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CARBON-ENHANCED METAL-POOR STARS: WITNESSES OF THE FIRST GENERATION OF STARS

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Abstract. Carbon-enhanced metal-poor (CEMP) stars are now accepted to be mass-transferred binary member of the first generation of stars. Indeed, the peculiar chemical fingerprints revealed by their spectra represent a unique opportunity to study their now extinct progenitor (basically all low-metallicity stars with $M > 0.8M_{\odot}$).

Keywords: Carbon stars, metal-poor,abundances

1 The method

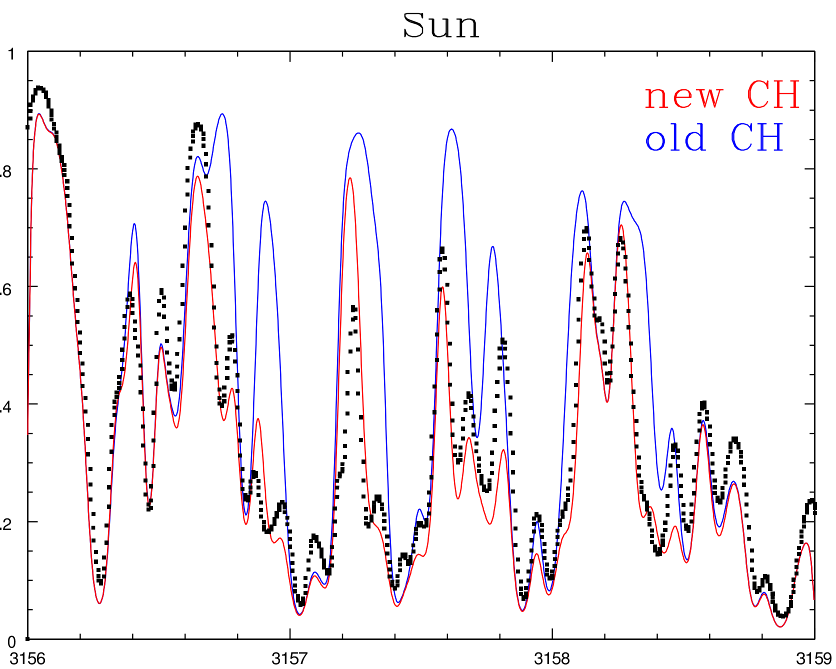

Fig. 1. : Example of synthesis of the Sun spectrum (black squares). The different colored lines show the improvement we made on molecular linelist.

In order to decipher the physics of these first generations of stars, we derive abundances from high resolution and high SNR spectra of a large sample of CEMP stars. For this, we use the radiative transfer code Turbospectrum, and specific stellar atmospheres (MARCS), taking into account the effect of large C enhancement on the atmosphere structure..

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One of the critical ingredients of abundance analysis are the input linelists. By using a combination of programs to simulate molecular structure and well selected laboratory measurements, we build new accurate molecular linelists. We show in Fig.1 the results for a part of the C-X band of the CH molecule.

Reciprocally, we also use stellar spectra probing thermodynamical conditions not available on earth to improve molecular constants (notably high rotational levels including predissociation levels).

2 The metal-poor stars zoo

Among metal-poor stars in the Galaxy, ∼20% show a high content of carbon, the so-called Carbon-Enriched Metal-Poor (CEMP) stars. It is now clear that most of them have transferred material from an Asymptotic Giant Branch (AGB) star. In particular, AGB stars are known to produced s-process elements (like Ba or Pb).

However, we show in Fig. 2 that many subclasses exists: we do find a subclass of CEMP stars which nicely falls along the s-process predictions, but there are also CEMP stars which show no capture elements enhancement. We observed that these stars tends to have a lower metallicity than other CEMP stars, pointing out that nucleosynthesis of AGB stars may drastically change at very-low metallicity.

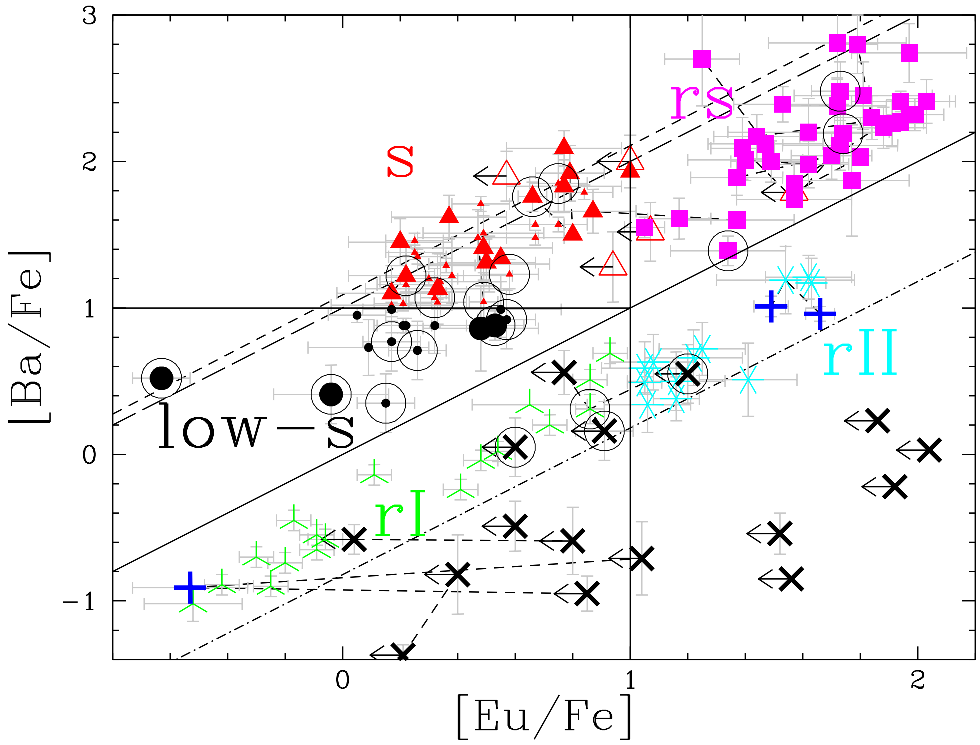

Fig. 2. : Ba vs Eu abundances in metal-poor stars. Lines represent the prediction for pure s-process nucleosynthesis (AGBs) (short and long dashed lines), and pure r-process nucleosynthesis (SNII) (dashed-dotted line). Except black dots, all symbols represent different categories of CEMP stars , according to their content of neutron-capture

In contrast, another subgroup of CEMP stars show a large excess of neutron-capture elements. We claim that another source of neutron is required in order to explain the existence of such stars (possibly the $^{22}Ne(\alpha,n)^{25}Mg$).

3 Fluorine

Fluorine is an element very sensitive of the thermodynamical conditions in AGB stars. While C is produced by He burning during the pulses of AGB stars, F is also produced in the He-rich layers of AGB stars, but is dependent on the presence of neutrons in the He intershell. Since the mechanism for making neutrons is still poorly understood, F is a very precious element to constrain the models.

Thanks to the IR high resolution spectrograph CRIRES, we were able to observe the HF lines in sample of CEMP stars (Fig.3). According to the observation of s-process elements, low-metallicity AGB models predict that the progenitor of CEMP stars should have a mass between $1.2M_{\odot}$ and $2M_{\odot}$. Although we measure mostly upper limits, we did not observe as much Fluorine as expected by the models.

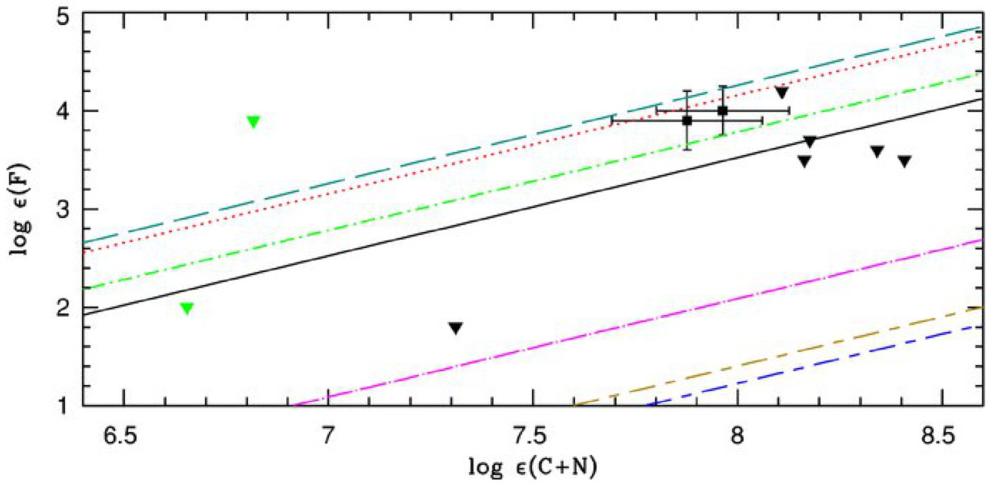

Fig. 3. : black triangles are CEMP stars. Models are from Karakas & Lattanzio (2007) for different masses; solid black line $1.25M_{\odot}$, red dotted line $1.75M_{\odot}$, teal dashed line $2.25M_{\odot}$, green dot-dashed $2.5M_{\odot}$, magenta dot-dashed line $3.0M_{\odot}$, short-long dashed yellow line $3.5M_{\odot}$, and short-long dashed blue line $4M_{\odot}$.

4 Lithium

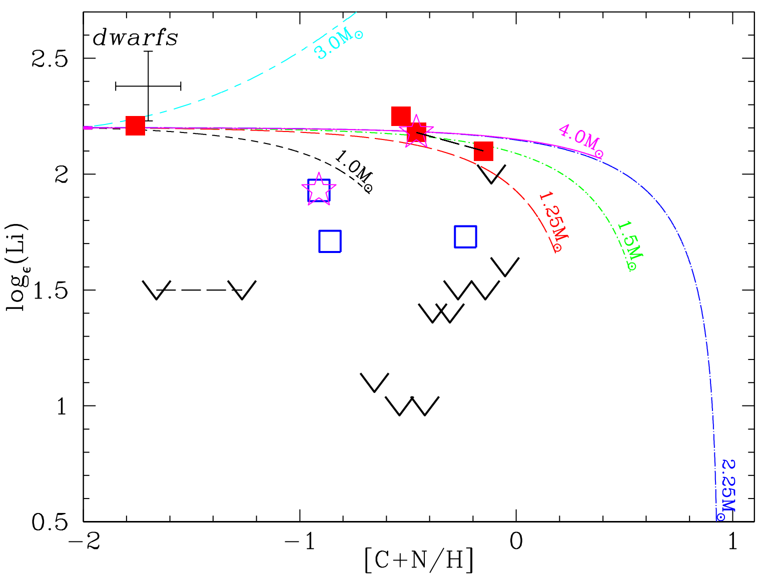

Fig. 4. red squares are CEMP Li-rich stars, blue open squares are Li-poor CEMP stars, black v signs are upper limits. Models are from Karakas & Lattanzio (2010).

While C is produced by AGB stars, Li is generally destroyed. Because CEMP stars have accreted large amount of this AGB material, it was not expected to find CEMP stars with high Li content (close to the Spite plateau). Since then, Li production in AGB stars has been required. However, we demonstrate in Fig.5 that Li-rich stars can naturally be explained by dilution of the AGB yields. In contrast it is more difficult to understand how some CEMP stars can have so low Li content. By looking at the rotation speed of the star, we

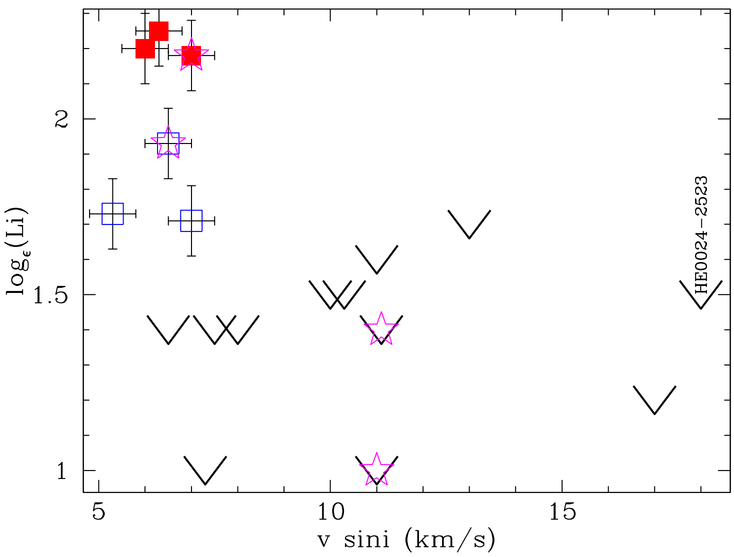

Fig. 5. Li abundance as function of rotational velocity. Red squares are CEMP Li-rich stars, blue open squares are Li-poor CEMP stars, black v signs are upper limits.

noticed that no fast rotating stars were observed with a high Li content, suggesting that rotation has played a role in the Li destruction.

5 Conclusions

AGB stars at low metallicity show a broad range of nucleosynthetic properties that still need to be understood by the models: it seems that various s-processes occur, but the origin of the neutron source is still not clearly established. Moreover, various mixing mechanisms are expected to occur (thermohaline mixing, canonical extra mixing, hydrogen injection flash, rotation...). The complex interplay of these mechanisms can either lead to the destruction or the production of Li and F. Our observations bring some more constrains to understand AGB stars, but more are needed. Furthermore, there is still a lot of improvement to be made in the analysis and in particular concerning molecular linelists. We plan to build new sets of accurate linelists that could be used for accurate abundance measurements.

References

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