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PARAMETERS T_{eff} AND $L/L_\odot$ FOR A GROUP OF λ BOOTIS CANDIDATE STARS AND THEIR EVOLUTIONARY STATUS

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ABSTRACT The T_{eff} value, according to the definition of this parameter, is computed with the procedure described; the observations are then compared with the flux distribution from Kurucz' LTE blanketed models for various values of the metallicity parameter [Z/H].

Then we derive the bolometric luminosity $L/L_\odot$ by combining the stellar bolometric flux with the values of the trigonometric parallaxes and of the colour excess found in the literature. These luminosities are then plotted on evolutionary sequences; from the position of some λ Boo stars (ρ Vir and π^1 Ori), we argue that their evolutionary stage, if interpreted as that of stars having left the main sequence, is too late to keep the λ Boo abundance anomalies.

These same λ Boo stars, plotted on pre-main sequence evolutionary tracks, would indicate increasing λ Boo character when the stars are approaching the main sequence showing the strongest character in λ Boo and 29 Cyg, the two stars nearest the ZAMS.

INTRODUCTION

There has recently been a revival of interest in the λ Boo stars. We stress that the importance of this small group of stars is related to the fact that they might represent the very last stage of stars arriving on the main-sequence. Their pattern of abundance, depleted of the iron-peak elements, has been shown by Venn and Lambert (1990) to be similar to that of the interstellar medium, as well as to that of some peculiar post-AGB stars. So, these authors suggested that these abundance anomalies could be understood in terms of depletion of the low-abundance elements onto grains. Scenarios for such depletion have been proposed by Mathis and Lamers (1992) and by Waters et al. (1992). The mechanism could be the following: near a λ Boo star there is a surrounding disk of gas and dust, a remnant of the circumstellar envelope from which the star has been formed. Iron-peak elements are accreted onto the grains leaving a depleted gas. The stellar radiation exerts pressure on the grains, while the gas is accreted by the star, thus creating a metal-depleted atmosphere on the surface. Later on, mixing with the underlying region removes these abundance anomalies.

Of great importance to our understanding of these stars is the knowledge of their basic parameters, to correctly determine their position in the HR diagram. Hence, in this paper we present a determination of T_{eff} and the luminosity $L/L_\odot$ for a set of λ Boo stars and some related objects (Table 1).

Table 1.: Parameters T_{eff} and $\log L/L_\odot$ computed with [Z/H] = −1.0 but for HD 210418 where [Z/H] = −0.5. For all stars E(B-V) = 0.0 was used.

HD	*Name*	T_{eff}	$\log L/L_\odot$	*comments*
31295	π^1 Ori	8560	1.471	λ Boo-star
39060	β Pic	7610	0.800	
39283	ξ Aur	8640	1.666	"metal weak"
98353	55 UMa	8350	1.289	MgII weak
110411	ρ Vir	8630	1.520	λ Boo-star
125162	λ Boo	8490	1.038	λ Boo-star
161868	γ Oph	8910	1.363	MgII weak
172167	Vega	9280	1.720	
192640	29 Cyg	7940	0.825	λ Boo-star
210418	θ Peg	8440	1.123	MgII weak
220061	τ Peg	7660	0.928	MgII weak

DETERMINATION OF T_{eff} AND $L/L_\odot$

As there is no measured angular diameter for the stars studied in this paper, we used an indirect procedure to determine T_{eff}. This method is based: a) on an iterative Blackwell and Shallis (1977)-like method; b) on visual and near-IR ground-based flux observations (13-colour photometry of Johnson and Mitchel (1975)), and on UV fluxes obtained by TD1 space observations; c) on classical LTE line-blanketed metal-underabundant model atmospheres (Kurucz 1990). For all stars we used models having metal abundances [Z/H] = −1.0 except for HD 210418 where [Z/H] = −0.5 gives the best fit of the observations with the models. In all cases we considered that the ISM absorption colour excess is E(B-V) = 0.0. This value may imply some error in the estimate of the stellar bolometric flux f used in $f = (\sigma/4)\theta^2 T_{eff}^4$ to determine the stellar angular diameter θ and T_{eff}; we recall that uncertainties on the colour excess of the order of $|\delta E(B\text{-}V)| \simeq 0.02$ mag, imply errors on T_{eff} determinations ranging from 3 % to 1.2 % depending on the sign of δE. Although the temperature T_{eff} was obtained using log g = 4.0, we point out that T_{eff} determined by this method does not significantly depend on the value chosen for log g, which mainly enters into the determination of $\theta \propto f_\lambda^{obs}/f_\lambda^{mod}(T_{eff}, \log g)$ at $\lambda > 8500 Å$. It may, however, depend on the model used, mainly owing to the chemical abundances adopted. At temperatures $T_{eff} \lesssim 9000$ K, underabundant models lead to higher values of θ compared to those obtained for [Z/H] = 0.0. These, in turn, produce lower values of T_{eff}. Using models of Kurucz (1979), the values of T_{eff} are systematically higher compared to those derived from models of Kurucz (1990), but the differences are not very important.

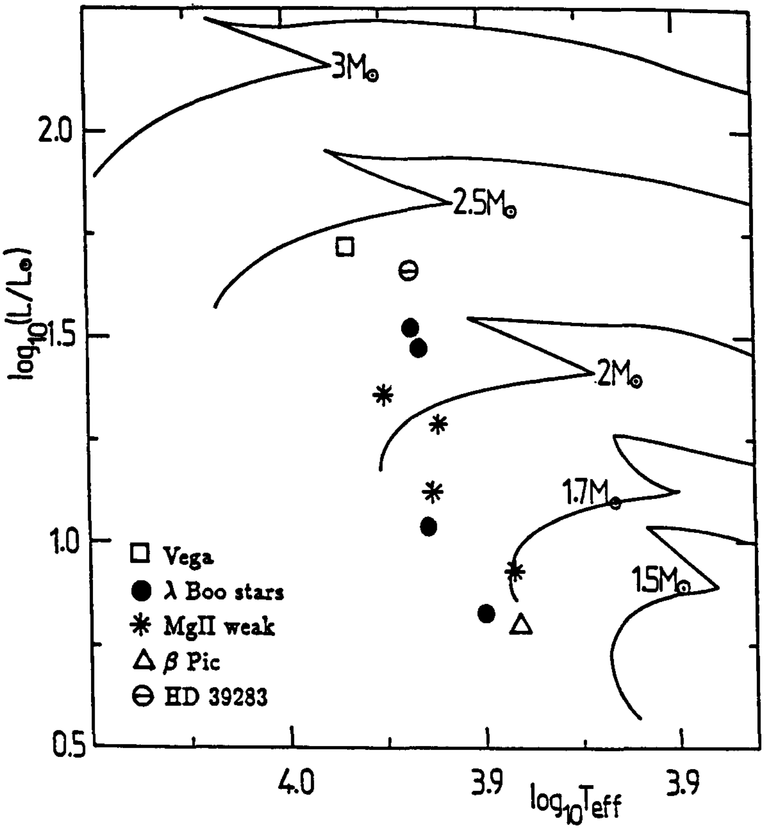

Fig. 1 HR diagram of the programme stars using the parameters given in Table 1. The evolutionary tracks are from Maeder and Meynet (1988).

To give a test of our T_{eff} determinations, we present the parameters obtained by this method for *Vega* (HD 172167), which is considered by some authors as a mild λ Boo-type. The value of T_{eff} given in Table 1 was obtained for [Z/H] = −1.0. However, when [Z/H] = −0.5 is used, the value T_{eff} = 9340 K is obtained, and for [Z/H] = 0.0 the temperature becomes T_{eff} = 9420 K which is almost the same as that given by Kurucz (1979): T_{eff} =

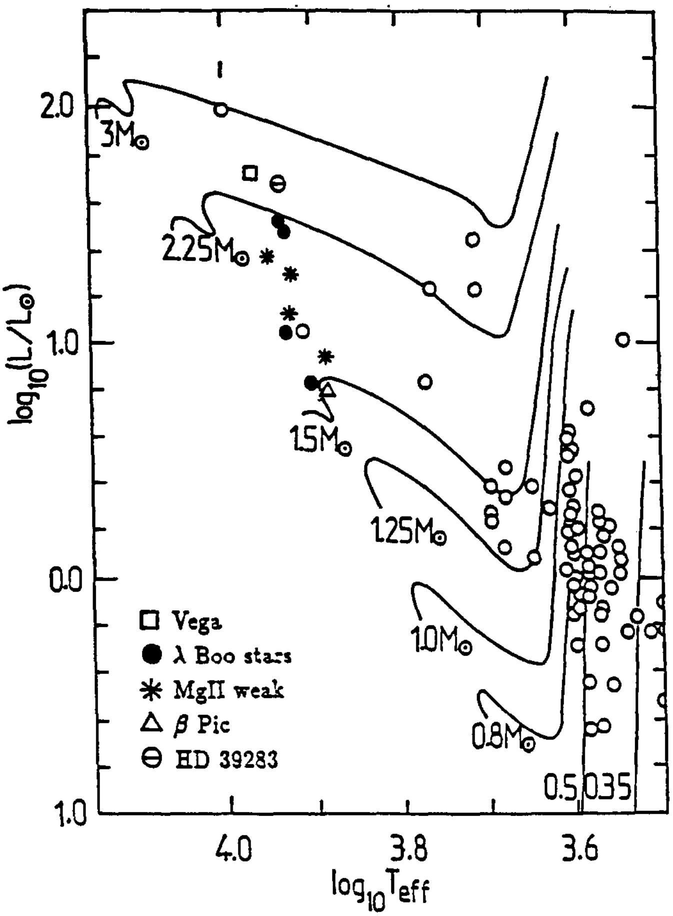

Fig. 2 HR diagram of the programme stars using the parameters given in Table 1. The pre-main-sequence evolutionary tracks and positions of young stars (○) are from Bodenheimer (1988).

9400 K. Nevertheless, the best fit of the calculated fluxes with the observations is obtained for [Z/H] = −1.0. We also note that the temperature of β Pic obtained here is lower than that given by Paresce (1991: T_{eff} = 8200, log g = 4.2). For the three λ Boo stars (π^1 Ori, λ Boo, 29 Cyg) studied by Venn and Lambert (1990), the temperatures obtained here are about 170 K lower than those adopted by these authors.

At $\lambda \lesssim 1700$Å the fit with the observed energy distributions of models computed for the T_{eff} obtained here, may still depend somewhat on the log g parameter, mostly when $T_{eff} \lesssim 8000$ K.

The bolometric luminosity $L/L_\odot$ is obtained by using the relation $L = 4\pi d^2(f_{obs} + \delta f_{mod})$ where f_{obs} is the integral of observed fluxes and δf_{mod}

is the integral of model-fluxes depending on T_{eff} and represents the non observed spectral region. The most important errors affecting $L/L_\odot$ are due to the distance d and to the E(B-V) determinations. For d we used the mean value obtained from ground-based trigonometrical parallaxes reported in the literature. The values obtained of log $L/L_\odot$ are given in Table 1.

THE HR DIAGRAM

In Figure 1 are plotted the stars of Table 1. This figure also displayes the evolutionary sequences computed by Maeder and Meynet (1988). Very near the main sequence, these tracks are similar to the most recent ones obtained by the same authors, so they can be used for the present purpose.

In Figure 2, the same stars are plotted together with a set of young stars over a pattern of pre-main sequence evolutionary tracks (Figure 11 from Bodenheimer (1988)). Considering the fact that the existence of evolved λ Boo stars has not been proved up to now (Gray 1988), and taking into account the position of ρ Vir and π^1 Ori in these two figures, we speculate that perhaps these stars are on their way to reaching the main sequence. In this respect, another argument can be used: from the position of λ Boo and 29 Cyg we can conclude that, when these stars are near the main-sequence or just arriving on it, the mechanism of accreting the depleted circumstellar gas is at its maximum, or at least, has produced a noticeable under-abundance. We notice that in Figure 1 ρ Vir and π^1 Ori occupy the region of slightly evolved stars. So, we can estimate their age using computed tracks of stellar evolution. This appears to be about 1000×10^6 yr. At the age estimated for ρ Vir and π^1 Ori, if considered as having left the main sequence, underabundances would be at the maximum according to the Michaud and Charland (1986) and Charbonneau (1991) models of chemical separation in the presence of mass-loss or of accretion-diffusion, contrary to the observations.

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