Carbon-enhanced metal-poor stars: witnesses of the first generation of stars

Thomas Masseron

Université Libre de Bruxelles, Belgium

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 $M>0.8M_\odot$).

The Method

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..

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).

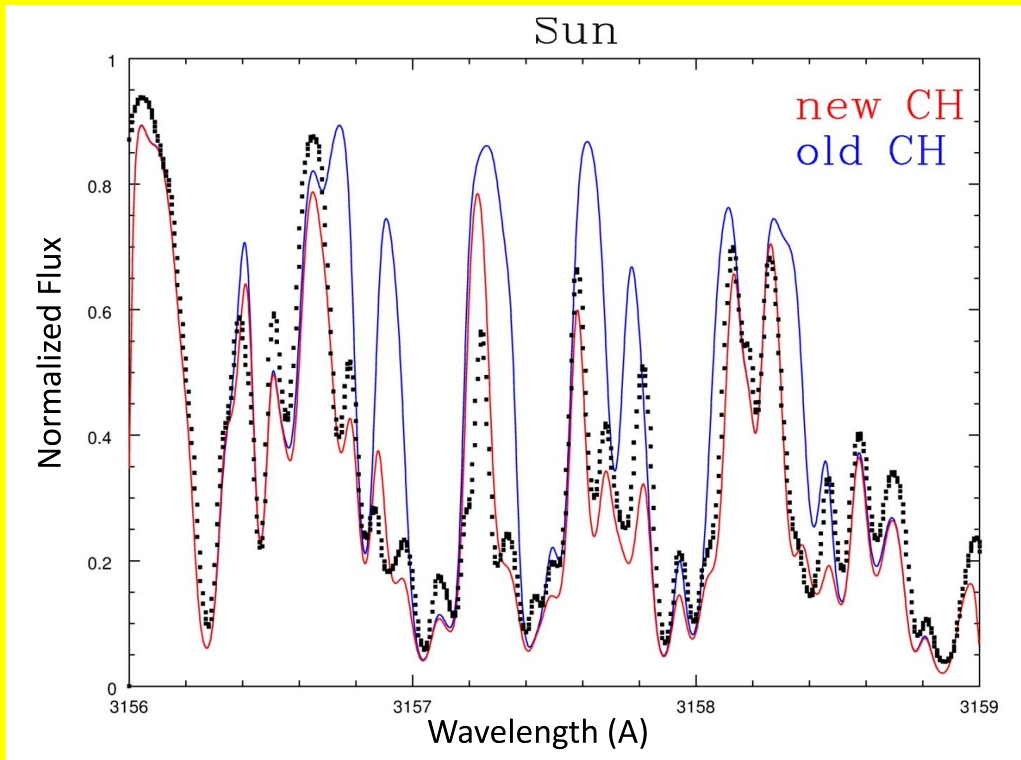

Fig.1: Example of synthesis of the Sun spectrum (black squares). The different colored lines show the improvement we made on molecular linelist.

The metal-poor stars zoo

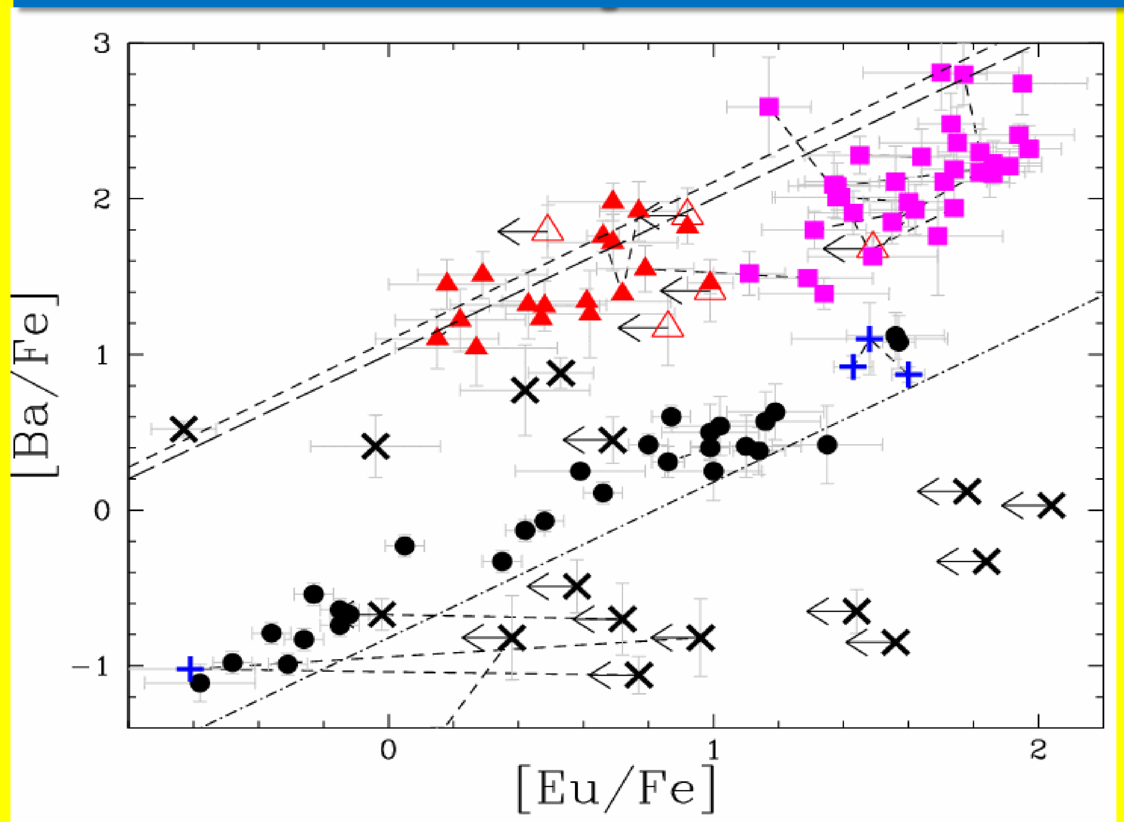

Fig.1: Ba vs Eu abundances in metal-poor stars. Lines represent the prediction for pure s-process nucleosynthesis (AGBs) (short and long dashed lines), and pure r-process nucleosynthesis (SNII) (dahsed-dotted line). Except black dots, all symbols represent different categories of CEMP stars , according to their content of neutron-capture elements.

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.

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 $^{22}Ne(\alpha,n)^{25}Mg$).

References:

Masseron, T., Johnson, J.A., Plez, B., van Eck, S., Primas, F., Goriely, S., & Jorissen, A. 2010, A&A, 509,A93

Lucatello, S., Masseron, T., Johnson, J.A., Pignatari, M., & Herwig, F. 2011, ApJ, 729, 40

Masseron, T., Johnson, J.A, Lucatello, S., Karakas, A., Herwig., F., Plez, B., Beers, T.C. & Christlieb, N., to appear in ApJ

Fluorine

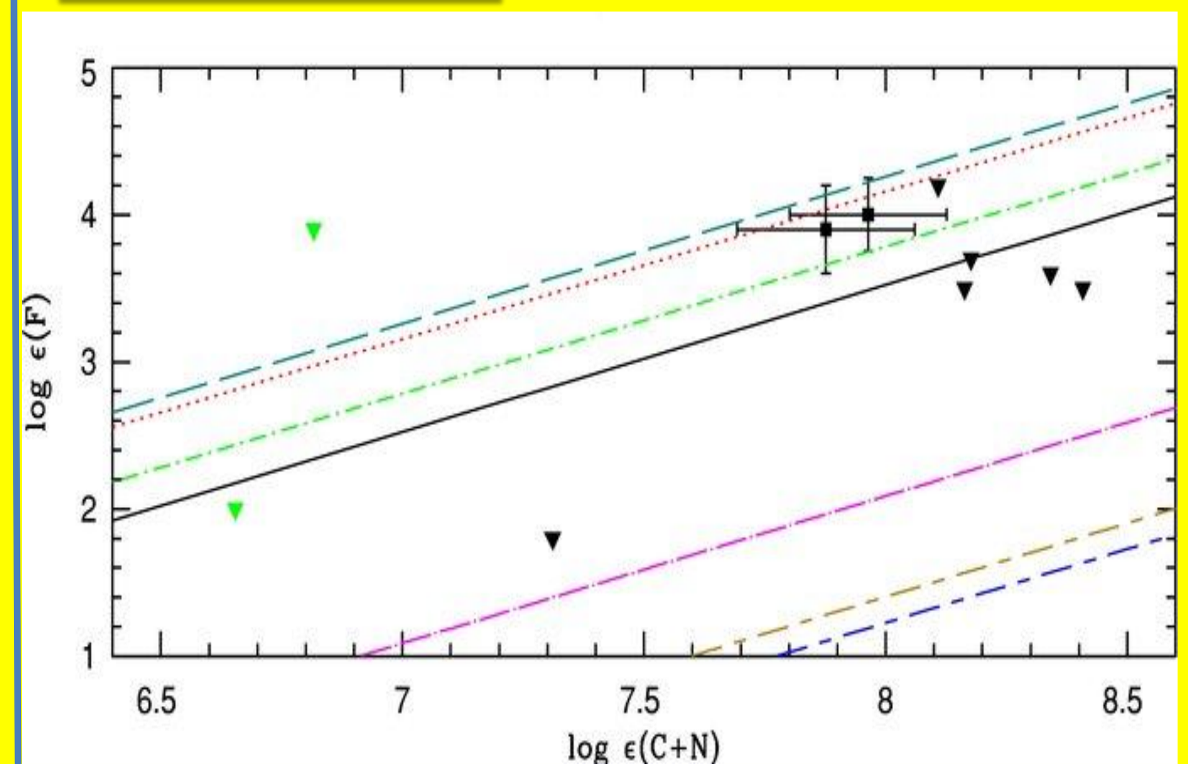

Fig.3: black triangles are CEMP stars. Models are from Karakas & Lattanzio (2007) for different masses; solid black line 1.25 $M_\odot$, red dotted line 1.75 $M_\odot$, teal dashed line 2.25 $M_\odot$, green dot-dashed 2.5 M, magenta dot-dashed line 3.0 $_\odot M$, short-long dashed yellow line 3.5 $M_\odot$,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

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.

Lithium

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.

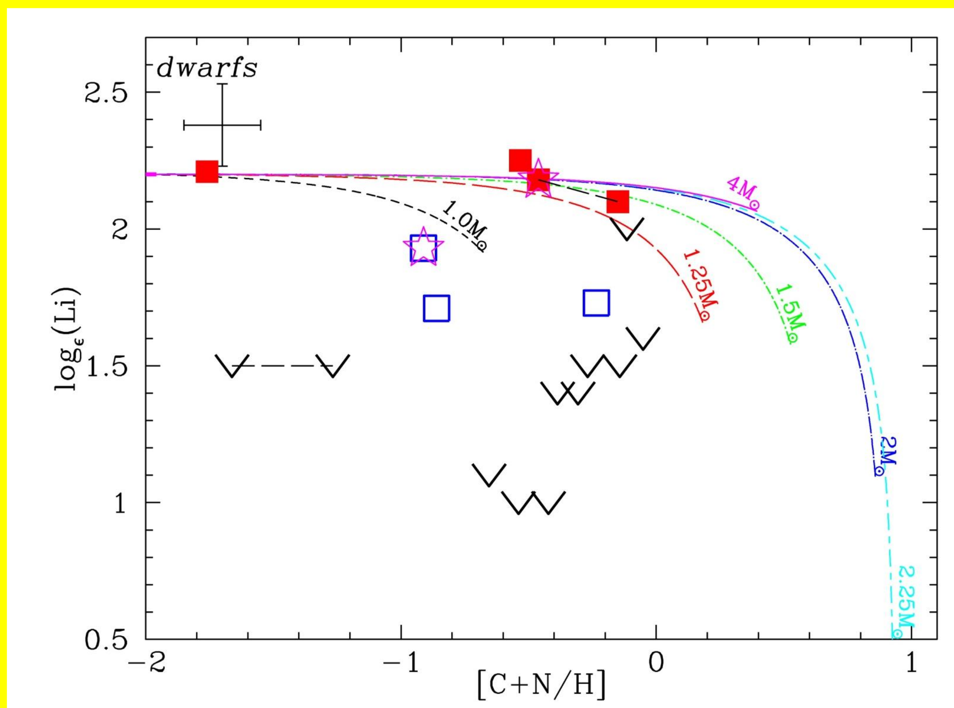

Fig.4: red squares are CEMP ¨Li-rich¨ stars, blue open squares are ¨Li-poor¨ CEMP stars, black v signs are upper limits. Models are from Karakas & Lattanzio (2010).

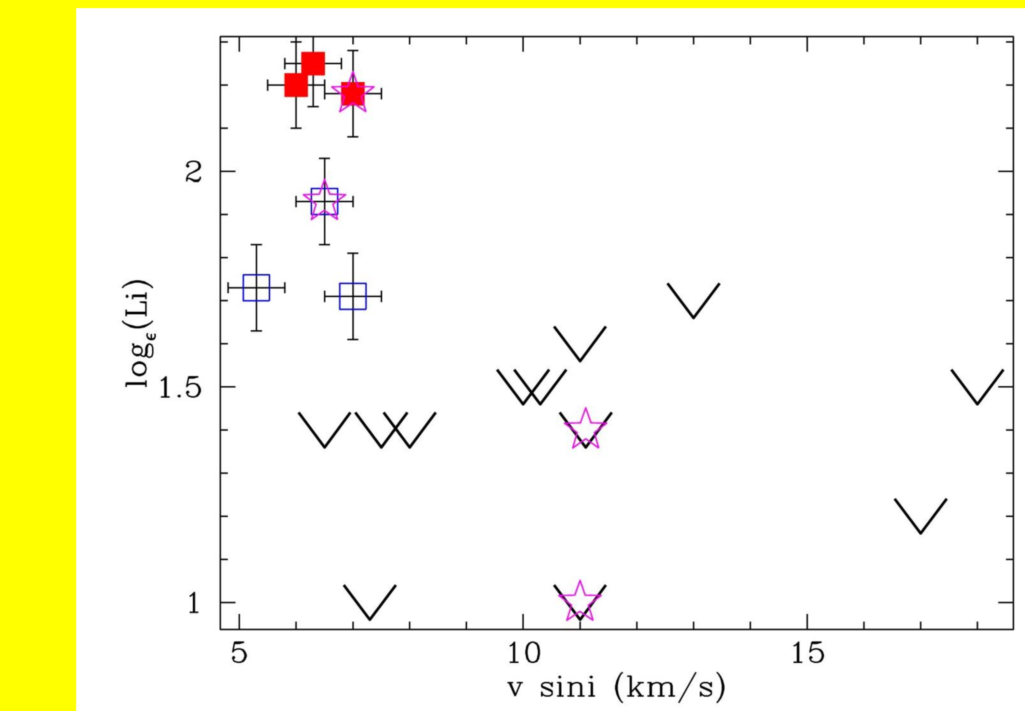

Fig.5: Li abundance as function of rotaional velocity. Red squares are CEMP ¨Li-rich¨ stars, blue open squares are ¨Li-poor¨ CEMP stars, black v signs are upper limits.

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