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LETTER

Letter to the Editor

HD 111786 : a spectroscopic binary λ Boo star*

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Abstract. HD 111786=HR 4881 is one of the most interesting λ Boo stars; in fact it is one of the few stars of this class which shows narrow features that can be interpreted as remnants of the circumstellar matter from which star was formed. On the basis of optical observations and inspection of IUE spectra, we demonstrate that HD 111786 is, as a matter of fact, a binary system and that one of the component is characterized by a narrow line spectrum; the main contribution to the narrow absorptions is not that of circumstellar gas related to the λ Boo phenomenon, but is due to the photosphere of the companion star.

Key words: stars : individual : HD 111786 - stars : atmospheres - stars : circumstellar matter

1. Introduction.

In order to understand the evolutionary status of the A-type stars belonging to the group of the λ Boo stars, a systematic search of circumstellar (CS) gas has been recently conducted by Holweger and Rentzsch-Holm (1995). The presence of CS gas around HD 111786 (HR 4881) has been confirmed by these authors. According to its properties, this star deserves special attention.

In their refined MK classification Gray and Garrison (1987) assign the type A1.5 a^{-} λ Boo to HD 111786 with the remark that "metals are normal for a A1.5 star except that λ4481 is very weak, and $\lambda\lambda$4447, 4226 and 4233 are slightly strong for the spectral type".

Later on, Gray (1988) pointed out the "unusual morphology of the spectrum" and the weakness of many Fe II lines. The discovery of a weak and narrow absorption core in the Ca II K line profile was also reported and interpreted as probably due to circumstellar material. A further remark concerns the Balmer line profiles which are peculiar showing weak cores with very broad, but shallow wings.

Holweger and Rentzsch-Holm (1995) note that this star is unique among the stars of the "β Pic category" because it has one single strong CS component that varies. On the basis of the constant radial velocity of this star derived by Nordström and Andersen (1985), they confirm the interpretation of the circumstellar origin of the narrow absorption in the core of the Ca II K line.

The intriguing properties of HD 111786 prompt us to investigate an alternative hypothesis about their origin: that of the double nature of its spectrum.

A search of the published notes on this star confirmed that several other peculiarities were detected by various authors. Let us quote one concerning the different spectral types assigned to this star. Its MK type (Michigan, 1982) is A0 III, while Andersen and Nordström (1977) classify it as A3p with the quite inconsistent remark for a λ Boo candidate: " Probably λ Boo star: neutral lines strong, Ca II K and Mg II λ4481 weak. Fast rotation and low radial velocity" and Baschek et al. (1984) classify the star A5 from its overall UV spectrum.

2. Observation.

One spectrum has been taken with the Echelec spectrograph mounted at the 1.5m ESO telescope on 3 April 1993. The chosen spectral range is 4210-4500 A. The resolution is 28000. The reduction of the observations were done as described by Burnage and Gerbaldi (1992). Most of the processing has been done in Midas except for the cross-correlation program which has been written by one of us (R.B.) in the Midas environnement in order to fit in a Midas procedure. This program differs from the Midas command XCORRELATE in the sense that the correlation index is normalized and ranges from 0 to 1. The template (synthetic spectrum) and the spectrum of the star, after the cali-

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* Based on observations collected at the European Southern Observatory (ESO), and on data from the International Ultraviolet Explorer of the European Space Agency.

bration in wavelength, are rebinned in logarithm, the rebinning being largely oversampled. The shift between the template and the spectrum is computed by cross correlation. In the process, the correlation curve obtained will show the signs of an eventual multiplicity of the star by displaying secondary maxima. All details of this procedure and of the program are available on request.

3. Analysis.

At first glance, it appears that the core of H_γ is blended. Such profile can be easily interpreted as due to a composite spectrum. To prove it, we have computed synthetic spectra from Kurucz models (1993); that computed with the parameters T_{eff}=7500 K, log g=4.0, solar abundances and vsini=10 km s^1 is overlapped on the observations in Fig.1.

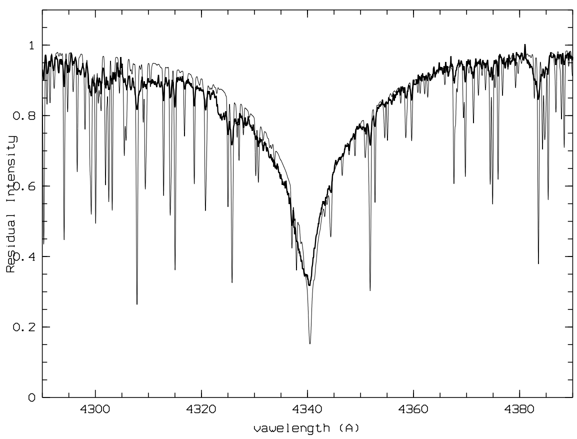

Fig. 1. The observed normalized spectrum in the region of H_γ (thick line) overlapped on the computed one (thin line).

The atmospheric parameters were determined from the Moon (1985) and Moon and Dworetsky (1985) calibrations of the Strömgren photometry. It results that HD 111786 is an unreddened star with T_{eff}=7450 K, log g =3.93; we underline that these parameters are very unusual for an A0 III star.

There is no inconsistency between the values of the colour indices of the Strömgrem system which would have been detected by a flag in Moon and Dworetsky programs; however we recall that the values of either (b-y) and (B-V)=0.23 indicate that the slope of the Paschen continuum is that of a late A-early F star.

Hauck and Slettebak (1983) had already noticed the very pronounced too red B2-V1 Geneva colour of this star for the A3p spectral type adopted by them.

We have correlated the observed spectrum with a computed one, adopting the following parameters : T_{eff}=7500 K, log g =4.0, solar abundances, vsini=5 km s^{-1} and a resolution (R=30000) just at the highest limit of that of our equipment. The result is plotted in Fig. 2: there is a double peak of correlation.

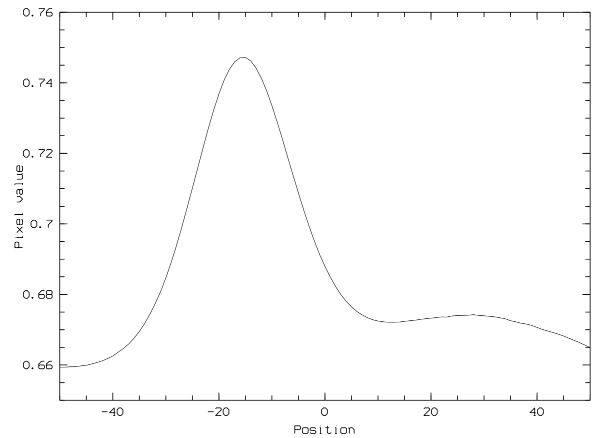

Fig. 2. Correlation between the observed spectrum and the computed one with T_{eff}=7500 K, log g =4.0, solar abundances and vsini=5 km s^{-1}. The abscissae, given in km s^{-1}, represents the difference between the observed and the theoretical spectrum.

We interpret the two correlation peaks as the result of two spectra blended, but having different radial velocities, these being separated by about 40 km s^{-1}.

The comparison between the observed and the synthetic spectrum shows that the observed spectrum has the appearence of a narrow system of lines superimposed on a spectrum with broad lines, as it has been already remarked by Stürenburg (1993) and, even earlier, by Holweger and Stürenburg (1991); however, in both papers, these narrow features were interpreted as circumstellar lines overimposed on the photospheric spectrum.

We have adjusted the broadening of the synthetic spectrum, computed with the atmospheric parameters previously quoted, in order to fit the width of the narrow system of lines; this broadening is 10 km s^{-1}.

Then, a second synthetic spectrum is computed with, as only difference, vsini=150 km s^{-1}. This latter vsini results from the aspect of the spectrum and the measure of Stürenburg (1993). Finally, we summed the fluxes of the two theoretical spectra , having shifted that brodened at 150 km s^{-1} by -40 km s^{-1}, and then, normalized this combined spectrum.

The overlap of the observed spectrum with these three computed ones, for the spectral range centered on λ4227, is plotted in Fig. 3 , 4, and 5. The “best” fit is obtained on Fig 5 with the composite synthetic spectrum. Almost all the narrow absorption features correspond to features of the synthetic spectrum; there are few exceptions, but easily explainable by the fact that the adopted parameters are derived from the composite flux.

An higher flux from the broad lined component is requested to reduce the depth of the narrow absorptions for fitting improvement; this is tantamount to say that the broad lined component has a higher temperature than the narrow lined one.

All over our observed spectrum, we have the same conclusion: the strongest lines of the spectrum are partly filled by a secondary broad component. Everywhere the narrow lines are too deep in the computed spectrum, if the same parameters are

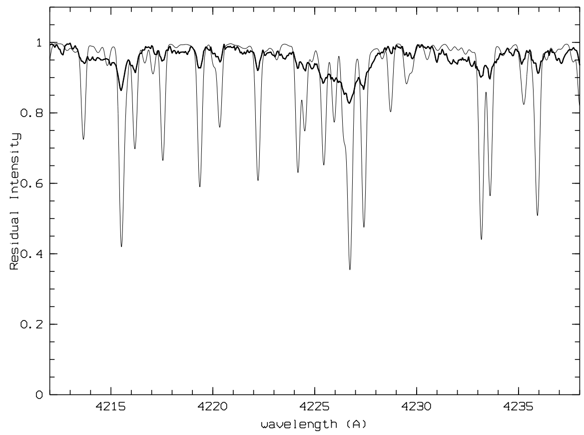

Fig. 3. The overlap of the observed spectrum (thick line) in the range around 4227 A on the computed spectrum with broadening=10 km s^{-1} (thin line).

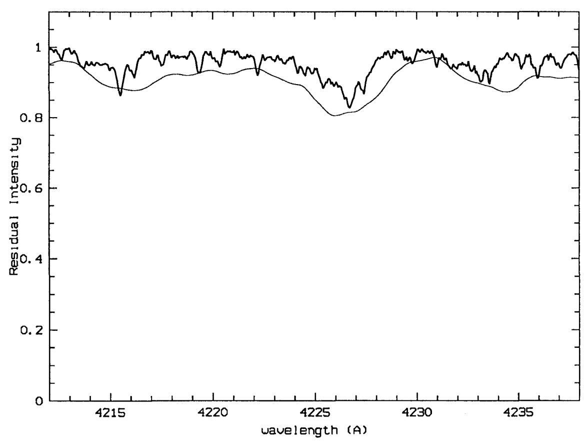

Fig. 4. The overlap of the observed spectrum (thick line) in the range around 4227 A on the computed spectrum with broadening=150 km s^{-1} (thin line).

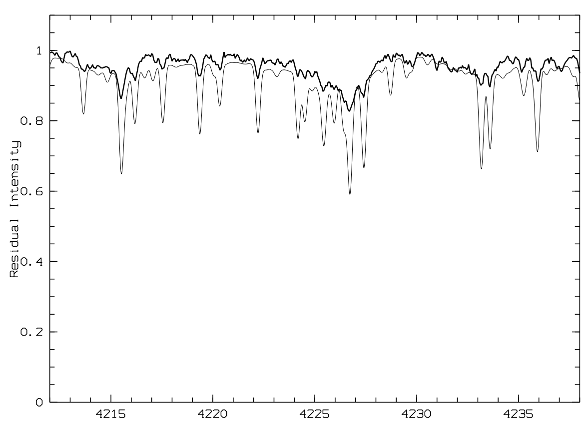

Fig. 5. The overlap of the observed spectrum (thick line) in the range around 4227 A on the computed combined spectrum with the two broadenings (thin line).

adopted for the two components, but without any knowledge of the difference in luminosity between the two components, any further attempt would have produced only better results aesthetically speaking.

Since the observations in the visual range suggest that the component with the higher vsini has an higher effective temperature, in the UV this component should predominate.

4. UV observations.

In our analysis of the UV spectra of λ Boo stars (Faraggiana et al. 1990) we concluded that the IUE spectrum of this star, taken in the short wavelength domain, shows clear caracteristics of the λ Boo phenomenon as they are illustrated in Faraggiana and Gerbaldi (1990).

The flux distribution below 2000 A is much higher than that expected for a T_{eff}=7500 K; the low resolution SWP spectra of HD 111786 and of the normal star HD 88824 (T_{eff}=7490 K, log g=3.8) are plotted in Fig. 6; the drop of the flux at a much shorter wavelength for HD 111786 indicates a temperature higher than 7450 K: the difference with the normal star is much too large to be explained by the low blanketing of a λ Boo star. The low temperature component cannot contaminate significantly the flux in the short wavelength domain, below 1800 A.

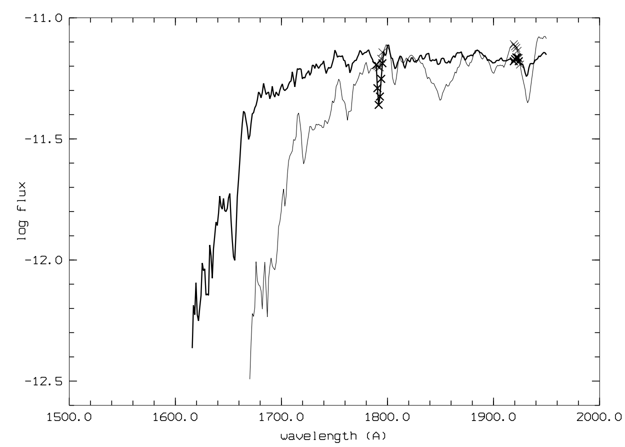

Fig. 6. The IUE spectrum of HD 111786 (SWP19124*l* thick line) and HD 88824 (SWP28721*l* thin line); the crosses represent the reseau marks. We note that the feature centered at 1865 A is much weaker in HD 111786; this feature is mainly due to Fe lines.

Inspection of high resolution IUE spectra confirms this interpretation; the narrow line components are missing in the short wavelength range (1400-2000 A) so confirming our hypothesis that the broad-lined component is the hotter one.

On the long wavelength range (2000-3000 A) there are only a couple of Fe II narrow absorptions (at 2586 and 2599 A), and others on Mg II 2802 and Mg I 2852. Residual flux from the cooler companion can easily explain these features.

Also Grady et al. (1996) have remarked that in the mid-UV narrow absorptions in FeII lines are absent in all but λ2599 and

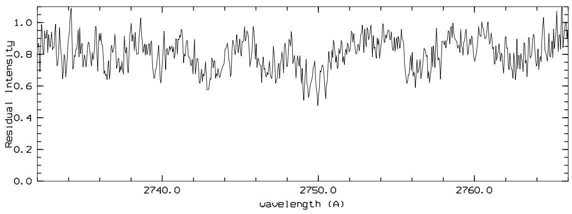

Fig. 7. The order 84 of the IUE high resolution spectrum of HD 111786 (LWP2561) where the strongest FeII lines are located; the comparison with Fig. 23 of Slettebak and Carpenter (1983) shows the lack of circumstellar absorptions in HD 111786.

in the far-UV there are no indication of accreting material in the CI and AlII lines.

The spectral region of the strongest Fe II lines is plotted in Fig. 7 and must be compared with Fig. 23 of Slettebak and Carpenter (1983) where shell stars and an A5 III-IV standard star are displayed. No features characteristic of the presence of a shell are detectable in the spectrum of HD 111786; the central depth of lines are similar to that of the standard star of Slettebak and Carpenter (1983).

5. Discussion and conclusion.

An accurate analysis of this system is outside the purpose of the present research; what we consider important is to present the interpretation of the many intriguing peculiarities of this object which find their explanation in the double nature of the stellar spectrum.

From the low resolution spectrum taken by IUE at short wavelength and from the high flux measured by TD1 at 2365 A, the component with the booader lines must have a higher temperature. The similarity of the UV flux distribution of HD 111786 and HD 290799 suggests that the broader line component of HD 111786 has atmospheric parameters similar to those of the λ Boo star HD 290799 (T_{eff}=8000 K, log g=4.26, Gerbaldi and Faraggiana, 1996).

After the correction of the observations for the Earth velocity, we found that the radial velocity which corresponds to the narrow lines component is +22 km s^{-1}. It is difficult to compare this value with that of Nordström and Andersen (1985) because the methods used to determine the radial velocity are totally different, but we notice that the value of -18.1 km s^{-1} found by Nordström and Andersen (1985) comes from three spectra which have been taken within one month; this indicates that very probably the period of the system is quite long and, in this case, the large separation can explain the rotation decoupling.

Holweger and Rentzsch-Holm (1995) observed a wavelength variation of the narrow feature located in the CaII line. This variation is measured relatively to the center of the broad CaII line. The velocity varies between -2.2 km s^{-1} to 23.0 km s^{-1} according to these authors. Our observation gives a relative value of about -40 km s^{-1} between the narrow and the broad features, but it refers to all the features observed in our spectral domain which is different from that analyzed by Holweger and Rentzsch-Holm. Our measure represents the relative radial velocity due to the orbital motion of the stars.

The observations of Holweger and Rentzsch-Holm (1995) and ours demonstrate that the system is a real binary and not an optical one. Therefore we have a broad system in which the two components have a large difference of vsini, which is not rare in that domain of T_{eff}. In this domain most of the low rotating-stars belong to the class of CP stars, however the ratio SrII 4215/ScII 4247 does not indicate an Am star.

Pulsations have been detected for HD 111786 by Kushnig et al. (1994) with a period of 46.42 mn. Pulsations are observed among some, but not all λ Boo stars (Pauzen et al., 1996). The pulsation period of HD 111786 is such that we cannot exclude that the pulsations originate in the cooler component.

We conclude that HD 111786 is a system composed by an A-type star of the λ Boo class and a low rotating early-F with one of them pulsating. If this double lined system is observed over a long time interval, we will have the possibility to determine the mass, the T_{eff} and log g of each component. So a complete analysis would allow to determine the mass of a λ Boo star through the analysis of its SB2 spectrum.

We recall that also two visual binaries belonging to the λ Boo class are known with both their components showing the characteristic metal deficiencies HR 7764 A/C and HR 7959/7960 (Gray, 1988; Stürenburg, 1993); the importance of a detailed analysis of all the λ Boo binaries for a more complete comprehension of the λ Boo phenomenon cannot be overemphasized.

References

Andersen J. Nordström B. 1977 Astron. Astrophys. Suppl. 29, 309
Baschek B. Heck A. Jaschek C. Jaschek M. Köppen J. Scholz M. Wehrse M. 1984, Astron Astrophys. 131, 378
Burnage R. Gerbaldi M. 1992 4th ESO/ST-ECF Data Analysis Workshop, eds. P.J. Grosbol and R.C.E. de Ruijsscher page 159
Faraggiana R. Gerbaldi M. 1990, ESA SP-310, Evolution in Astrophysics, page 287
Faraggiana R. Gerbaldi M. Bohm C. 1990 Astron. Astrophys. 235, 311
Gerbaldi M. Faraggiana R. 1996 ESO Workshop "The Role of Dust in Star Formation" eds. Kaeufl H. U., Siebenmorgen R., Springer Verlag
Grady C.A. McCollum B. Rawley L.A. England M.N. Groebner A. Schlegel M. 1996 Ap. J. Letters 464, L182
Gray R.O. 1988 Astron. J. 95, 220
Gray R.O. Garrison R.F. 1987 Astrophys. J. Suppl. 65, 581
Hauck B. Slettebak A. 1983 Astron. Astrophys. 127, 231
Holweger H. Stürenburg S. 1991 Astron. Astrophys. 252, 255
Holweger H. Rentzsch-Holm I. 1995 Astron. Astrophys. 303, 819
Kurucz R. L. 1993 CD-Rom 13 and 18
Kuschnig R. Paunzen E. Weiss W.W. 1994 IAU Inform. Bull. Var. Stars 4069, 1
Michigan Catalogue, 1982 Vol. 3
Moon T.T 1985 Comm Univ. London Obs No. 78
Moon T.T. Dworetsky M.M. 1985 Mon. Not. R. Astron. Soc. 217, 305
Nordström B. Andersen J. 1985 Astron. Astrophys. Suppl. 61, 53
Pauzen E. Weiss W.W. and Kushnig R. 1996, IBVS Bulletin 4302, 1
Slettebak A. Carpenter K.C. 1983 Astrophys. J. Suppl. 53, 869
Stürenburg S. 1993 Astron. Astrophys. 277, 139