

CNO and F Abundances in the Barium Star HD123396

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Introduction

Barium stars are chemically peculiar objects - dwarfs, subgiants, and giants - which are believed to be the result of the pollution of an otherwise normal star by material from an evolved companion on the asymptotic giant branch (AGB).

In this work we derive carbon, nitrogen, oxygen, and fluorine abundances for the first time from the infrared spectra of the barium red giant star HD 123396 to quantitatively test AGB nucleosynthesis models for producing barium stars via mass accretion. The abundances of the CNO elements and F need to be considered together with the s-process elements, because in the context of the AGB mass transfer hypothesis, C and F are produced together with the heavy elements.

Methods

High-resolution and high S/N infrared spectra were obtained using the Phoenix spectrograph mounted at the Gemini South telescope (Figure 1).

The abundances were obtained through spectrum synthesis of individual atomic and molecular lines, using the MOOG stellar line analysis program, together with Kurucz's stellar atmosphere models.

The analysis was classical, using 1D stellar models and spectral synthesis under the assumption of local thermodynamic equilibrium (Figure 2).

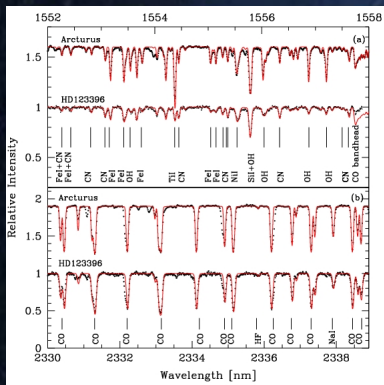


Figure 1. Observed (points) and synthetic (lines) spectra of Arcturus and HD123396 in the H (a) and K (b) bands. Several atomic and molecular lines are identified.

Methods (Continued)

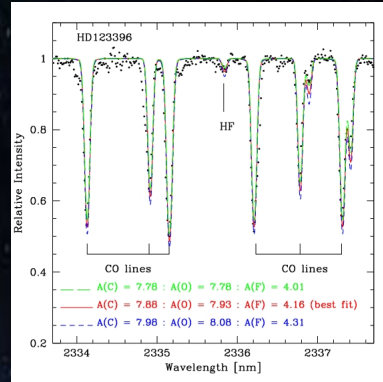


Figure 2. Observed (points) and synthetic (line) spectra of HD123396 for a sample of the wavelength regions in the K band. The abundances derived for C, O, and F are labeled in the figure. The synthetic spectra stand for the best fit (solid line) and unsatisfactory ones (short and long dash lines) by varying the abundances of C by ± 0.10 dex, and O and F by ± 0.15 dex, respectively.

Results

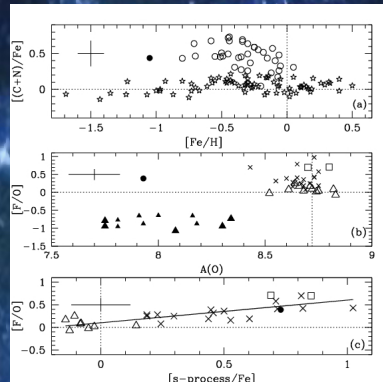


Figure 3. (a): $[(C+N)/Fe]$ vs. $[Fe/H]$ for normal K giants (stars) and barium stars in this work (filled circle) and from the literature (open circles). (b): $[F/O]$ vs. $A(O)$ for HD123396 (filled circle) compared to (i) field stars --- two barium stars (open squares), M giant stars (open triangles), MS and S stars (crosses) and compared to (ii) GC's stars --- M4 (small filled triangles) and NGC 6712 (large filled triangles). (c): $[F/O]$ vs. $[s\text{-process}/Fe]$, where s-process stand for Y, Zr and Nd. The s-process abundances were taken from Allen & Barbuy (2006). The dotted lines indicate the solar abundances. Typical uncertainties are quoted.

Results (Continued)

We confirm that HD 123396 is a metal-deficient barium star ($[Fe/H] = -1.05$), with $A(C) = 7.88$, $A(N) = 6.65$, $A(O) = 7.93$, and $A(Na) = 5.28$, leading to $[(C+N)/Fe] \sim 0.5$ (Figure 3).

We also found $A(F) = 4.16$, which implies $[F/O] = 0.39$, a value that is substantially higher than the F abundances measured in globular clusters of a similar metallicity, noting that there are no F measurements in field stars of comparable metallicity (Figure 3).

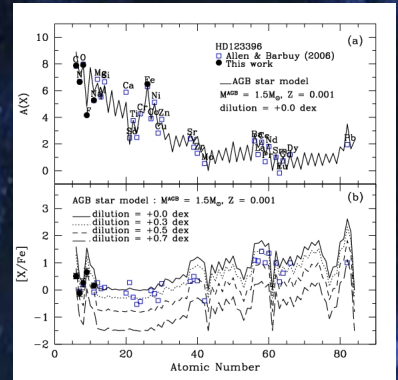


Figure 4. The barium giant star HD123396 observed abundance pattern compared with theoretical predictions of a 1.5Msun AGB star of $Z=0.001$.

Conclusions

The observed abundance pattern (Figure 4) of the light elements (CNO, F, and Na) recovered here as well as the heavy elements (s-process) studied elsewhere suggest that the surface composition of HD 123396 is well fitted by the predicted abundance pattern of a 1.5Msun AGB model star with $Z = 0.001$. Thus, the AGB mass transfer hypothesis offers a quantitatively viable framework.