithmic gravity and the value for microturbulence were adopted. Theoretical COG and the relevant calculations were conducted according to the Milen-Eddington model. By shifting the theoretical COG onto the empirical COG along the ordinate and the abscissa turbulent velocity and the number of absorbing atoms of Fe I were calculated respectively. Despite of the error caused by the oscillator strength values, calculated Fe I abundance was 7.43 $\pm$ 0.33 which is a logarithmic value.

1. INTRODUCTION

HD26574 (Beid) belongs to spectral type F0 II-III and is a bright star in the Eridanus constellation at RA: $04^h\ 11^m\ 51.94^s$ and DEC: -06° 50' 15.29". Spectrum of the star was obtained in medium resolution at 45 cm Cassegrain telescope at Arthur C. Clarke Institute for Modern Technologies with 120 seconds exposure time [1]. The relationship between equivalent width of a line profile and number of atoms absorbed from the line is called the Curve of Growth (COG) and is used to calculate the chemical abundances of stars. Apart from the chemical abundances, curve of growth can be used to determine fundamental parameters such as, the excitation temperature, ionization temperature, kinetic temperature and electron pressure of a star.

Wavelength calibration of the spectrum of the star was conducted using IRAF (Image Reduction and Analysis Facility). Calibrated wavelength measurements for H_γ and H_β were compared with the wavelength values of those hydrogen lines in air. A deviation of 0.54 Å was observed.

Absorption line profiles were identified using a synthetic spectrum created using Kurucz model atmosphere which matches with the effective temperature, Log gravity and metallicity of the star. The synthetic spectrum was generated using the SPECTRUM software. Spectrum of the star and the synthetic spectrum were plotted in the same graph and peaks were identified.

Table 1: Adopted stellar parameters of Beid

HD Number	Spectral Type	Effective Temp (K)	Gravity Log (g)	Micro Turbulences (km s^{-1})
26574	F0 II-III	7050	2.7	3.2

Analysis of Curve of growth was conducted in order to obtain Fe I abundance as number of absorbing atoms.

2. CURVE OF GROWTH ANALYSIS

2.1. Empirical Curve of Growth

Equivalent width measurements of identified Fe I peaks were obtained using IRAF by fitting different line profiles such as Gaussian and Voigt profiles. Measurements of the most suitable fit for an observed line profile were taken into account. Most of the line profiles were successfully interpreted by fitting Doppler profiles. Blended lines found in the spectrum were heavily convolved with strong absorption lines and it was found very difficult to deconvolve them. Therefore, blended lines were not considered for the analysis.

Lists of both absolute and relative oscillator strength values (dimensionless quantity) are required to construct the COG. One way is to adopt the oscillator strength values available for the Sun (spectral type G). Since Beid belongs to F spectral class the solar oscillator strength values cannot be adopted. A list of relative oscillator strength values (Log gf) of Fe I from Bridges and Kornblith [2], which were derived using a wall stabilized arc lamp, was used for the analysis (Table 2). The list was truncated for the selected wavelength region which extends from 4200 Å to 5000 Å. The analysis of empirical COG was conducted using the method given by Abhyankar [3]. Ordinate of the empirical curve was plotted as ($\log \frac{w}{\lambda}$) using the measured equivalent width values. The abscissa of the empirical curve was calculated using Eq. 1,

$$\log X = \log(gf\lambda) - \frac{5040}{T}\chi(\lambda) - \log \kappa_c \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where, T and κ_c represents the ionization temperature and the continuum absorption coefficient respectively. A value for absorption coefficient $\kappa_c = -1.14$ was adopted as a constant by considering the line absorption coefficient (κ_L) for a line close to the center line. In this case we have approximated that κ_c and κ_L values are equal at optically thin limit since identified Fe I line profiles were belonged to the optically thin limit. Also κ_c depends only on the temperature and the electron pressure. At optically thin limit, total absorption (R_λ) of a line approximates to $\chi(\lambda)$ which can be calculated using the Voigt function for Doppler profiles [4]. Calculated $\chi(\lambda)$ values for Fe I peaks at same wavelengths of a similar F spectral class star at Galactic cluster NGC 752 were adopted.

Table 2: List of oscillator strength values and measured equivalent width values for identified line profiles.

Reference Wavelength (A^0)	Measured Wavelength (A^0)	Equivalent width (A^0)	Log (gf)	χ
4247.48	4246.94	0.1810	-0.19	3.63
4282.41	4283.18	0.2526	-0.70	2.17
4290.38	4289.60	0.6501	-1.76	0.00
4315.09	4314.27	0.5023	-0.87	0.00
4325.76	4325.76	0.4213	0.03	2.19
4374.49	4374.94	0.4684	-2.08	0.00
4384.00	4384.54	0.4993	0.19	1.48
4408.42	4409.02	0.2545	-1.61	0.00
4415.12	4416.62	0.7761	-0.55	1.60
4494.57	4495.34	0.1303	-1.04	2.19
4528.62	4528.78	0.1657	-0.73	2.17
4736.78	4737.39	0.0979	-0.72	3.29

The ionization temperature of the NGC star which is 5870 K was considered for the analysis depending on three factors [5]. The most important factor is that two stars belong to the same spectral class where they tend to show similar characteristics most of the time. When it comes to effective (T_{eff}), excitation (T_{exc}) and ionization (T_{ion}) temperature of a star there is a rule of thumb as $T_{eff} > T_{exc} > T_{ion}$ [6]. Since the effective temperature of Beid is 7050 K, the adopted ionization temperature value is acceptable. Even for calculations of excitation temperature values of former studies have found probable errors from ± 400 K to $\pm$ 800 K and no considerable evidence of the change of temperature values according to the different ionization levels of elements [6].

2.2. Theoretical Curve of Growth

The theoretical COG was plotted using the $log\, \eta_0$ calculated values by Wrubel [7] according to the Milen-Eddington model. There are different studies which had published theoretical COGs and universal COGs over the last century. The ordinate and the abscissa of the theoretical COG were $\log\left(\frac{W.c}{\lambda.v}\right)$ and $\log \eta_0$ where c and v denotes the velocity of light and the turbulent velocity respectively. η is the ratio of the line absorption coefficient to the continuous one and η_0 denotes the fictitious value of η at the line centre. From the ordinate shift of the theoretical curve, turbulent velocity (v) was calculated as 2.9 km s^{-1} which is a reasonable value when compared to the adopted turbulent velocity of Beid. Hence from the shift along the abscissa, number of absorbing atoms was calculated. The shift of the abscissa yields the relationship of number of absorbing atoms according to the Eq. 2 [3].

$$\log \eta_0 - \log X = \log\left[\frac{\sqrt{\pi}\,e^2}{mcv}\,\frac{N}{B}\,\frac{f_{abs}}{gf}\right] \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.(2)$$

Here N and f_{abs} denotes the number of absorbing atoms and the absolute oscillator strength values respectively. The ratio between absolute oscillator strength values and relative oscillator strength values was assumed to be equal to 1 since we have used the oscillator strength values derived under laboratory conditions using a wall stabilized arc lamp. Also the ratio of B, $\left(B = \frac{B^0}{B'}\right)$, gives a measure of limb darkening which is equal to $\frac{1}{3}$ at the blue region or the Balmer wavelength region [8].

3. RESULTS AND DISCUSSION

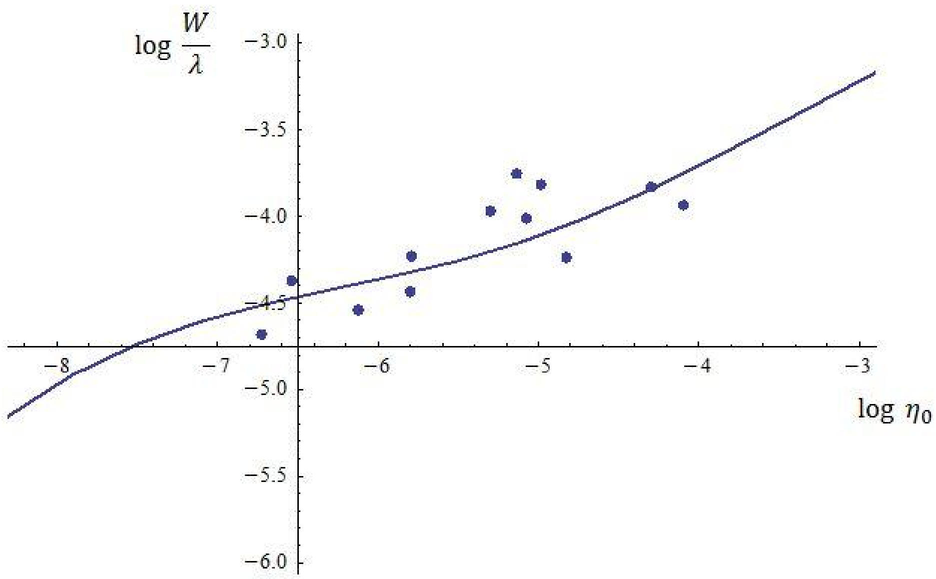

Fig. 1: Curve of growth of HD26574 for Fe I. Solid line represents the shifted theoretical curve [7].

Derived number of absorbing atoms or the column density, $\log(N_{Fe\,I})$ of Fe I was 7.43. The uncertainty for adopted oscillator strength values [2], vary from 5% to 15%. The uncertainty due to calibration of wavelength of the spectrum was 0.54 Å. During the measurements of equivalent widths an exact uncertainty cannot be defined. Since the equivalent width is measured considering the continuum of the spectrum. The standard deviation of the empirical plot with 90% confidence interval is 0.33. The new value derived for atomic Iron abundance 7.43 is in agreement with the value 7.40 given by Luck and Wepfer [6], within the uncertainties of the observations & adopted parameters such as oscillator strength values and broadening parameter.

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