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CS 30322–023: An Ultra Metal-Poor TP-AGB Star?

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Abstract. The remarkable properties of CS 30322–023 became apparent in the course of a study of a sample of 23 carbon-enhanced, metal-poor (CEMP) stars. Its abundance pattern is one of the most well-specified of all known extremely metal-poor stars. With [Fe/H]= −3.5, this is the most metal-poor star to exhibit a clear s-process signature, and the most metal-poor "lead star" known. The available evidence indicates that it is presently a thermally-pulsing asymptotic giant branch (TP–AGB) star, with no strong indication of binarity thus far.

1. Evolutionary Status

Several high-resolution spectra have been obtained at the European Southern Observatory with the VLT/UVES spectrograph, and with the 2.2-m/FEROS spectrograph.

An LTE analysis of the Fe I/Fe II ionization balance yields a very low gravity of $\log g = -0.3$. Although it is likely that the LTE analysis underestimates the gravity, a comparison with the other CEMP stars analyzed through LTE reveals that CS 30322–023 is the most evolved example among known metal-poor stars (Figure 1). It is most likely a low-mass (0.8 $M_\odot$) TP–AGB star. Larger masses would put it too far (> 20 kpc) in the outskirts of the halo, where no recent star formation is expected to have occurred.

2. Abundances

The observed abundance pattern of CS 30322–023 is, however, quite puzzling, in that it exhibits s-process elements (Figure 2) without a strong C overabundance, as would be expected if the s-process operates in a He–burning environment. The light-element abundance pattern is instead reminiscent of the operation of the CN cycle (strong N overabundance, low $^{12}C/^{13}C$ ratio, Na overabundance). Hot bottom burning is not expected to operate in such low-mass stars. We therefore suggest that the enrichment of the envelope with nuclear-burning products does not result from the traditional third dredge-up events, but rather may be

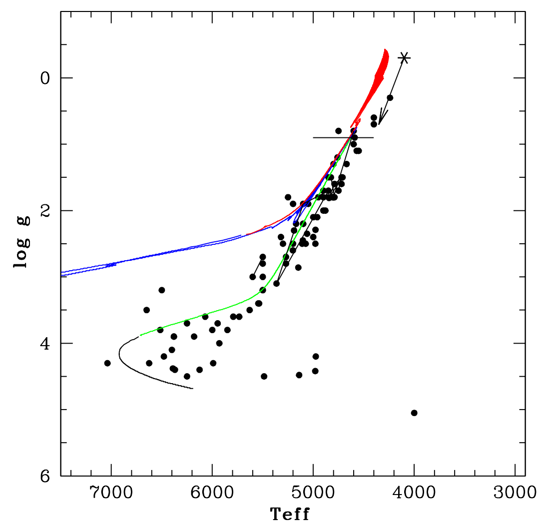

Figure 1. HR diagram for CEMP stars collected from the literature revealing that CS 30322–023 (asterisk) is the most extreme case known. The solid line corresponds to the evolutionary track of a 0.8 $M_{\odot}$ model with [Fe/H] = −3.8. The horizontal bar on the evolutionary track marks the tip of the RGB. The arrow corresponds to a conservative 250 K uncertainty in T_{eff} and a 1.0 dex uncertainty in the gravity.

caused by some mixing mechanism that has yet to be identified. Although the radial velocity variations of this star might be explained by the pulsations of the stellar envelope, an alternative possibility is that CS 30322–023 has accreted matter from an intermediate-mass companion that produced s-process elements and experienced HBB episodes. Clearly, a full understanding of the abundance pattern and apparent evolutionary state of CS 30322–023 will depend on future high-resolution studies of stars with similar characteristics.

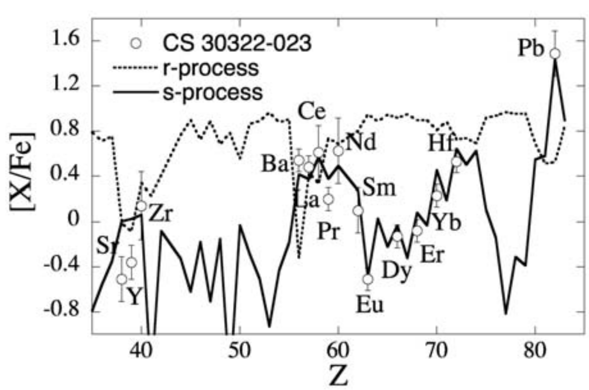

Figure 2. Abundance pattern of CS 30322–023 compared to two model predictions for the s- and r-processes. The s-process abundance pattern has been computed by post-processing an AGB model of mass 0.8 $M_{\odot}$ and metallicity [Fe/H] = −3.8. The r-process pattern corresponds to scaled solar r-process abundances.

References

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