Carbon stars within the Gaia-ESO survey

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We present the detection and chemical analysis of carbon-enriched stars discovered within the Gaia-ESO survey. In a first step, carbon-enriched candidates are identified from the analysis of a series of enhanced molecular features, measured through photometric and narrow-band spectroscopic filters. Then, the atmospheric parameters, C/O ratios and s-process element abundances are determined. The nature of these carbon-enriched stars is discussed together with the expected impact of the Gaia mission on the knowledge of these objects in the Milky Way.

What is a carbon star?

The overwhelming majority of the astronomical objects are oxygen-rich, i.e. they show an abundance ratio C/O < 1. Carbon-rich stars are indeed rare; most probably polluted with the ashes of He-burning. The so-called *intrinsic carbon stars* (C/O > 1) are formed during the AGB phase evolution of low mass stars (1.5 < $M/M_\odot$ < 3) through the mix of fresh ^{12}C from the interior into the envelope, during the 3rd dredge-up mechanism after each thermal pulse. They also show s-element enhancements produced by slow neutron captures in the He-rich intershell provided by the $^{13}C(\alpha,n)^{16}O$ reaction. The prototype of these stars are the AGB C-stars. *Extrinsic carbon stars* on the other hand, are formed in binary systems by mass transfer of C-rich material from a former AGB star (now seen as a WD) onto the secondary star. Prototype of these class are the CH stars. Indeed a zoo of carbon-rich type stars exits (e.g. Abia et al. 2003), all being tracers of intermediate-age stellar populations. Therefore they are extremely useful for studies of the star formation history and chemical evolution of the galaxies.

The Working Group 14 (WG14) within the GES Survey is in charge of the characterization and analysis of the peculiar objects discovered, among these are the carbon-enriched stars (see Fig. 1).

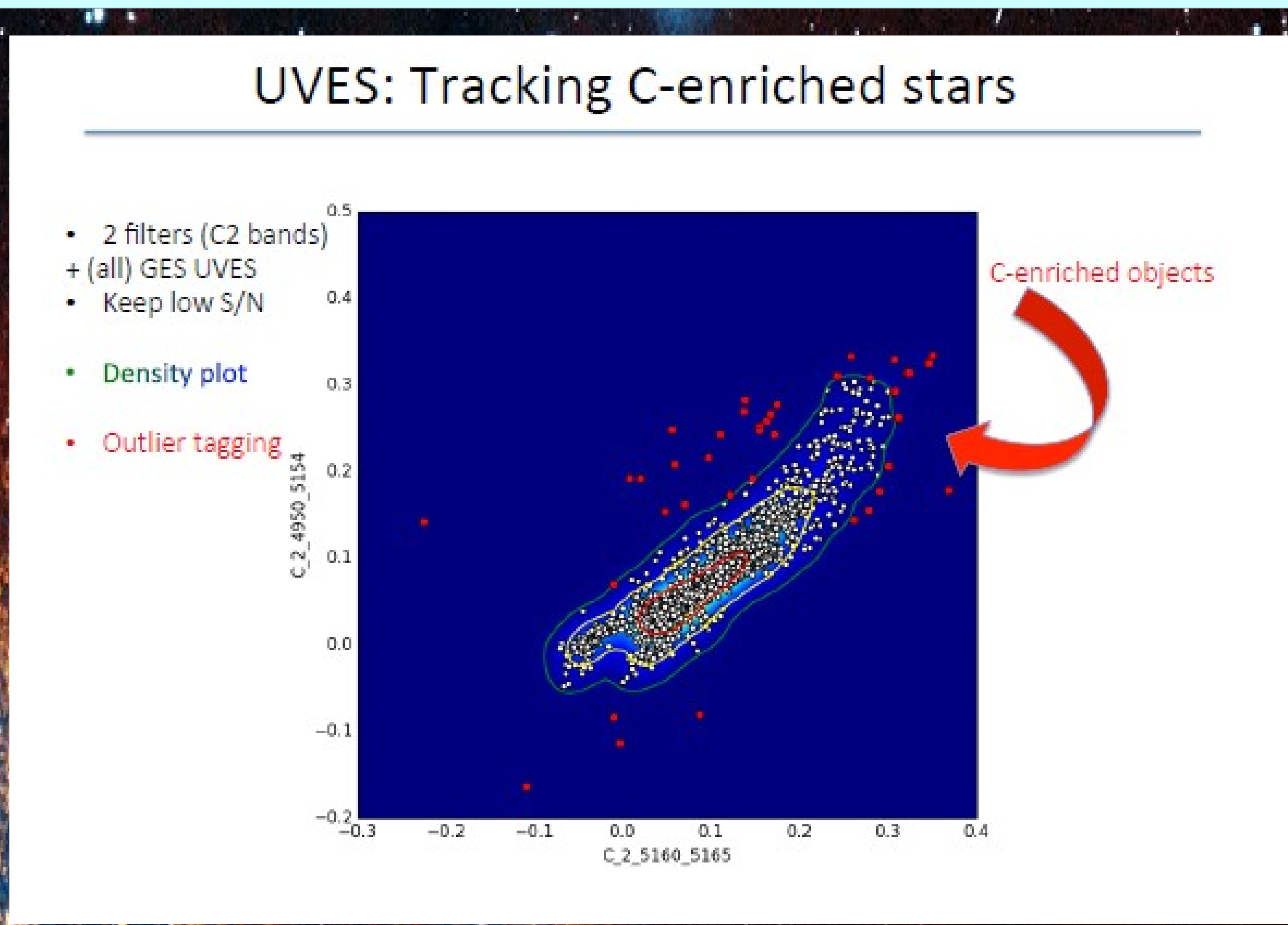


Figure 1: C_2 molecular band intensity indixes for the GES stars so far observed with UVES. Red points inticate the outlier objects, those at the upper right corner are the C-rich candidate objects.

Possible C-enriched stars were selected using both photometric and spectroscopic indixes defined in the WG14. So far we have detected 13/53000 candidates. Note that the GES survey was planned to observe FGK type stars and not cool C-rich stars!!

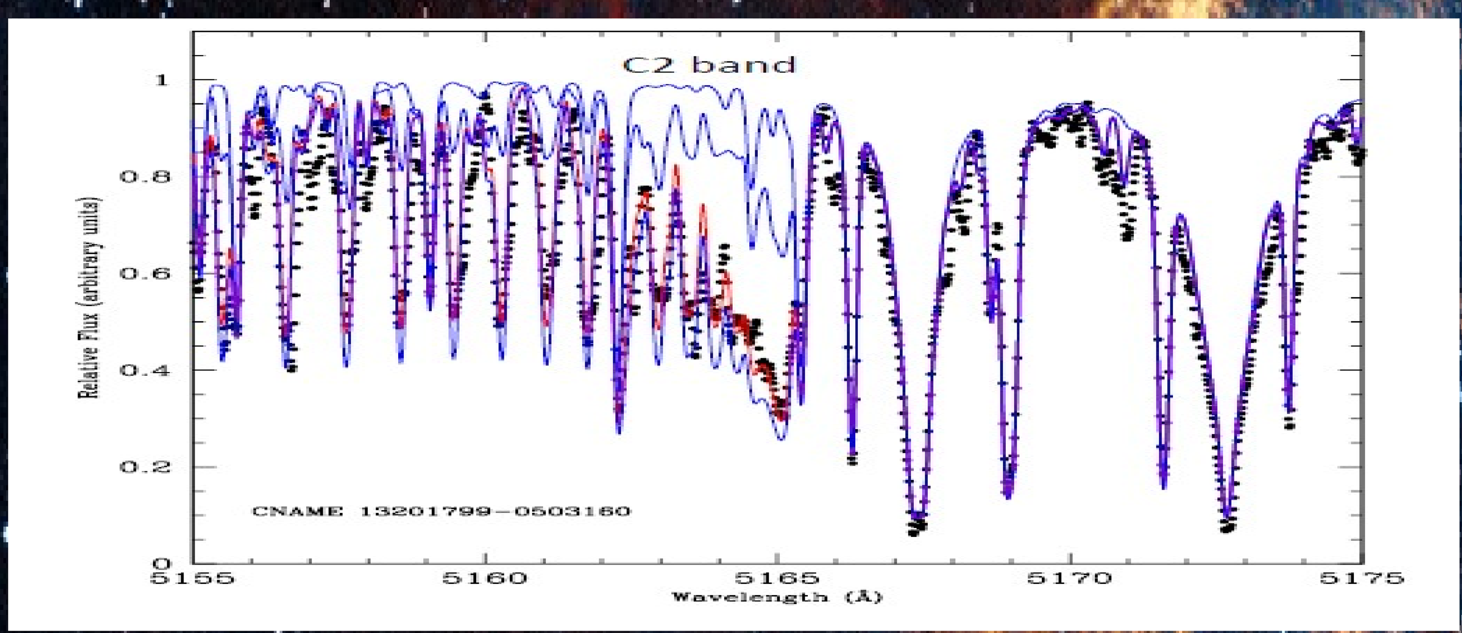
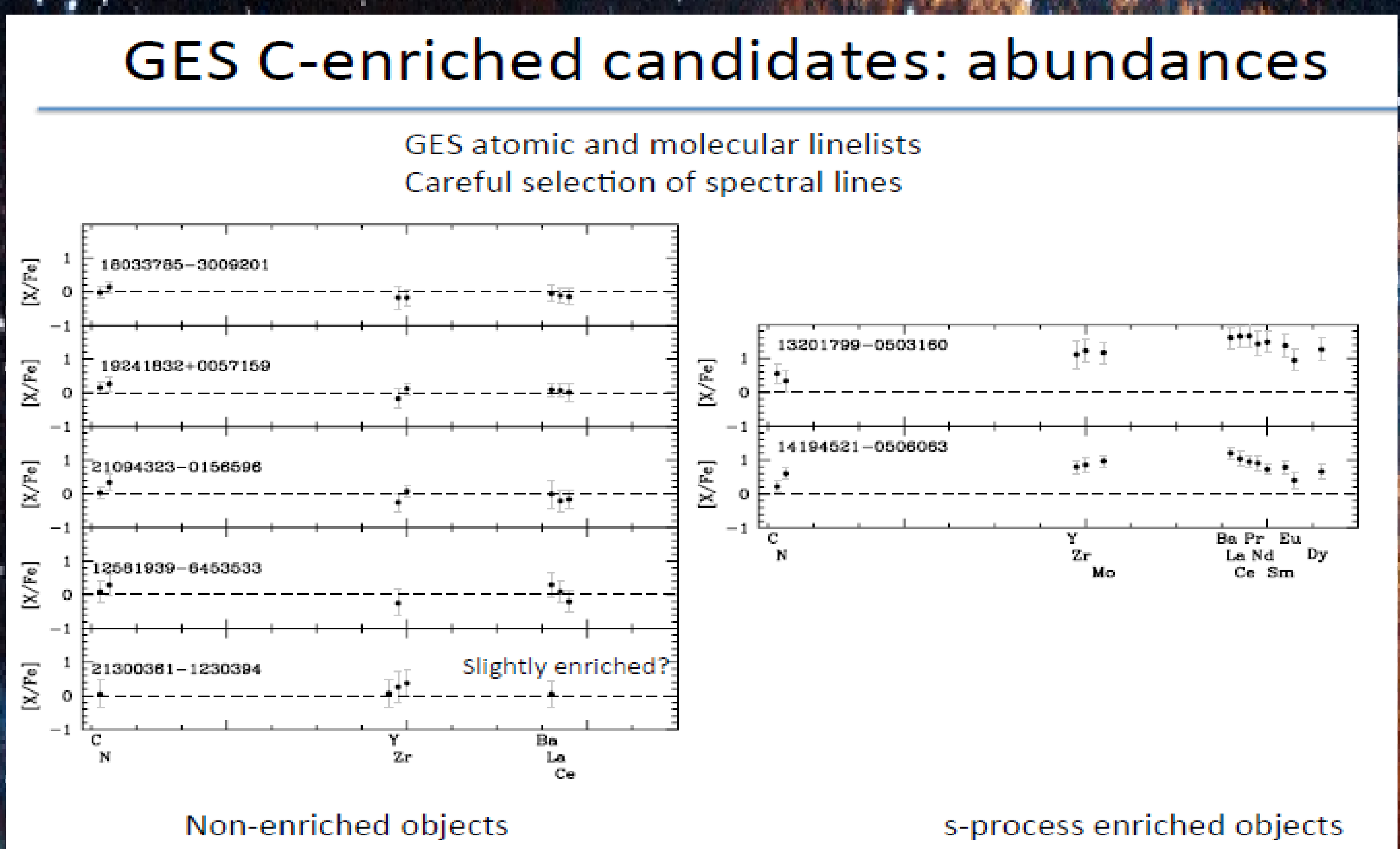


Figure 2: An example of a theoretical fit to the C_2 band at 5160 Å



Seven previously unknown stars are found to be C-enhanced. Two of them show also s-element enhancements; because their binary nature they are probably extrinsic CH stars. The other stars show abundance patterns typically of the R-hot type carbon stars which origin is still not understood (Zamora et al. 2009). Parallaxes and kninematics to be measured by the Gaia mission will discern the evolutionary status of these stars.

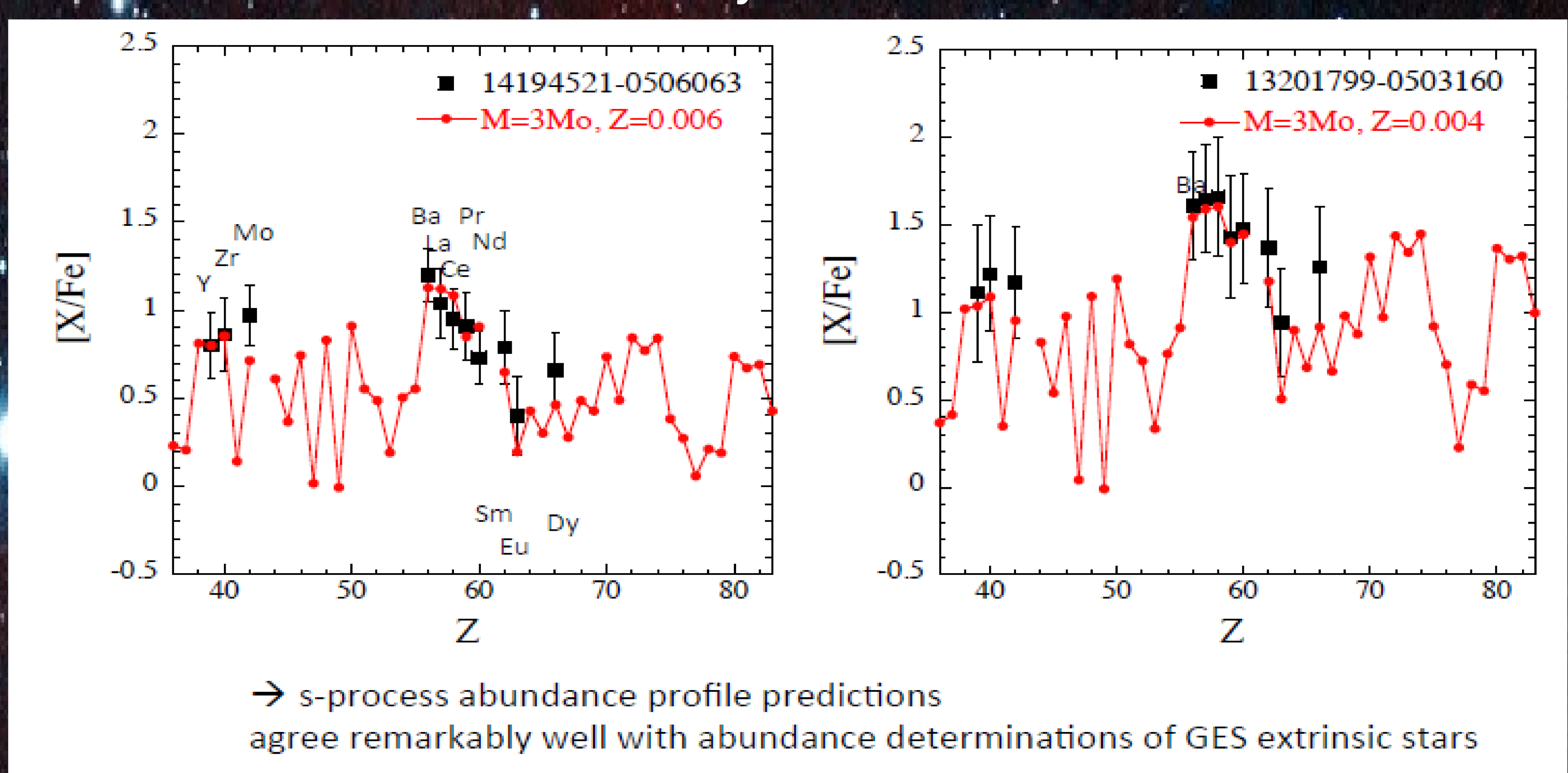


Figure 3: Comparison of the abundance patterns found in the two CH stars with theoretical predictions (Cristallo et al. 2010).

Extrinsic C-stars: Why are they interesting ?

Theoretically the ratio between the low (Sr, Y, Zr) and the heavy (Ba, La, Nd, Sm) mass s-elements is a strong function of the stellar metallicity. High-precision determinaton of this abundance ratio [hs/ls] in the GES sample will challenge this prediction and allow to detect a possible second parameter (rotation, neutron density..etc) to explain the observed dispersion.

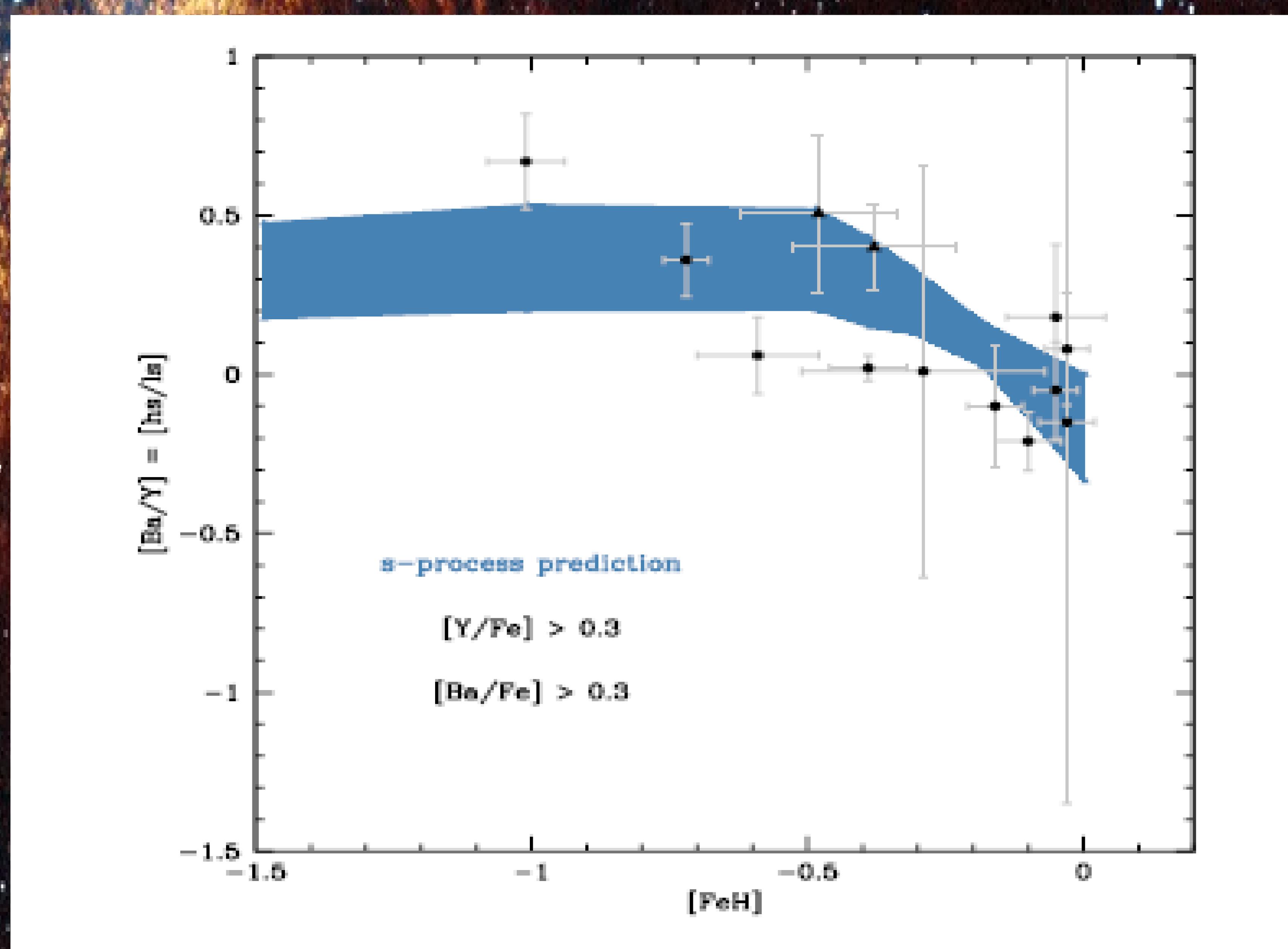


Figure 4: Observed [hs/ls] vs. [Fe/H] relationship in the C-rich GES sample analyzed so far compared with theoretical predictions (Cristallo et al. 2010; Siess et al. 2004; Goriely & Siess 2004).

Abia, C., et al. 2003, PASP, 20, 314
Cristallo, S., et al. 2010, ApJS, 197, 17
Gorlely, S., & Siess, L. 2004, A&A, 421, L25
Siess, L., et al. 2004, A&A, 415, 1089
Zamora, O., et al. 2009, A&A, 508, 909