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A Li-rich post-AGB star HD 172481

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Abstract. Our abundance analysis of this post-AGB candidate star confirms that the HD 172481 is indeed a post-AGB star. It belongs to an important, but relatively rare class of post-AGB stars showing Li I features in their spectra. The strength of OI triplet at 7774 Å confirms its high luminosity (log, $(L/L_{\odot}) \sim 4$). It is moderately metal-poor with [Fe/H] of – 0.6 but shows significant enrichment of s-process elements indicating that the star has gone through the third dredge-up. We find C/O of ~ 0.4 for this star. Hot Bottom Burning scenario can explain the production of Li as well as the destruction of carbon via CN cycle that could prevent C/O ratio from exceeding one.

1. Introduction

The surface composition of post-Asymptotic Giant Branch stars (POST-AGB) and that of their circumstellar envelopes give a wealth of information leading to better understanding of evolutionary changes experienced by low and intermediate mass stars. These are also known to be major contributors of carbon and s-process elements to the interstellar medium (ISM).

HD 172481 shows light variations of very small amplitude, ± 0.15 mag (van Winckel 1995). It shows strong IR flux and hence the spectral energy distribution of this star has an unusual multi-peaked shape (Bogart 1994) indicating the presence of circumstellar material around it. Hydrogen lines have strong emission components of variable strengths. It was included in the study of van Winckel (1995) who, by fitting the observed flux distribution to those generated using model atmospheres from the grid published by Kurucz (1993) derived $T_{\rm eff}$ of 7000K.

2. Description of the spectra and abundance analysis

We have obtained high resolution (R = 50,000) and high S/N (80) spectra of HD 172481 covering 3600 Å to 1μ region. The spectrum obtained in July 9, 1999, led us to believe that the star is highly evolved since in addition to emission components in hydrogen lines, we could identify several lines of C I and also detected Li I line at 6708 Å. This feature incidentally, was showing distinct doubling. We could identify and measure many lines of s-process elements. However, the S/N ratio of the July 9 spectrum was not good so another spectrum was obtained in May 13, 2000. On this spectrum we found Li I feature to be single with some asymmetry in the blue wing but Li I feature much deeper than what it was in July 1999. We were puzzled by the change in appearance of Li I feature at 6707 Å, so on August 11 one more spectrum was obtained. The spectrum again showed a suggestion of doubling at the line core though the components were not well separated. It is not clear if the line is splitting periodically or the emission at the core is causing it to appear double. The overall strength of Li I feature in the August spectrum has reduced. The variation of Li I profile at different epochs is presented in the Figure 1.

For abundance calculations, we used the line strengths measured on the spectrum taken on May 2000. Not only the spectrum has better S/N ratio, the stellar atmosphere appear to be at a stable phase at this epoch, the lines of Fe II, Si II etc have symmetric profiles with no suggestion of doubling or asymmetries. The same cannot be said of the August spectrum and hence no analysis was attempted using August spectrum. July 9 spectrum was also not used to derive complete abundances due to poor S/N of the spectrum.

We have used the 1997 version of the spectrum synthesis program MOOG developed by Sneden (1973) for our abundance calculations. The procedure assumes plane-parallel atmospheres, hydrostatic equilibrium and LTE. The adopted procedure of deriving atmospheric parameters T_{eff}, gravity and microturbulence, also the atomic data base has been described in detail in Arellano Ferro et al. (2000) hence will not be repeated here. We derived microturbulence velocity of 4.6 kms^{-1} using Fe I lines covering a large range in equivalent widths. From the excitation and ionisation equilibrium of Fe I, Fe II lines we derived T_{eff} of 7250K and log g of 1.5 that was supported by Si I, Si II and Mg I, Mg II lines. The extensive spectral coverage enabled us to measure a large number of unblended lines for several light and heavy elements.

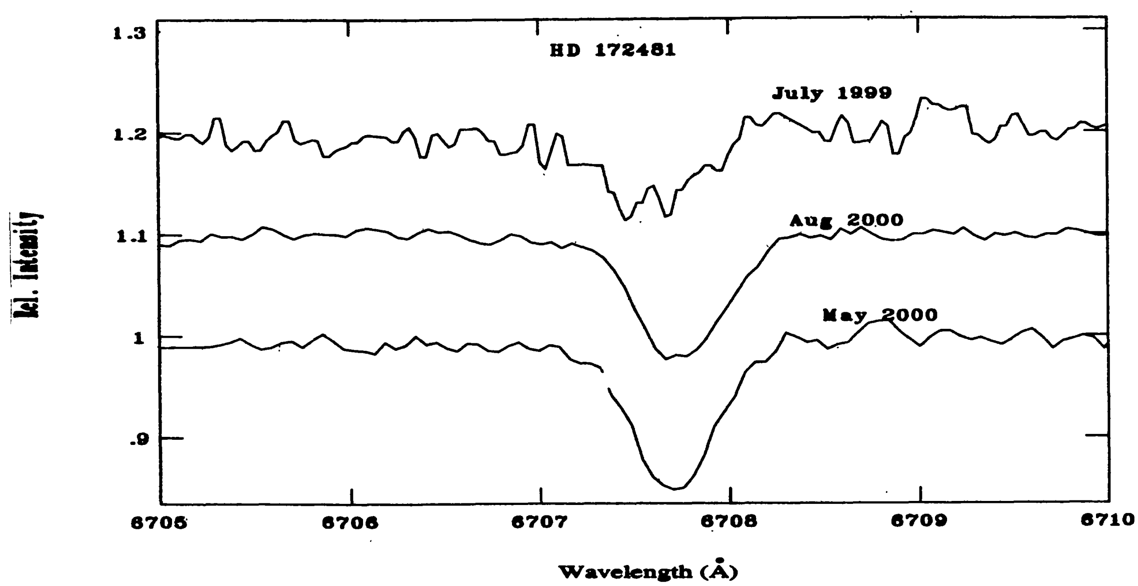

Figure 1.

We derived the Li abundance by spectrum synthesis. All the four hfs components of Li I feature at the 6708 Å region were included. We find log ϵ (Li) of + 3.7, that is surprisingly high. In the light of Li I profile variation observed so far, the abundance estimate may have larger uncertainly (± 0.3 dex) but the enrichment of Li cannot be refuted.

We could measure large number of C I lines to estimate carbon abundance. The three N I lines in the near infrared also enabled us to derive nitrogen abundance. The estimated C/O is +0.43. The s-process elements Y, Ba, La, Ce Nd and Eu led to a mean [s/Fe] of + 0.6 dex. Our derived abundances are presented in Table 1. The second column gives solar-system abundances compiled by Grevesse et al. (1996) with Li abundances derived from meteorite data. The third column shows the abundances relative to sun.

Table 1. Elemental abundances for HD172481.

Species	log $\epsilon_\odot$	[X/H]	s.e.	N	[X/Fe]
Li I	3.31	+ 0.39 :		1	+ 1.01 :
C I	8.55	− 0.62	± 0.21	12	− 0.01
N I	7.97	− 0.63	± 0.10	3	− 0.02
O I	8.87	− 0.58	± 0.05	2	+ 0.04
Mg I	7.58	− 0.13	± 0.21	2	+ 0.48
Mg II	7.58	− 0.06	± 0.54	3	+ 0.55
Si I	7.55	− 0.05	± 0.17	6	+ 0.57
Si II	7.55	− 0.10	± 0.06	3	+ 0.52
S I	7.21	− 0.04	± 0.16	7	+ 0.58
K I	5.12	− 0.28		1	+ 0.34
Ca I	6.35	− 0.28	± 0.19	12	+ 0.34
Sc II	3.13	− 0.20	± 0.23	6	+ 0.41
Ti I	4.98	− 0.31		1	+ 0.31
Ti II	4.98	− 0.28	± 0.30	6	+ 0.34
V II	4.00	− 0.00	± 0.14	2	+ 0.62
Cr I	5.67	− 0.34	± 0.05	3	+ 0.28
Cr II	5.67	− 0.41	± 0.16	10	+ 0.21
Mn I	5.39	− 0.51	± 0.11	3	+ 0.11
Fe I	7.51	− 0.62	± 0.15	43	
Fe II	7.51	− 0.61	± 0.14	13	
Ni I	6.25	− 0.31	± 0.22	6	+ 0.30
Zn I	4.60	− 0.23	± 0.08	2	+ 0.39
Y II	2.23	+ 0.08	± 0.26	4	+ 0.69
Zr II	2.60	− 0.14		1	+ 0.46
Ba II	2.13	+ 0.03	± 0.20	2	+ 0.65
La II	1.21	− 0.55	± 0.14	2	+ 0.07
Ce II	1.55	− 0.24	± 0.19	7	+ 0.38
Nd II	1.50	+ 0.03	± 0.09	3	+ 0.64
Eu II	0.51	+ 0.24		1	+ 0.86

3. Discussion

The strength of near-infrared OI triplet at 7774 Å (which is known to be a good indicator of luminosity, see Osmer 1974 for the first W(OI) - M_v calibration). leads to an estimate of log $(L/L_{\odot})$ = 4.5 for this star. The effective temperature determined spectroscopically and the calibration of Schmidt-Kaler (1982) gives a very similar value of log $(L/L_{\odot})$ of 4.1.

The presence of strong Li I feature and the significant enrichment of s-process elements exhibited by HD 172481 makes it a very interesting object. Li is considered a fragile element that gets destroyed in the course of the evolution. The primordial abundance of Li has been difficult to estimate. From the study of population II stars, log ϵ(Li) estimated to be near 2.2. The excess abundance of Li might be caused by AGB evolution described below or must owe its origin to binarity. Lattanzio (1997), in his AGB evolutionary model calculation has predicted that for stars more massive than $4M_{\odot}$ the bottom of the convective envelope penetrates into the top of H-shell where nuclear reactions take place. This is called "hot bottom hurning" (HBB) and results in many important changes in chemical composition of the envelope. Lattanzio (1997) predicted the production of Li by the Cameron-Fowler mechanism operating at the bottom of the envelope. Sackmann & Bootyroyd (1992) showed that log e (Li) of ~ 4.5 could be produced in stars with bolemetric magnitude between – 6 and – 7 when convective envelope base temperature exceeds 50 x 10^6K. Lattanzio (1997) also predicted the destruction of carbon via CN cycle that could prevent C/O ratio from exceeding one. Theoretical models for AGB stars of mass 4, 5 and $6M_{\odot}$ computed by Boothroyd, Sackmann & Ahren (1993) encountered HBB with a temperature at the base of the convective envelope reaching 80 x 10^6 K. These models predict C/O of 0.4 to 0.5 for ~ 10^3 *yr* on the AGB. This value is remarkably close to the C/O estimated by us for HD 172481.

The abundance pattern of HD 172481, bears some resemblence to those found for HR 7671, well-known post-AGB star. This object has the estimated C/O of 0.4 and also shows the Li I feature though the Lithium is not as overbundant as that found in HD 172481.

The existence of objects like HD 172481 and HR 7671 lend further support to the HBB scenario, put forward to explain the paucity of carbon-rich stars among AGB stars. The observed variation of Li I feature in HD 172481 makes it a very promising candidate to search for binarity.

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