Astron. Astrophys. 323, 393–394 (1997)

ASTRONOMY AND ASTROPHYSICS

The iron abundance in helium star HD 144941*

C.S. Jeffery[1] **and P.M. Harrison**[2]

[1] Armagh Observatory, College Hill, Armagh BT61 9DG, Northern Ireland
[2] Dept of Physics & Astronomy, University of St Andrews, Fife KY16 9SS, UK

Received 14 October 1996 / Accepted 29 October 1996

Abstract. The iron abundance in the helium star HD 144941 has been measured from ultraviolet Fe III lines. It is 1.9 ± 0.2 dex below solar and confirms the low metallicity (Z = 0.0003) previously determined from measurements of CNO and other light elements. The result is important because the low CNO metallicity must be reflected in the iron-group elements in order to explain why HD 144941 does not show pulsations.

Key words: stars: helium – stars: individual (HD 144941) – stars: abundances

1. Introduction

It has been well-established that high-luminosity helium stars ($L/M \gtrsim 10^4$) are unstable against radial or non-radial pulsations at effective temperatures up to at least 30 000 K (Saio & Jeffery 1988). An explanation for pulsations in the lower-luminosity helium star V652 Her (Hill et al. 1981) was only obtained (Saio 1993) with the publication of new opacities. These opacities (Iglesias et al. 1992) show a peak due to iron-group elements in the region of 10^6K capable of driving pulsations in low-luminosity helium stars with $T_{\rm eff} \sim 25\,000$K. The success of the theory was vindicated by the prediction (Saio 1995) and discovery (Kilkenny & Koen 1995) of pulsations in the helium star LSS 3184. A problem was that the helium star HD 144941 shows no evidence for pulsations (Jeffery & Hill 1996, Paper I), although it lies in the same pulsational instability strip (Harrison & Jeffery 1996, Paper II). A possible solution and an important test of the theory lay in the prediction that the extent of the pulsational instability finger to low luminosity is strongly metal-dependent (Saio 1995). Measurements of light elements (C,N,O,Si,S) in V652 Her (Jeffery et al. 1986), LSS 3184 (Drilling et al. 1996) and HD 144941 (Paper II) appeared to confirm this.

However pulsations are driven by iron-group elements and the optical spectra of these stars contain only a few weak lines of Fe III. In particular, the iron abundance in HD 144941 had been measured from only one very weak line (Paper II) and indicated an iron underabundance (relative to solar) roughly 0.5 dex smaller than for lighter elements. Thus it is vital to confirm the iron abundance of HD 144941 in order to interpret the absence of pulsations correctly.

2. Observations

Two well-exposed high-resolution spectra of HD 144941 were obtained with the IUE SWP camera (image numbers SWP23961 and SWP23962) and have already been used to investigate the stellar wind (Jeffery et al. 1987). The region between 1830Å and 1960Å is known to contain a number of strong Fe III lines. Kurucz' (1992) list of lines with accurate wavelengths reveals 1020 Fe III transitions, of which 280 have $gf > 0.1$, many of which are clearly present in the IUE spectrum of HD 144941.

Since $T_{\rm eff}$ and $\log g$ have already been derived from a high-resolution high-S/N optical spectrum (Paper II), and an appropriate model atmosphere exists it was decided to synthesize the Fe III spectrum of HD 144941 in the ultraviolet in order to determine the iron abundance.

3. Iron abundance

The LTE radiative transfer program SPECTRUM (Dufton, Lennon, Conlon & Jeffery, unpublished) and the Kurucz list of theoretical probabilities for transitions between measured energy levels were used to synthesize spectra including contributions from all species in the wavelength interval 1880 – 1920 Å. As a starting approximation, all abundances were set 1.5 dex below solar. Comparing the result with a spectrum containing only Fe III lines it was clear that very few lines of other species contribute in this region.

The synthetic spectrum was convolved with an instrumental profile (Gaussian FWHM=0.2Å). The continuum level of the observed spectrum was adjusted to match the continuum of the synthetic spectrum, which can be identified with reasonable confidence despite the line crowding.

There are line-to-line variations in the quality of the fit (Fig. 1). These are due to errors in the adopted gf-values, ob-

Send offprint requests to: C.S.Jeffery
* Based on observations obtained with the IUE satellite

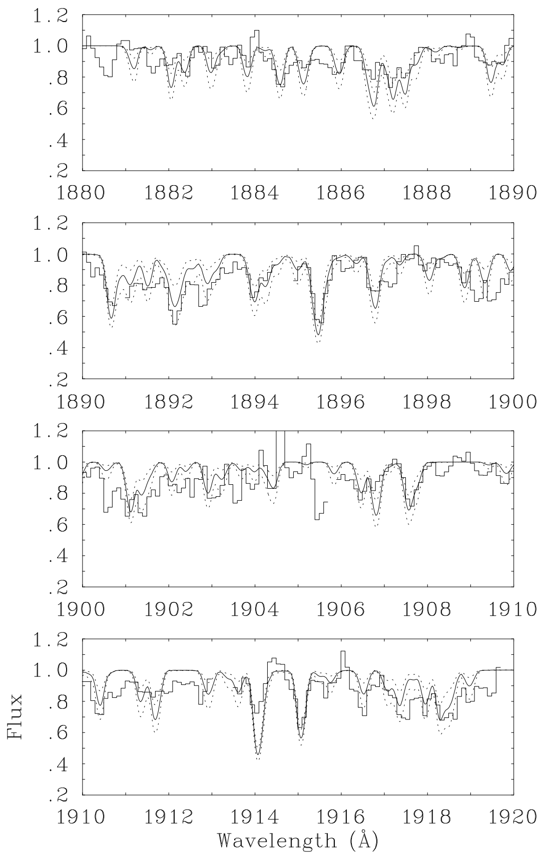

Fig. 1. The IUE high-resolution spectrum of HD 144941 (histogram) compared with three synthetic spectra, with $\log n_{\rm Fe} = -5.8$ (smooth line) ± 0.4 (dotted lines) and $v_{\rm t}$ = 5 km/s.

served lines not present in Kurucz' linelist and noise in the observations. A comparison of thirteen predicted transition probabilities (Ekberg 1993) revealed one significant discrepancy (λ1901.10Å) in favour of the observed spectrum.

With both strong and weak Fe III lines accessible, it was possible to check the value of the microturbulent velocity ($v_{\rm t}$). Jeffery et al. (1987) had determined $v_{\rm t}$ = 10 km/s from fits to the C II λ1324 Å line profile, which is sensitive to the adopted microturbulence. For the Fe III lines, both $v_{\rm t}$ and $n_{\rm Fe}$ were determined by minimizing the integrated square residual between the observed and synthetic spectra in the interval 1880 - 1920 Å. The best fit was obtained with $v_{\rm t} = 5 \pm 5$ km/s and $\log n_{\rm Fe}/n_{\rm He} = -5.8 \pm 0.2$ (Fig. 1). There is not sufficient S/N and resolution in the observed spectrum, or confidence in the atomic data, to rule out the value of $v_{\rm t}$ = 10 km/s adopted in Paper II. Increasing $v_{\rm t}$ by 5 km/s reduces $n_{\rm Fe}$ by $<< 0.1$ dex. It reduces the CNO abundances by < 0.05 dex.

Normalizing to $\log \Sigma \mu_{\rm i} n_{\rm i} = 12.15$ gives $\log n_{\rm Fe} = 5.7 \pm 0.2$, compared with a solar value of $\log n_{\rm Fe} = 7.48$ (Holweger et al. 1990), implying that iron is underabundant in HD 144941 by 1.8 ± 0.2 dex. This is in excellent agreement with the well-determined CNO abundances (Paper II).

4. Pulsations in helium stars

The improved iron abundance indicates a fractional heavy element abundance (by mass) of $Z = 0.00024$ and that the iron-group abundances follow the CNO abundances. It confirms that the absence of pulsations in HD 144941 (Paper I) is due to its very low metallicity.

References

Drilling J.S., Jeffery C.S., Heber U.: 1996. A&A, submitted
Ekberg J.O.: 1993. A&AS 101, 1
Harrison P.M., Jeffery C.S.: 1996, A&A in press (Paper II)
Hill P.W., Lynas-Gray A.E., Kilkenny D., Walker H.J.: 1981, MNRAS 197, 81
Holweger H., Heise C., Kock, M.: 1990, A&A 232, 510
Jeffery C.S., Heber U., Hamann W.-R., 1987. New Insights in Astrophysics, ESA SP-263, 369.
Jeffery C.S., Heber U., Hill P.W.: 1986, Hydrogen-deficient stars and related objects, IAU Coll. 87, p. 101, Hunger K., Schönberner D. & Rao N.K., Reidel, Dordrecht, Holland.
Jeffery C.S., Hill P.W.: 1996, Observatory 116, 156 (Paper I)
Kilkenny D., Koen C.: 1995, MNRAS 275, 326
Kurucz R.L.: 1992, Stellar atmospheres: beyond classical models, p. 441, Crivellari L., Hubeny I., & Hummer D.G., Kluwer, Dordrecht, The Netherlands
Iglesias C.A., Rogers F.J., Wilson B.G.: 1992, ApJ 397, 717
Saio H., Jeffery C.S.: 1988, ApJ 328, 714
Saio H.: 1993, MNRAS 260, 465
Saio H.: 1995, MNRAS 277, 1393

This article was processed by the author using Springer-Verlag LaTeX A&A style file *L-AA* version 3.