An ultra metal-poor star ([Fe/H]=−4.7) star is found

P. Jablonka
LASTRO
ÉCOLE POLYTECHNIQUE
FÉDÉRALE DE LAUSANNE

Galactic archeology or near-field cosmology

The first (Pop III) stars were the sources of the first hydrogen-ionizing photons, thus initiating the extended process of reionization, and of the first heavy chemical elements.

Primordial star formation thus fundamentally changed the conditions in the early Universe, during its first billion years of existence.

Predictions for the Pop III era, will be tested with the James Webb space telescope (JWST), the thirty-meter telescope (TMT), and the European extremely-large telescope (E-ELT), to hopefully close the final gap in our cosmic view.

Terminology

Extremely metal-poor	$[\mathrm{Fe/H}] < -3.0$
Ultra metal-poor	$[\mathrm{Fe/H}] < -4.0$
Hyper metal-poor	$[\mathrm{Fe/H}] < -5.0$

$$[\mathrm{X/H}] = \log_{10}(n_{\mathrm{X}}/n_{\mathrm{H}}) - \log_{10}(n_{\mathrm{X}}/n_{\mathrm{H}})_{\odot}$$

These extremely metal-poor stars are difficult to find

- In a typical halo field, only one in 80,000 stars is expected to have [Fe/H]< -4 (Youakim et al. 2017).

- 11 stars known to have intrinsic iron abundances [Fe/H] < -4.5

(Christlieb,Wisotzki & Graßhoff 2002; Frebel et al. 2005; Norris et al. 2007; Caffau et al. 2011; Norris et al. 2012; Keller et al. 2014; Hansen et al. 2014; Allende Prieto et al. 2015; Frebel et al. 2015; Bonifacio et al. 2015; Caffau et al. 2016; Bonifacio et al. 2018; Aguado et al. 2018).

- Current record holder amongst iron-poor stars at [Fe/H] $< - 7.1$

The SkyMapper Southern Sky Survey star SMSS J031300.36-670839.3 shows a very high carbon abundance of [C/Fe]> 5 (Nordlander et al. 2017).

Information EMPS provide

- Explosion mechanisms

Constraints on the dominant explosion mechanism(s), which in turn yield insight on the primordial IMF → mass, number density of the first galaxies

- Fragmentation

Guidance for the theoretical modeling of the Pop III–Pop II transition, and predictions for the critical metallicity

The questions they raise - Explosion mechanisms

Example

There is no sign for a pair-instability supernova (PISN) enrichment.

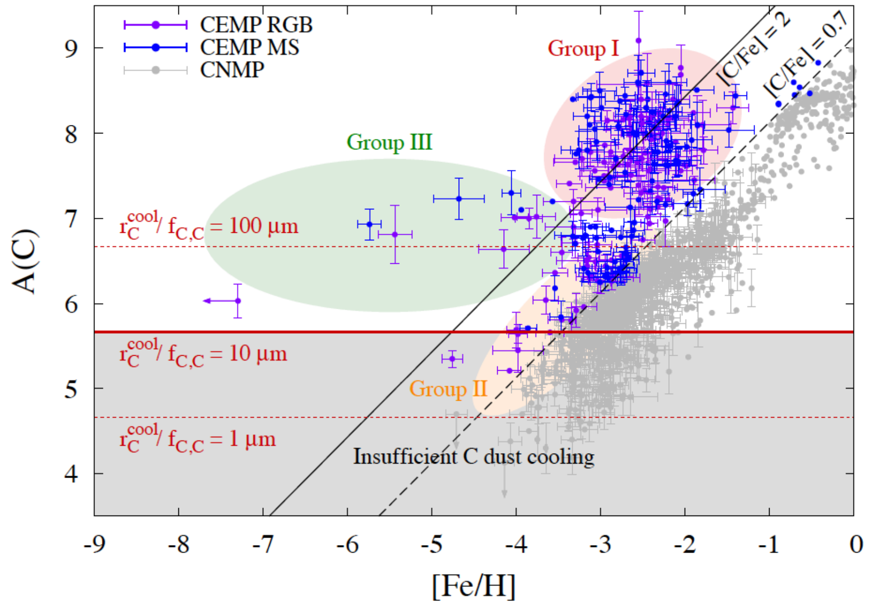
This would manifest itself in a strong elemental odd-even effect, and the complete absence of any neutron-capture elements.

The questions they raise - Explosion mechanisms

- Trend with increasing carbon-to-iron ratio as [Fe/H] decreases

For many of the most iron-poor stars, the absolute abundance of carbon lies around a value of A(C) ~6.5 (Spite et al. 2013; Yoon et al. 2016)

- Other light elements, such as nitrogen, oxygen, and sodium, are also often greatly enhanced in these stars with respect to solar [X/Fe] abundance ratios



Chiaki et al. 2017

The questions EMPS raise - Explosion mechanisms

These carbon-enhanced extremely metal-poor (CEMP) stars have long been recognized as possibly holding the key to the first stars (Spite et al 2013)

The CEMP abundance pattern has been explained with the yields from *faint*, BH forming SNe.

Their Pop III progenitors would have been too massive to trigger conventional Type II events; instead, the central region containing the heavier elements would be devoured by the BH, whereas only the outer envelope, enriched with the lightest, CNO, elements, could escape the deep potential well of the star (Iwamoto et al 2005).

The questions EMPS raise - Fragmentation

Fine-structure line or/and dust-continuum cooling?

- The fine-structure theory identifies CII , and to a lesser extent OI , as main coolants. This resonates nicely with the prevalence of C-enhanced stars at the lowest values of [Fe/H]; the resulting [C/H] can then still exceed the predicted critical level.

The questions EMPS raise

However

SDSS J102915+172927 (Caffau et al. 2011), the most metal-poor star known today is the ultra metal-poor star

It has no carbon-enhancement

difficult to accommodate with fine-structure line cooling

There might be multiple formation routes for ultra metal-poor stars, with important consequences for theories of early star formation in the Galaxy

The questions EMPS raise - Fragmentation

Fine-structure line or/and dust-continuum cooling?

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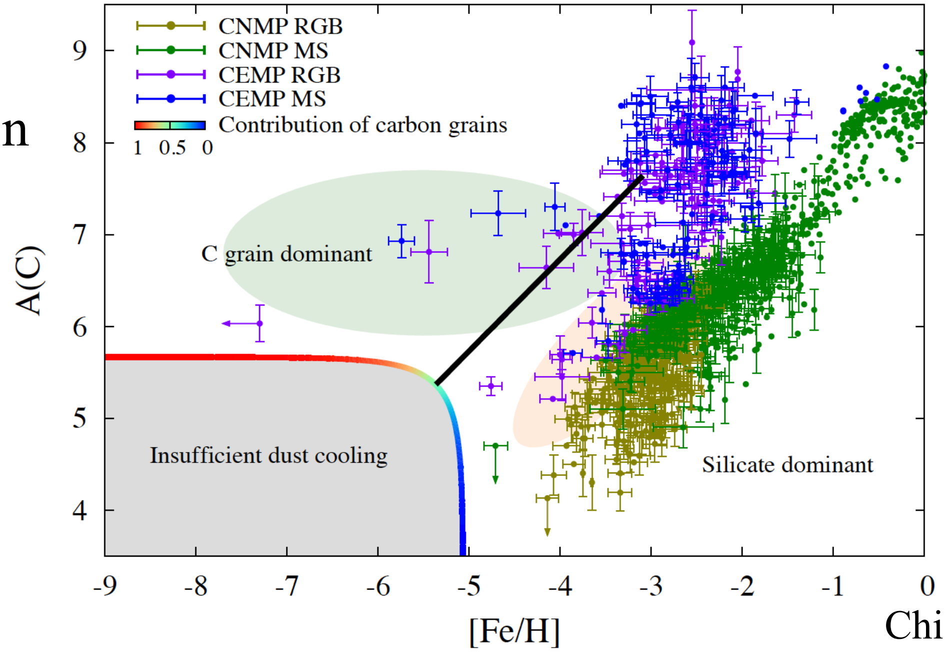
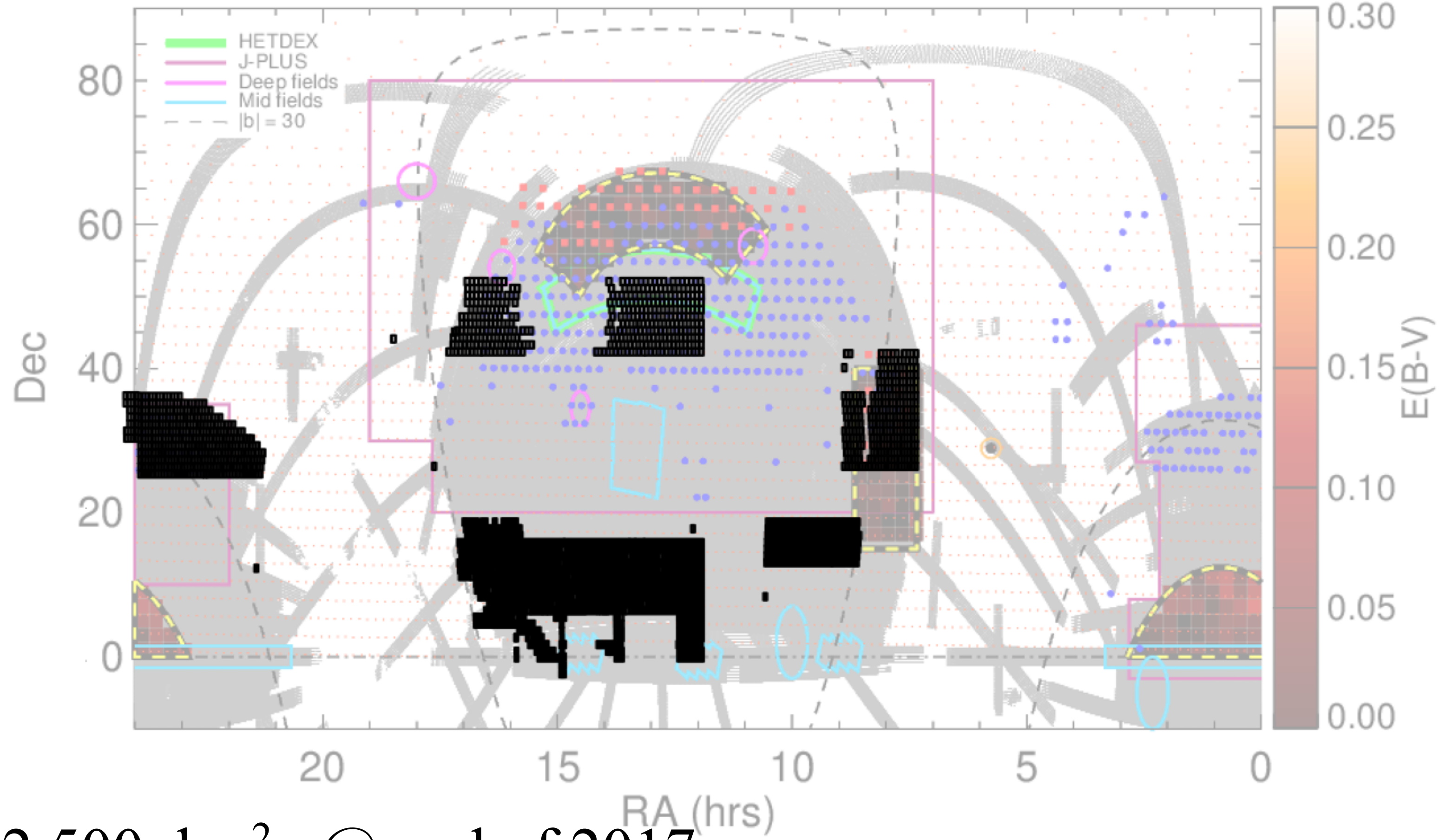
- Gas cooling by dust thermal emission



Chiaki et al. 2017

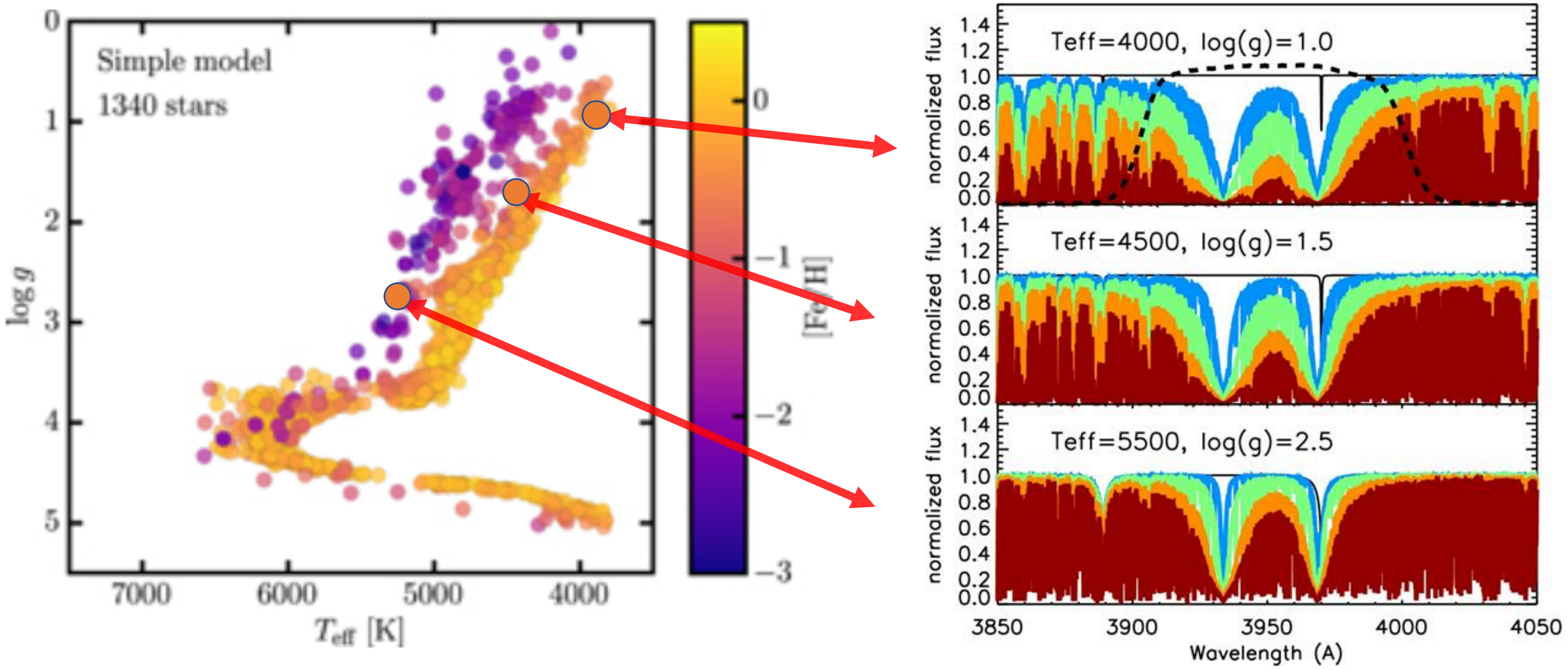
Pristine



Pristine ~2,500 deg^2 @ end of 2017

Pristine

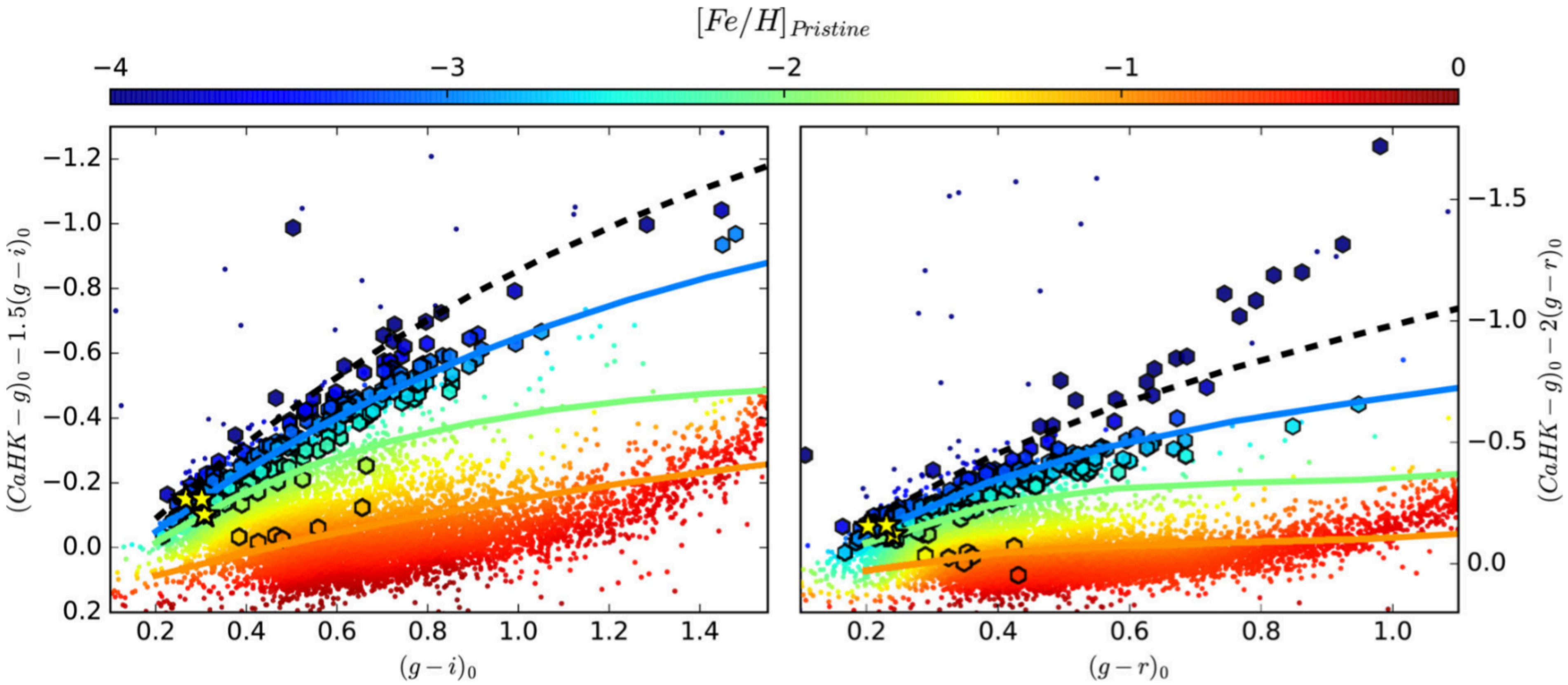
CaII H&K lines at 3968.5 and 3933.7 Å



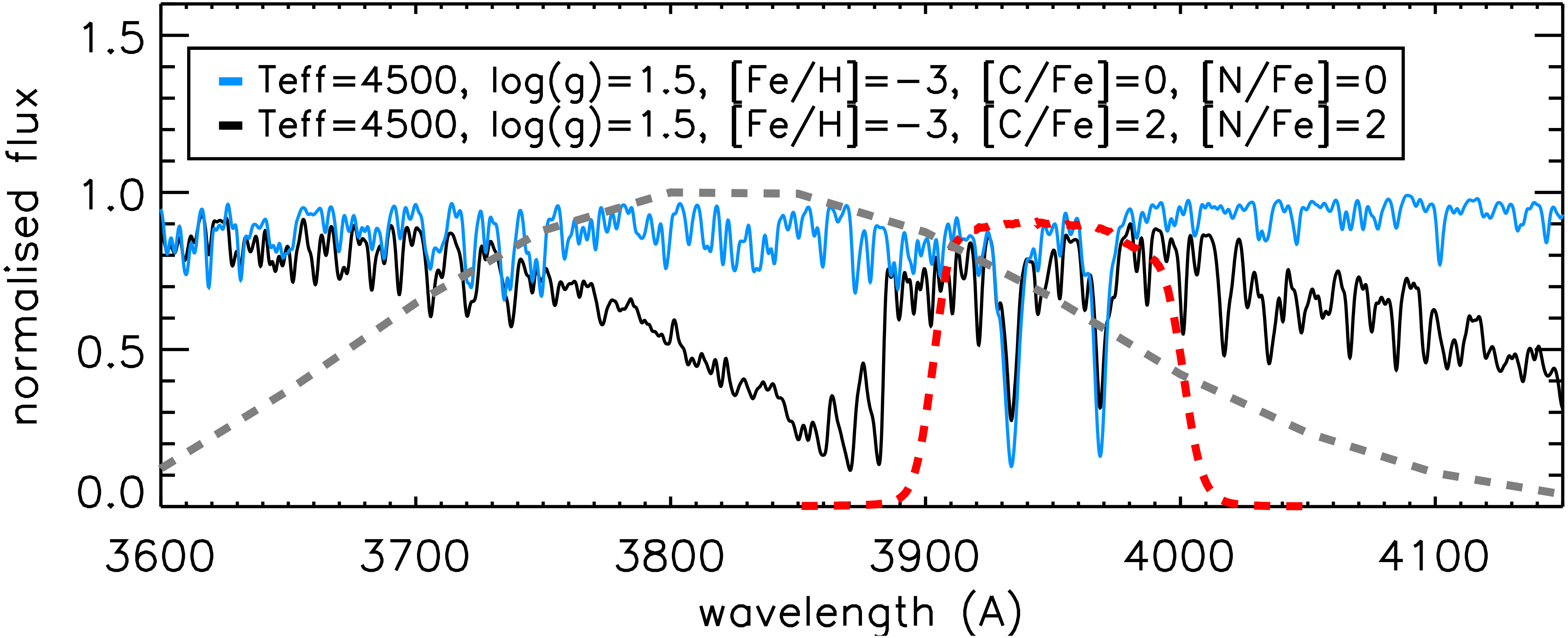
Casey et al., 2017, AJ, 840, 1

Youakim et al., 2017, MNRAS, 472, 2963
Starkenburg et al., 2017, MNRAS, 471, 2587

Selection of targets

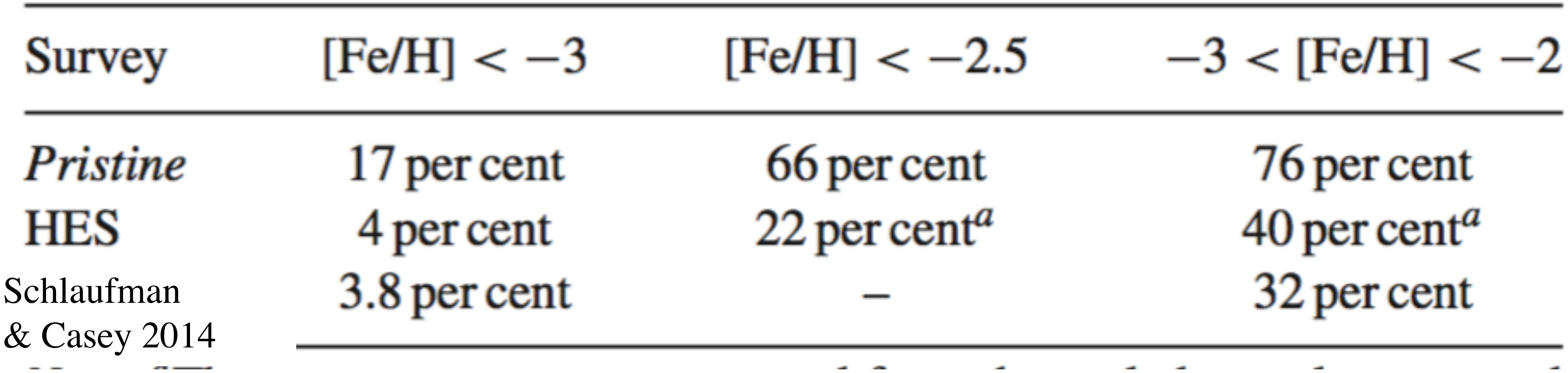


Pristine vs. SkyMapper (Keller et al. 2007)



Fractions of metal-poor stars in *Pristine* compared to other surveys

A success rate up to 4 times larger



Hamburg/ESO survey

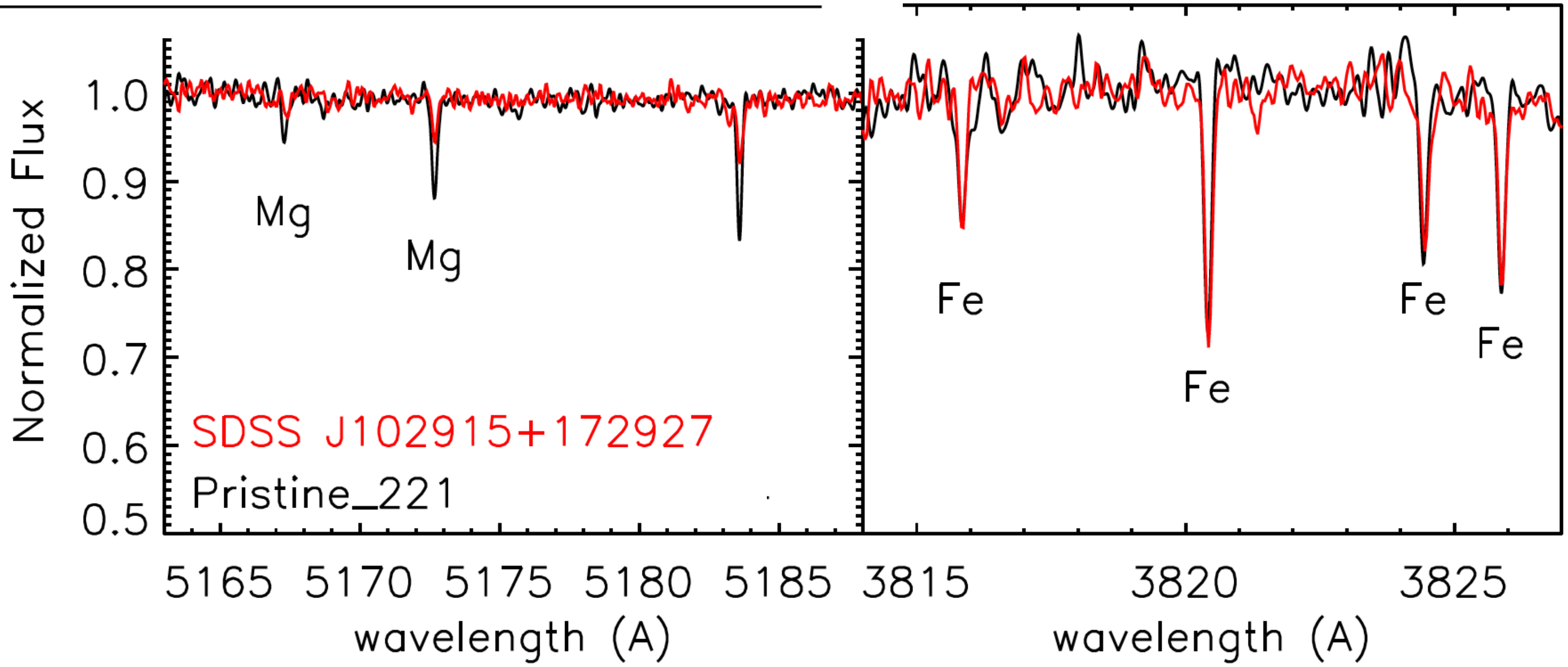
Survey	$[\mathrm{Fe/H}] < -3$	$[\mathrm{Fe/H}] < -2.5$	$-3 < [\mathrm{Fe/H}] < -2$
Pristine	17 per cent	66 per cent	76 per cent
HES	4 per cent	22 per cent[a]	40 per cent[a]
Schlaufman & Casey 2014	3.8 per cent	–	32 per cent

At full completion, Pristine will clearly change the observational landscape of near-field cosmology, delivering thousands of stars with [Fe/H] −3 and a few tens below −4.

Pr 221

[Fe/H]=−4.7

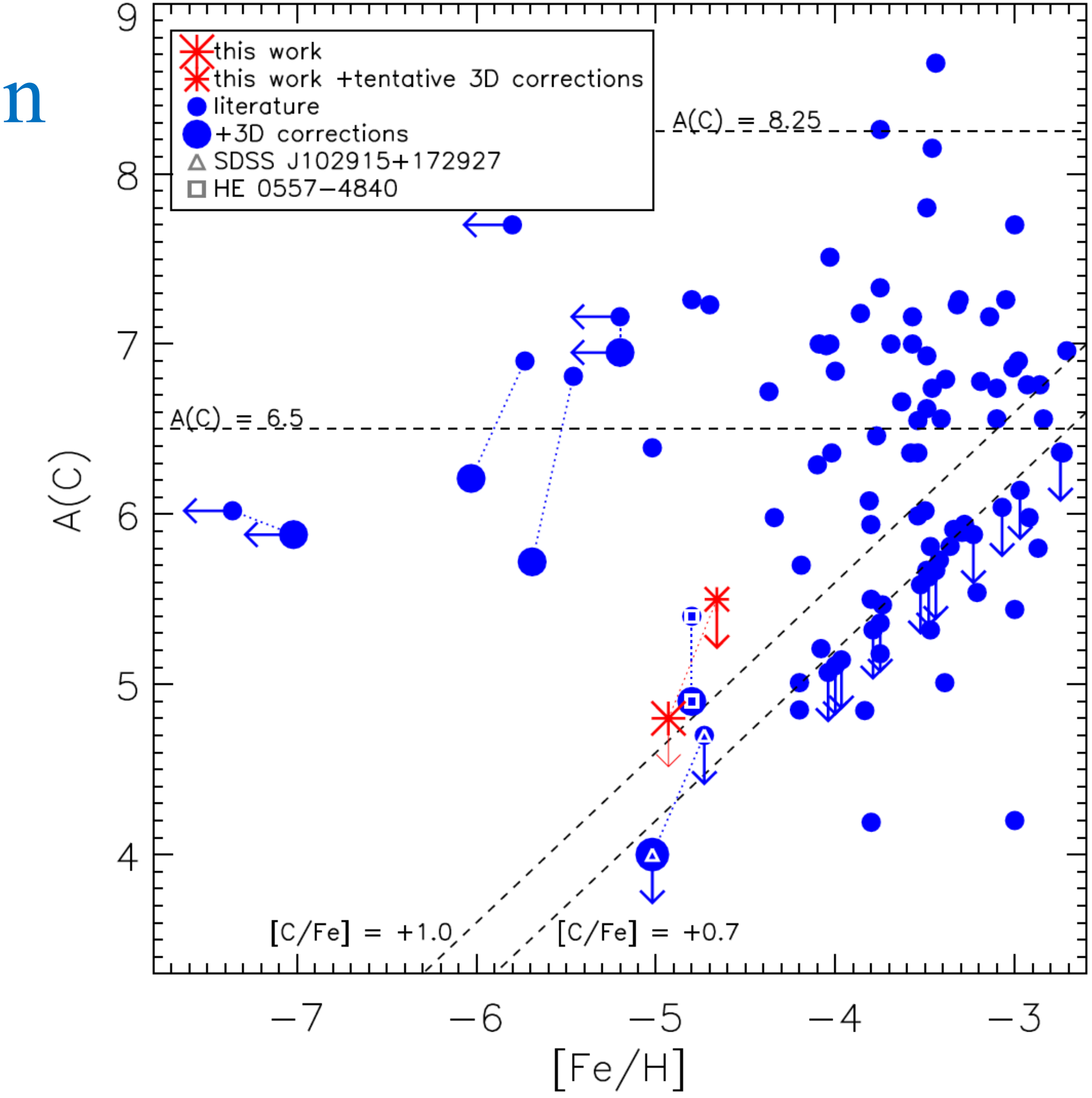
Ion	A(X)$_\odot$	A(X)	[X/H]	σ	[X/Fe]
Na I	6.30	2.21	−4.09	0.08	0.59
Mg I	7.54	3.38	−4.16	0.07	0.50
Si I	7.52	3.23	−4.29	0.09	0.37
Ca I	6.33	1.86	−4.47	0.14	0.19
Ca II	6.33	2.19	−4.14	0.14	0.52
Ti II	4.90	0.69	−4.21	0.20	0.45
Fe I	7.52	2.86	−4.66	0.14	0.00



VLT/UVES
HR spectrum

ESO DDT time

Pr 221 is not carbon rich



Summary

- Pristine 221 is found to be similar to the most metal-poor star known (SDSS J102915+172927, Caffau et al., 2011) in terms of stellar parameters, as well as [Fe/H] in standard 1D LTE analysis.

- However, that Pristine 221 has an [a/Fe] ratio of 0.3–0.4 dex, significantly larger than that of SDSS J102915+172927.

- Like SDSSJ102915+172927, Pristine 221 has no detectable CH features. This leaves open the possibility that this star is carbon-normal, or even carbon depleted, which would be an anomaly at this extreme [Fe/H] level.

These objects belong to a class of rare, ultra metal-deficient stars that they can provide important constraints on cooling and formation of long-lived stars in the low metallicity environment of the early galaxy formation era.