Astron. Astrophys. 313, 191–196 (1996)

ASTRONOMY AND ASTROPHYSICS

HD 105262: a high latitude metal-poor post-AGB

A supergiant with large proper motion

B.E. Reddy, M. Parthasarathy, and T. Sivarani

Indian Institute of Astrophysics, Bangalore-560 034, India

Received 6 November 1995 / Accepted 4 January 1996

Abstract. The large proper motion post-AGB supergiant stars are very rare. HD 105262 is a high galactic latitude (+72^o) A-type star with large proper motion ($0''.057$ year^{-1}) and high c1-index. Earlier, it was classified as a Field Horizontal Branch (FHB) star. Recently, Abt (1993) suggested that it may be a star similar to HR 4049. From an analysis of the spectra the chemical composition of HD 105262 has been determined. The elemental abundances are found to be, [Fe/H]= -2.2, [C/H]= -0.1, [N/H]= -0.2, [O/H]= -0.5, [α/H]= -1.6. The C/O= 1.2 shows that HD 105262 is a carbon rich star. The chemical composition of HD 105262 indicates that it has gone through the AGB nucleosynthesis. The chemical composition, absolute magnitude, high galactic latitude and kinematics indicate that HD 105262 is a halo metal-poor post-AGB A supergiant. It is not a FHB star.

Key words: stars: abundances – stars: evolution – stars: supergiants – stars: population II – stars: post-AGB – stars: individual: HD 105262

1. Introduction

The fact that some bright high galactic latitude supergiants have planetary nebula colours in the far-infrared was first pointed out by Parthasarathy and Pottasch (1986). Several high latitude A and F supergiants were found to show circumstellar dust shells (Parthasarathy and Pottasch 1986; Lamers et al. 1986) and CO molecular envelopes (Likkel et al. 1987). The observed characteristics of these stars and their circumstellar dust shells have revealed that they are in post-Asymptotic Giant Branch (AGB) stage of evolution (Parthasarathy 1994). Detailed chemical composition analysis of some of the post-AGB A supergiants HR 4049, HD 52961 and HD 44179 show that they are very metal-poor (Waelkens et al. 1991, 1992). The peculiar abundances of these stars appear to be due to fractionation. The presence of circumstellar dust shells lends strong support to the idea that the depleted refractory elements are locked up in circumstellar dust grains (Bond 1991, Van Winckel et al. 1992, Parthasarathy et al. 1992).

Recently Corbally and Gray (1993) surveyed the spectral characteristics of A-type stars in the galactic halo. It is possible that some of the halo A-type stars are misclassified as Field Horizontal Branch (FHB) stars. It may be likely that some of them may be post-AGB A supergiants. Recently, Abt (1993) classified the spectrum of the halo A star HD 105262 (galactic latitude +72°) as A0p Ib and found that its spectrum is similar to that of the metal-poor post-AGB A supergiant HR 4049. HD 105262 also shows a high c1-index (Eggen 1974) similar to the post-AGB A and F supergiants (Bidelman 1993). In fact Eggen (1974) suggested that HD 105262 may be similar to the metal-poor post-AGB A supergiant BD+39^o 4926 (Kodaira 1973). However Glaspey (1982) argued that HD 105262 is a FHB A-type star.

In order to understand the evolutionary stage and chemical composition of HD 105262 we have carried out an analysis of its spectrum, and the results are presented in this paper.

Send offprint requests to: B.E. Reddy

2. Observations

We have obtained optical spectra of HD 105262 on 13th (UT:22h30m) and 14th (UT: 22h30m) February, 1995 with the 2.3m (VBT) telescope at Kavalur equipped with a B & C- spectrograph and a CCD detector. Spectra cover the wavelength ranges: 4200 - 4600Å, 4900 - 5300Å, 6000 - 6400Å, 6300 - 6700Å, 6800 - 7200Å, 7200 - 7600Å and 7400 - 7800Å. The effective resolution obtained from the FWHM of comparison lines for all the frames is around 1.1Å and the spectra of all the frames has S/N$\approx$100. Spectroscopic reductions were done using the standard IRAF package.

3. Analysis

3.1. The spectrum of HD 105262

The spectrum of HD 105262 in the Hγ region is shown in Fig. 1 together with the spectra of normal supergiants HD 87737 (A0 Ib), HD 202850 (B9 Iab) and also the spectrum of the FHB

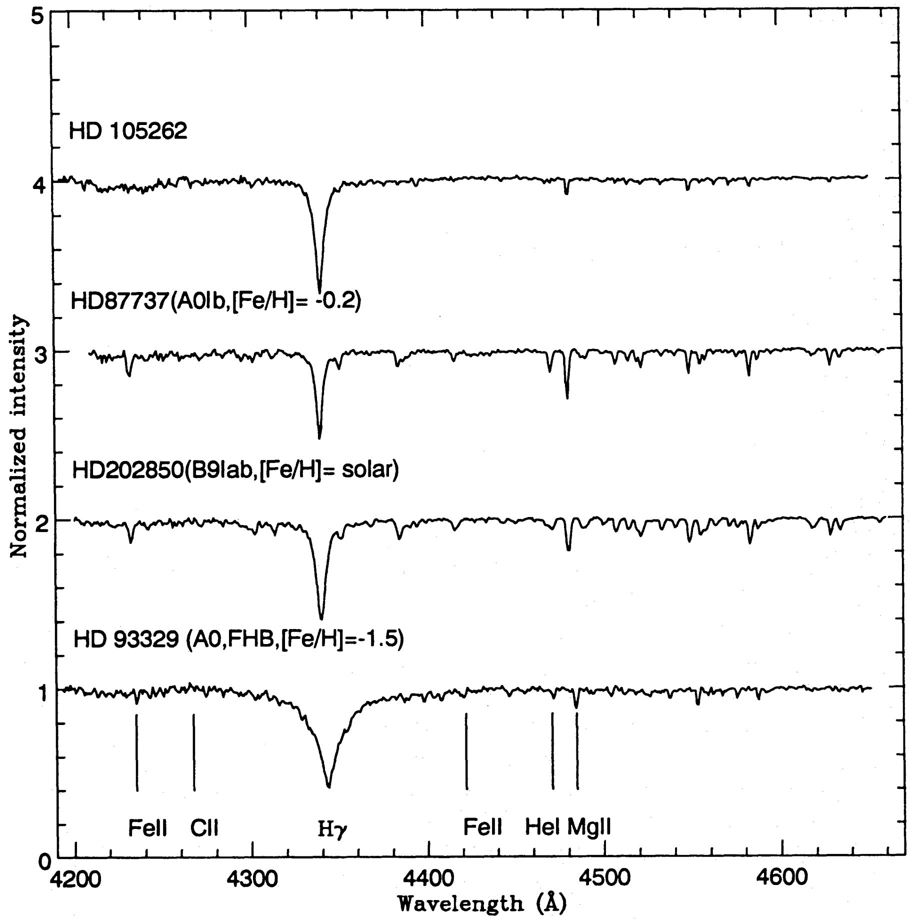

Fig. 1. Spectra of HD 105262, normal supergiants, HD 87737(A0 Ib), HD 202850(B9 Iab) and the FHB star HD 93329 (A0, [Fe/H]= -1.5). HeI, 4471Å CII, 4367Å ,Hγ, 4340.4Å and metallic lines are identified.

star HD 93329 (A0, [Fe/H]= −1.5). The strength and shapes of the hydrogen line profiles in the spectrum of HD 105262 are similar to that of B9 Iab or A0 Ib supergiants, for example, the $H\gamma$ profile in Fig. 1. They are not as broad as in FHB stars. The strengths of Mg II 4481Å and Fe lines are much weaker in the spectrum of HD 105262 compared to that of normal A-type supergiants, and they are weaker than those in the metal-poor ([Fe/H]= −1.5) A0 FHB star HD 93329. There is a weak HeI line at 4471Å. The Fe I lines are extremely weak or absent. The presence of weak HeI line in the spectrum of HD 105262 indicates that its spectral type may not be later than A0. We estimate the spectral type and luminosity class of HD 105262 to be A0 Ib, in good agreement with that found by Abt (1993).

3.2. Atmospheric parameters

The physical parameters, surface temperature T_{eff}, surface gravity log g and microturbulent velocity ξ_t required to determine the elemental abundances, are estimated as follows.

The surface temperature and micro turbulent velocity can be estimated by demanding that there should be no dependence of the FeI abundances upon lower excitation potentials and equivalent widths of FeI lines, respectively. Surface gravity can also be determined spectroscopically by forcing FeI and FeII to give the same abundance. It is, however, difficult to apply these methods, given that the neutral metallic lines are absent or very weak in the spectrum of HD 105262.

The surface temperature T_{eff} can be derived from the spectral type, UBV and Strömgren uvbyβ photometry. The UBV photometry V= 7.08, B-V= −0.01, U-B= −0.05 and Strömgren photometry b-y= 0.056, c1= 1.406, m1= 0.074 have been taken from Eggen (1977). The colour excess derived by Feltz (1972) for normal stars in the vicinity of HD 105262 are consistent with little or no interstellar reddening. The calibration of spectral-type−T_{eff} relation for supergiants (Flower 1977) yields T_{eff}= 9500K for A0 supergiants. The T_{eff}= 8500K, and log g= 1.5 for HD 105262 have been derived by Klochkova and Panchuk (1987) using the half widths and equivalent widths of the Balmer $H\gamma$ and $H\delta$ lines in the T_{eff} versus log g diagram. By comparing UBV colours of HD 105262 with the theoretical UBV colours (Relyea and Kurucz 1978) for [M/H]= −2.0, we estimate T_{eff}= 9000K and log g= 2.0. An upper limit for the model temperature can be found by considering the absence or presence of HeI lines in the spectra. The strength of HeI line at 4471Å (EW=40mÅ), is expected for the T_{eff}=9000K, and log g=2.0 model. We also estimated T_{eff} and log g, by comparing the $H\gamma$ profile, with the Kurucz (1979) LTE Balmer $H\gamma$ grids of [M/H]= −2.0 for different temperatures and surface gravities (Fig. 2). We obtained T_{eff}= 9500K, and log g= 2.0 from matching both the wings and core of the $H\gamma$ profiles (Fig. 2).

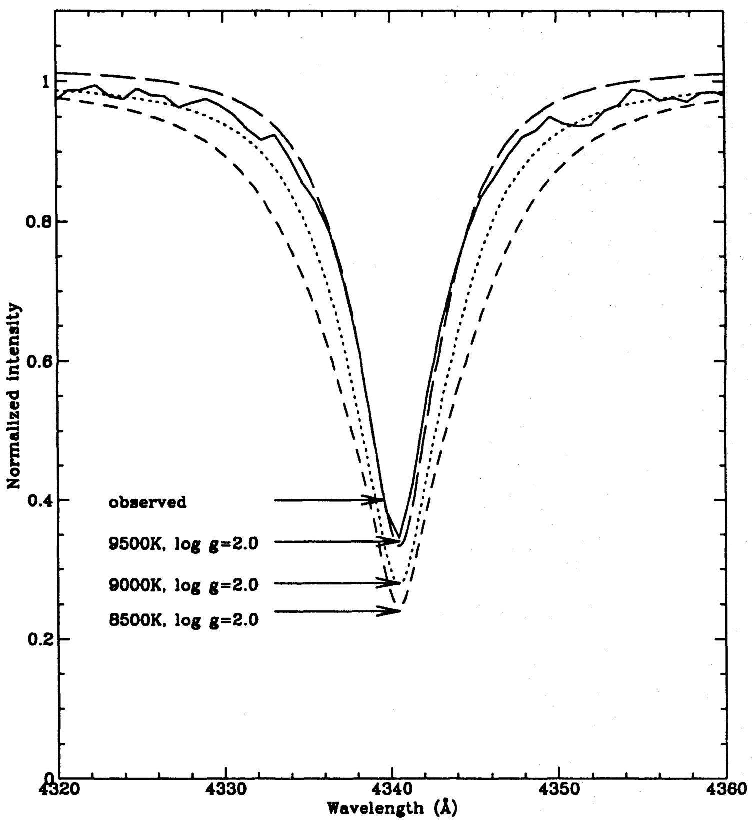

Fig. 2. The observed Hγ profile of HD 105262 (solid line) compared with the Kurucz (1979) synthetic Hγ profiles for different temperatures.

Another parameter involved in deriving the chemical composition is the microturbulent velocity ξ_t. We adopted ξ_t= 4 km s^{-1}. This value is typical for low surface gravity metal-poor supergiant stars such as HD 56126 (ξ_t= 4 km s^{-1}, Parthasarathy et al. 1992), HD 52961 (ξ_t= 5 km s^{-1}; Waelkens et al. 1991), BD+39^o 4926 (5 km s^{-1}; Kodaira 1973). We adopt for our abundance analysis T$_{eff}$= 9000K, log g= 2.0 and ξ_t= 4 km s^{-1}.

3.3. Absolute magnitude

The equivalent width of the OI triplet at 7771Å in the spectrum of A-type stars is sensitive to the luminosity (Sorvari 1974). Using the equivalent width of OI 7771Å triplet and M$_v$ calibration of Sorvari (1974) we derive M$_v$= −4.0. Klochkova and Panchuk (1987) derived M$_v$= −4.8 from the equivalent width of Hγ profile. The M$_v$ versus uvby and β photometry calibration for high proper motion, metal poor, A-type giant stars (Stetson 1991) yields M$_v$= −5.0.

The absolute magnitude (M$_v$) may also be calculated using a standard formula,

$$M_v = -2.5\log(M/M_\odot)+2.5\log g-10\log T_{eff}-B.C+31.3 \quad (1)$$

By using the adopted photospheric parameters of HD 105262, (T$_{eff}$=9000K, log g=2.0) and the typical mass of 0.6M$_\odot$ of pop II stars, we find M$_v$=−2.5. The bolometric correction (B.C) of −0.2 has been applied. However this formula is very sensitive to log g and T$_{eff}$ (e.g T$_{eff}$=9500K, log g=1.5 yield M$_v$=−4.0). Uncertainties in derived T$_{eff}$ and log g values, introduce an uncertainty of about 1.5 mag in M$_v$.

3.4. Chemical composition

Abundances of the chemical elements were determined with the local thermodynamic equilibrium (LTE) model atmosphere grids computed by Kurucz (1979). For computing the synthetic spectra and equivalent widths, we used updated codes LINES and MOOG (Sneden 1973). We have used oscillator strengths (log gf) of OI-triplet at 6156Å and NI lines, listed by Waelkens et al. (1991). For OI-triplet at 7771Å, we used gf values of Takeda (1994). For other metallic lines, we have taken gf values from NBS (1988).

We have derived elemental abundances of HD 105262 using the model atmosphere: T$_{eff}$= 9000K, log g= 2.0, [M/H]= −2.0 and microturbulent velocity ξ_t= 4 km^{-1}. Keeping in mind the uncertainties in the T$_{eff}$ of this kind of stars, we also carried out abundance analysis using the models with T$_{eff}$= 8500K, and T$_{eff}$= 9500K for different microturbulent velocities. The uncertainties in the estimated atmospheric parameters, T$_{eff}$ of ±500K, log g of ±0.5 dex and ξ_t of ±2 km^{-1} introduce uncertainties in derived abundances approxmately by ± 0.3 dex.

The carbon abundance is based on the CI lines at 6587.62Å, 7115.17Å, 7113Å, and CII line at 4267.27Å. Abundance of carbon has been derived both from the line analysis and synthetic spectra. The nitrogen abundance is derived from lines in the red region at 7442.63Å and 7468.28Å. The oxygen abundance is derived from the OI-triplet lines at 6156Å and at 7771Å. The oxygen abundance ([O/H]= 0.2) derived from 7771Å triplet lines is larger than the oxygen abundance ([O/H]= −0.5) obtained from 6156Å triplet lines. The overabundance of oxygen from

7771Å triplet lines may be due to Non-LTE effects. We applied Non-LTE correction of 0.6 dex (Baschek et al. 1977) to our LTE abundance of oxygen, the abundance [O/H]= -0.4 after correction is comparable to the abundance derived from the OI lines at 6156Å. The CNO abundances are found to be [C/H]= -0.1, [N/H]= -0.2, [O/H]= -0.5. The abundances of α-process elements Mg, Si have been found to be [Mg/H]= -1.6, [Si/H]= -1.4. The abundance of silicon and magnesium are derived from the lines at 6347.09Å, 6371.35Å and 5183.60Å, 5172.69Å respectively. The abundance of barium is estimated from the line at 6142Å. We estimated the He abundance ([He/H]=-0.2), using the HeI line at 4471Å. Since the HeI line at 4471Å is weak and blended with metallic lines, the abundance of He is highly uncertain. To check our abundance analysis, we also carried out spectrum synthesis analysis of the FHB star HD 93329 using the spectra of the same resolution obtained with the same instrument. The derived metal abundances are in good agreement with the abundances obtained by Adelman and Philip (1994). The CNO abundances of HD 105262 with respect to iron are found to be over abundant: [C/Fe]= +2.1, [N/Fe]= +2.0, [O/Fe]= +1.7. The CNO, Mg, Si and metal abundances of HD 105262, HD 107369, HD 46703 and BD+39^o 4926 are compared in Fig. 3. The abundance (Table. 1) pattern of HD 105262 is similar to that of the metal-poor high galactic latitude post-AGB supergiant BD+39° 4926 (Kodaira 1973).

3.5. Space motions

From our spectra the radial velocity of HD 105262 is found to be V_r= 38±6 km s^{-1}. This is in agreement with the radial velocity measurements made eariler: +42.0±3.7 km s^{-1} (Young 1942), +42.0±6.8 km s^{-1} (Albizkij 1947), +41.4 km s^{-1} (Wilson 1953) and +45.0 km s^{-1} (Glaspey 1982).

The proper motion of +0$''$.038 year^{-1} and -0$''$.042 year^{-1} in right ascension and declination respectively, are listed in the SAO catalogue. The total proper motion of HD 105262 is μ= 0$''$.056 year^{-1}. Taking the heliocentric radial velocity V_r= 41 km s^{-1}, proper motion μ= 0$''$.057 year^{-1} and M_v= -5 the space motion is found out to be V_s= 700 km s^{-1} with respect to the Sun. The high space velocity of HD 105262, is larger than the escape velocity from the Galaxy of 290 km s^{-1} near the Sun. The positions of HD 105262 in the equatorial galactic plane are X= -73pc, Y= -765pc, and Z= 2.5 kpc. The radial velocity V_r= 41 km s^{-1} and a distance 2.6 kpc of HD 105262 from the Sun yields space velocity components with respect to the galactic co-ordinate system: U= 445 km s^{-1}, V= -545 km s^{-1}, and W= -12 km s^{-1}. However by taking the M_v=-2.5 as derived from Eq. 1, we find a distnce of only 850pc and its space motion 230km s^{-1}. In that case, it may be a nearby object and which is consistent with the high proper motion. Correspondingly its space velocity components become: U= 150 km s-1, V= -170 km s^{-1} and W= 28 km s^{-1}. The (U,V) components of HD 105262 suggest that the star is a member of the halo group of stars and it does not belong to the wolf 630 group of stars (Eggen 1969).

4. Discussion

The main results found from our analysis of HD 105262 are: (1) that it is a metal-poor evolved population II star, (2) the photospheric abundances of metals are very low [Fe/H]= -2.2, but the CNO and the α-process elements Mg and Si are overabundant with respect to iron. The chemical composition of HD 105262 clearly differs from the chemical composition of population I giants and halo dwarfs. Population I supergiants have elemental abundances: [Fe/H]= 0, [C/Fe]= -0.5, [N/Fe]= +0.5 and [O/Fe]= -0.3 (Luck 1993), whereas in metal-poor halo dwarfs : [C/Fe]= 0, [N/Fe]= -0.25, and [O/Fe]= 0.35 (Wheeler et al. 1989) and in metal-poor(Fe/H=-1.1) Blue Horizontal Branch (BHB) star No. 4408 in M4 (Lambert et al. 1992): [C/Fe]=+0.1, [N/Fe]=+1.1 and [O/Fe]=+0.2. However, the elemental abundances of HD 105262 using model atmosphere parameters, T_{eff}= 9000K, log g= 2.0, ξ_t= 4.0 km s^{-1} and [M/H]= -2.0 are found to be [Fe/H]= -2.2, [C/Fe]= +2.1, [N/Fe]= +2.0, [O/Fe]= +1.7, [α/Fe]= +0.7 and [Ba/Fe]= +0.3. Recently Van Winckel (1995) has studied a similar metal-poor (Fe/H=-1.1) star HD 107369. This star was first classified as a horizontal branch (HB) star. HD 107369 is a high latitude A-type star having high Strömgrem c1-index similar to HD 105262. Bond and Philip (1973) suggested from its photometry that HD 107369 is similar to the metal-poor high latitude object BD+39^o 4926. Though HD 107369 shares some of its properties with HD 105262, it differs in chemical composition (Table. 2). The small C/O=0.2 and no enhancement of α-process elements, indicate that the star HD 107369 has not gone through the third dredge-up which occurs on the AGB. On the other hand, in HD 105262, the observed large C/O=1.2 and over abundance of Mg are the result of 3α-process via He-burning on the AGB, which are brought to the photosphere during the third dredge-up episode. However, [Mg/Fe]=+0.4 has been found as an upper limit, in metal-poor stars with [Fe/H]= -1.0 to -2.0 (Fuhrmann et al. 1995). The abundance ratio [Mg/Fe]=+0.6 in HD 105262 suggests that the star is metal-poor and slight excess in Mg abundance may be attributed to stellar evolutionary effects on the AGB. The star HD 107369 has neither Hα emission nor observed IR excess, which are similar to HD 105262. But the much pronounced excess in both CNO and α-process elements compared to HD 107369 clearly demonstrates that HD 105262 is relatively in an advanced stage of evolution. But as shown in Fig. 3 , the chemical abundance pattern is strikingly similar to that of the metal-poor high latitude post-AGB stars, such as BD+39^o 4926 (Waelkens et al. 1992) and HD 46703 (Bond and Luck 1987). The overabundance of C and the mild excess of Ba suggest that these elements have been brought up to the surface during the AGB phase. However, as the Ba abundance is based on a single line at 6142Å, this should be considered uncertain.

Though HD 105262 shares its chemical composition and high luminosity similarities with high latitude post-AGB supergiants, it differs from other high latitude post-AGB stars, in its large proper motion, high space velocity and the absence of circumstellar dust. Most of the known high latitude post-AGB stars such as, HR 4049, HD 52961, HD 46703 and BD+39^o 4926

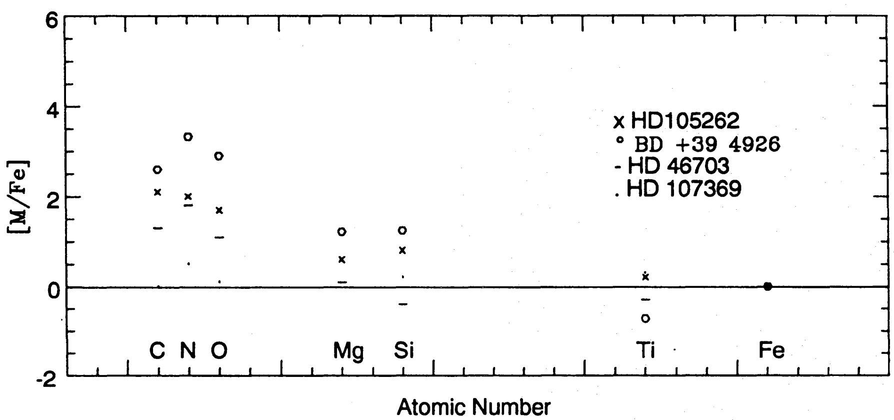

Fig. 3. Elemental abundances of HD 105262, metal-poor post-AGB supergiants HD 46703, BD+39° 4926 and an evolved pop II A star HD 107369.

Table 1. Elemental Abundances of HD 105262 for different temperatures

Teff log g=2.0 ξ_t=4km s^{-1}	[C/H]	[N/H]	[O/H]	[Mg/H]	[Si/H]	[Ti/H]	[Fe/H]	[Ba/H]
8500	-0.3	-0.3	-0.6	-1.9	-1.8	-2.1	-2.3	-2.1
9000	-0.1	-0.3	-0.5	-1.6	-1.4	-2.0	-2.2	-1.9
9500	0.3	0.1	-0.4	-1.0	-1.0	-1.8	-2.1	-1.7

Table 2. Comparison of chemical composition of HD 105262 with variuos types of evolved stars.

[el/H]	HD 105262	HD 46703	BD+39° 4926	HD 107369	PopI supergiants	BHB star M4 No. 4408
[C/H]	-0.1	-0.27	-0.4	≤-1.27	-0.25	-0.99
[N/H]	-0.2	+0.22	0.4	-0.68	+0.7	+0.1
[O/H]	-0.5	-0.46	-0.1	-1.10	-0.16	-0.9
[MgII/H]	-1.6	-1.48	-1.5	-	-0.12	-0.35
[SiII/H]	-1.4	-1.94	-1.7	-0.95	-0.22	-0.57
[TiII/H]	-2.0	-1.89	-3.7	-0.84	-0.07	-0.6
[FeII/H]	-2.2	-1.56	-2.9	-1.16	0.11	-1.06
[BaII/H]	-1.9	-2.36	-	-1.18	-	-0.47

are radial velocity variables. However, radial velocity measurements of HD 105262 over the last few decades do not show any evidence for variability indicating that it is not a binary star. Thus, HD 105262 may be a single star which has evolved with primordial metallicity in the halo. However, the peculiar chemical composition observed in high-latitude post-AGB stars has been attributed to selective depletion of iron peak elements. The presence of circumstellar dust around these stars and the over abundance of sulphur with respect to iron strongly supports the idea that depleted refractory elements are locked up in the circumstellar dust grains. The question, whether the low metallicity [Fe/H]=−2.2 of HD 105262 is primordial and CNO and α-process abundances are stellar evolutionary effects, can be explained by two diagnostic elements zinc and sulphur. Our spectral resolution is not sufficient enough to resolve zinc lines and unfortunatley we do not have spectra covering the SI lines to estimate its abundance.

Finally we discuss the kinematics of HD 105262. The large proper motion $0''.057$ year^{-1} and its distance 2.6 kpc from the Sun can be understood from its high space motion. Most of the halo objects were discoverd from their large proper motion. As the star approaches the galactic plane, it attains high velocity because of gravitational potential of the Galaxy and therefore shows peculiar large proper motion. Thus, the large proper motion of HD 105262 is not because of proximity, may be due to high space motion in the orbit. Since the HD 105262 is an evolved low mass (as seen in the discussion) star, with an extended atmosphere, it may be mimicking the supergiant spectrum (Parthasarathy 1994). Hence the derived M_v from balmer profiles, should be taken with caution. And may be we sholud not use the MK luminosity class and M_v calibration to estimate absolute luminosities and distance of these stars. Also, the M_v derived from equivalent width of the OI triplet vs luminosity class, may not represent the true luminosity of HD 105262. Instead if we take M_v=−2.5 (see section 3.3), we arrive at a distance of only 850pc and space velocity 230 km s^{-}. In that case, HD 105262 is a nearby evolved object with a luminosity of only 800$L_{\odot}$. The large proper motion and chemical composition indicate that it is a nearby low mass star in an advanced stage of evolution.

5. Conclusion

From our spectrum synthesis analysis, we conclude that HD 105262 is not a FHB star. The low metallicity, over abundances of CNO and α-process elements and its locus in the HR diagram suggest that it is a low-mass population II star in the post-AGB stage of evolution. The large ratio of C/O= 1.2 shows that HD 105262 is a carbon rich star. The absolute luminosity and the distance of HD 105262 are uncertain. To disentangle this luminosity problem, it is highly important to remeasure the proper motion of this star.

Acknowledgements. We are thankful to Prof. Abt for bringing this star to our attention. We are also thankful to Dr. H. Van Winckel for sending us a copy of his Ph.D thesis during the preparation of this paper. We thank Dr. C. Waelkens for valuable comments.

References

Abt, H. 1993 (private communication)
Adelman, J., Philip, A.G.D. 1994, MNRAS, 269, 579
Albizkij, W.A. 1947, Publ. Crimean AstroPhys. Obs., 1, 20
Baschek, B., Schulz, M., Sedlmayr, E. 1977, A&A 55, 375
Bidelman, W.P. 1993, in "Luminous High-Latitude Stars", ASP Conference Series 45, ed. D.D. Sasselov, p. 49
Bond, H.E., Philip, A. 1973, PASP 85,332
Bond, H.E., Luck, R.E. 1987, ApJ 312, 203
Bond, H.E. 1991,in "The evolution of stars: photospheric abundance connec tion", IAU Symp. 145, ed. G. Michaud and A. Tutokov, p. 341
Corbally, C.J., and Gray, R.O. 1992 in "Peculiar Versus Normal Phenomena in A-type and Related Stars", IAU Coll., N0. 138, ed., F. Castelli and M.M. Dworetsky, p. 432
Eggen, O.J. 1969, PASP 81, 553
Eggen, O.J. 1974, PASP 86, 162
Eggen, O.J. 1977, ApJ 215, 812
Flower, J.J. 1977, A&A 54, 31
Feltz,K. 1972, PASP 84, 497
Fuhrmann, K., Axer, M., Gehren, T. 1995, A&A 301, 492
Glaspey, W.J. 1982, ApJ 258, L71
Hill, G.M., Walker, G.A.H., Yang, S. 1986, J.R. Astron.Soc.Can 80, No. 5, 275
Klochkova, V.G., Panchuk, V.E. 1987, Sov. Astron. 31 (1)
Kodaira, K. 1973, A&A 22, 273
Kurucz, L.R. 1979, ApJS 40, 1
Lambert, D.L., McWilliam, A., Smith, V.V. 1992, ApJ 386, 685
Lamers, H.J.G.L.M., Water, L.B.F.M., Garmany, C.D., Perez, M.R. and Waelkens, C. 1986, A&A 154,L20
Likkel, L., Omont, A., Morris, M., Forveille, T. 1987, A&A 173, L11
Luck, R.E. 1993 in " Luminous High-Latitude Stars", ASP Conference Series 45, ed. D.D. Sasselov, p. 87
NBS, 1988, J. Phys. Chem. Ref. Data 17, Suppl. 4
Parthasarathy, M., Garcia Lario, P., Pottasch, S.R. 1992, A&A 264, 159
Parthasarathy, M., Pottasch, S.R. 1986, A&A 154, L16
Parthasarathy, M. 1994 in " The MK Process at 50 years", ASP Conference Series 60, ed., C.J. Corbally, R.O. Gray, and R.F. Garrision, p. 261
Relyea, L.J., Kurucz, L.R.1978, ApJSS 37, 45
Sneden,C. 1973, Ph.D. thesis, University of Texas
Sorvari, J.M. 1974, AJ 79, 1416
Stetson, P.B. 1991, AJ 102, 589
Takeda, Y. 1994, PASJ 46, 53
Van Winckel, H., Mathis, J.S., Waelkens, C. 1992, Nature 356, 500
Van Winckel, H., Waelkens, C., Waters, L.B.F.M. 1995, A&A 293, L25
Van Winckel, H. 1995, Phd. Thesis, Katholieke Universiteit Leuven, Belgium
Waelkens, C., Van Winkel H., Bogaert E., Trams N.R.1991, A&A 251, 495
Waelkens, C., Van Winckel H., Bogaert E., Trams N.R. 1992, A&A 264, 159
Wheeler, J.C., Sneden, C., Truran, J.W. 1989, ARA&A 27, 279
Wilson, R.E. 1953, General Catalogue of Stellar Radial Velocities Washing ton.D.C.: Carnegie Institution), Carnegie Inst. Washington Pub.
Young, R.K. 1942, Publ. David Dunlap Obs., 1, 251

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