Baltic Astronomy, vol. 15, 163–166, 2006.

NON-LTE METAL ABUNDANCES IN V652 HER AND HD 144941

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Received 2005 July 31

Abstract. Two evolutionary scenarios are proposed for the formation of extreme helium stars: a post-AGB star suffering from a late thermal pulse, or the merger of two white dwarfs. An identification of the evolutionary channel for individual objects has to rely on surface abundances. We present preliminary results from a non-LTE analysis of CNO, Mg and S for two unique objects, V652 Her and HD 144941. Non-LTE abundance corrections for these elements range from negligible values to ∼0.7 dex. Non-LTE effects typically lead to systematic shifts in the abundances relative to LTE and reduce the uncertainties.

Key words: line: formation – stars: abundances – stars: atmospheres – stars: evolution – stars: individual (V652 Her, HD 144941)

1. INTRODUCTION

Extreme helium stars (EHes) are a rare class of low-mass H-deficient objects with spectral characteristics similar to those of B-giants. Most of the two dozen known EHes could be explained by post-AGB evolution, linking R CrB stars to Wolf-Rayet type central stars of planetary nebulae, see Heber (1986) and Jeffery (1996) for reviews. The two stars studied here, V652 Her and HD 144941, are unique among the class members because of surface gravities too high for post-AGB evolution and atypical surface abundances. A merger of two He white dwarfs was suggested for the evolutionary origin of V652 Her (Saio & Jeffery 2000). The chemical composition puts important observational constraints on evolutionary scenarios. However, all elemental abundance analyses of EHes to date are based on the *assumption* of local thermodynamic equilibrium (LTE), therefore being subject to potential systematic uncertainties. We investigate here which improvements can be expected from a state-of-the-art non-LTE abundance analysis.

2. MODELS, OBSERVATIONS AND STELLAR PARAMETERS

The model calculations are carried out in a hybrid non-LTE approach, see Przybilla et al. (2005) for details. In brief, the atmospheric structure computations are performed using Atlas12 (Kurucz 1996) for an appropriate chemical mixture.

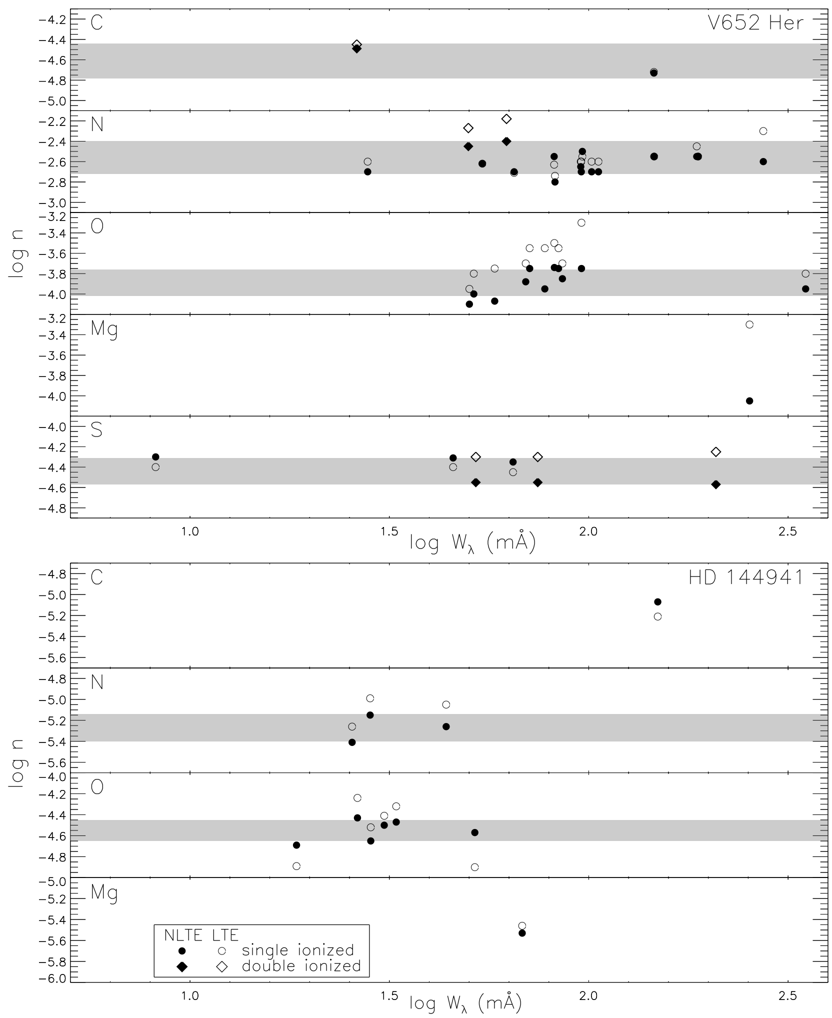

Fig. 1. Elemental abundances in the sample EHes from individual spectral lines

Table 1. Non-LTE model atoms.

Ion	Source
H	Przybilla & Butler (2004)
He I/II	Przybilla (2005)
C II/III	Nieva & Przybilla (in prep.)
N II/III	Przybilla & Butler (2001), with extensions
O II	Becker & Butler (1988)
Mg II	Przybilla et al. (2001)
S II/III	Vrancken et al. (1996), with updated atomic data

Table 2. Stellar parameters.

	V652 Her ($R_{\rm max}$)	HD 144941
$T_{\rm eff}$ (K)	22 000±500	22 000±1 000
$\log g$	3.20±0.10	4.15±0.10
ξ (km/s)	4±1	8±2
$n_{\rm H}^{\rm NLTE}$	0.005±0.0005	0.035±0.005

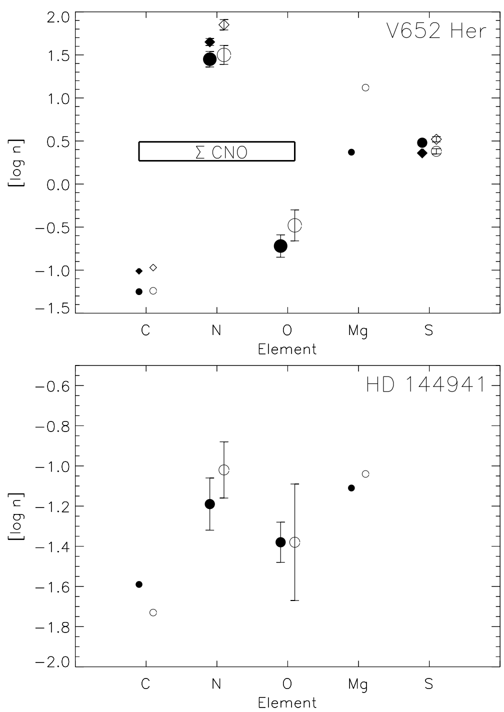

Fig. 2. Metal abundances in the sample EHes (symbols as in Fig. 1)

Note that metal bound-free opacities are of minor importance for the two objects. Then, non-LTE line-formation is carried out on the resulting model stratifications. Updated and improved versions of DETAIL and SURFACE (Giddings 1981; Butler & Giddings 1985) are used for this, in combination with state-of-the-art non-LTE model atoms, see Table 1. High-resolution spectra at high-S/N are adopted for the analysis. Details on observations and data reduction are discussed by Jeffery et al. (2001) and Harrison & Jeffery (1997). The final model parameters are summarized in Table 2, including microturbulence ξ and H abundance $n_{\rm H}^{\rm NLTE}$ (by number). They are derived from the He I/II ionization equilibrium, Stark-broadened He I lines and H Balmer line strengths, using state-of the-art model atoms.

3. NON-LTE ABUNDANCES

Elemental abundances are derived from line-profile fits, using a χ^2-minimization technique based on small grids of synthetic spectra with varying metal abundances for given stellar parameters. This puts tighter constraints than the standard equivalent-width analysis. Abundances (by number) from individual spectral lines as a function of equivalent width W_λ are displayed in Figure 1. The grey bands indicate the 1σ-uncertainty range of the resulting abundances for the chemical species.

The non-LTE analysis reveals: (i) a reduction of systematic trends of abundance with W_λ, (ii) systematic shifts in the abundances relative to LTE, implying a downward revision in most cases and (iii) a potential for reducing the statistical scatter by a significant amount, e.g., for O II in HD 144941. Non-LTE abundance corrections for individual lines can be as large as $\sim$0.7 dex (Mg II at 4481 Å in V652 Her), but usually they are (much) smaller. Note that the available spectra cover only a restricted wavelength range, such that the analysis has to rely on a rather small number of metal lines. Consequently, we view our results as preliminary, also because of residual uncertainties in the stellar parameter determination, which are indicated by a slight mismatch in the metal ionization equilibria in V652 Her. The situation is more aggravated in HD 144941 because of its strong metal-deficiency that is larger than in any other EHe star. The only metal ionization equilibrium available for an independent verification of the stellar parameter determination is that of silicon, for which we lack a reliable non-LTE model atom at present (the model atom of Becker & Butler (1990) is too rudimentary in Si II).

The abundance patterns in the sample stars relative to the solar standard (Grevesse & Sauval 1998) are discussed in Figure 2. For each ionic species non-LTE and LTE results with uncertainties derived from the line-to-line scatter are displayed, using the same symbols as in Figure 1. The symbol size encodes the number of lines used for the abundance determination.

Both stars exhibit CNO-processed material in their atmospheres. For V652 Her the sum of CNO-abundances correlates well with the super-solar metallicity as indicated by the magnesium and sulphur abundances. Note the large non-LTE correction for magnesium, by a factor ∼5. Enhanced magnesium abundances as derived from LTE analyses of several EHe stars have been controversial because they cannot be consistently explained by nucleosynthesis (Jeffery 1996). The current findings indicate a solution of this issue. No further conclusions can be drawn for HD 144941 at present. We intend to extend the non-LTE study to aluminum, silicon and iron in the near future in order to complete the diagnostic inventory.

The preliminary non-LTE analysis of the two unique hydrogen-deficient, high-gravity objects V652 Her and HD 144941 does not drastically change our view of their evolutionary origin as constrained from surface abundances. While the non-LTE abundance corrections are small in most cases, they can be highly important in other cases. Accounting for non-LTE effects improves on the significance of abundance studies of extreme helium stars.

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