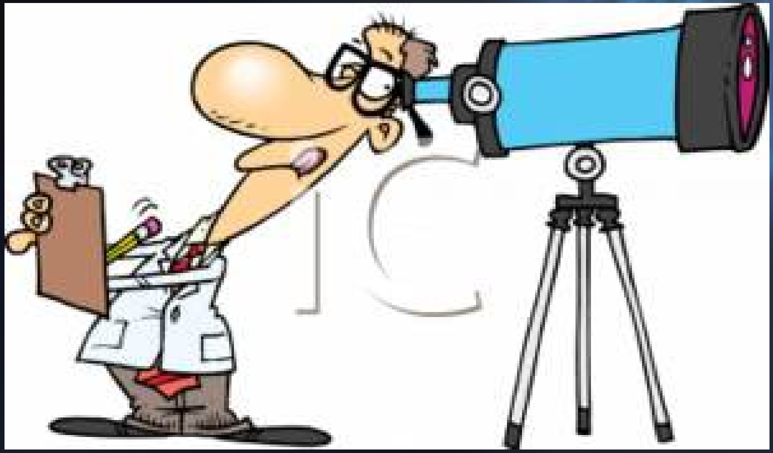
Looking for the Most Metal-Poor Stars with Large Surveys

(an observational approach)

David Aguado



ioa

CEMP Conference
GENEVA 20190909

UNIVERSITY OF CAMBRIDGE

The Core Team

Jonay I. González Hernández IAC

Carlos Allende Prieto IAC

Rafael Rebolo IAC

The Core Team

Jonay I. González Hernández IAC

Carlos Allende Prieto IAC

Rafael Rebolo IAC

The Full Team

Paris Obs.

Piercarlo Bonifacio

Elisabetta Caffau

Pristine Col.

Else Starkenburg

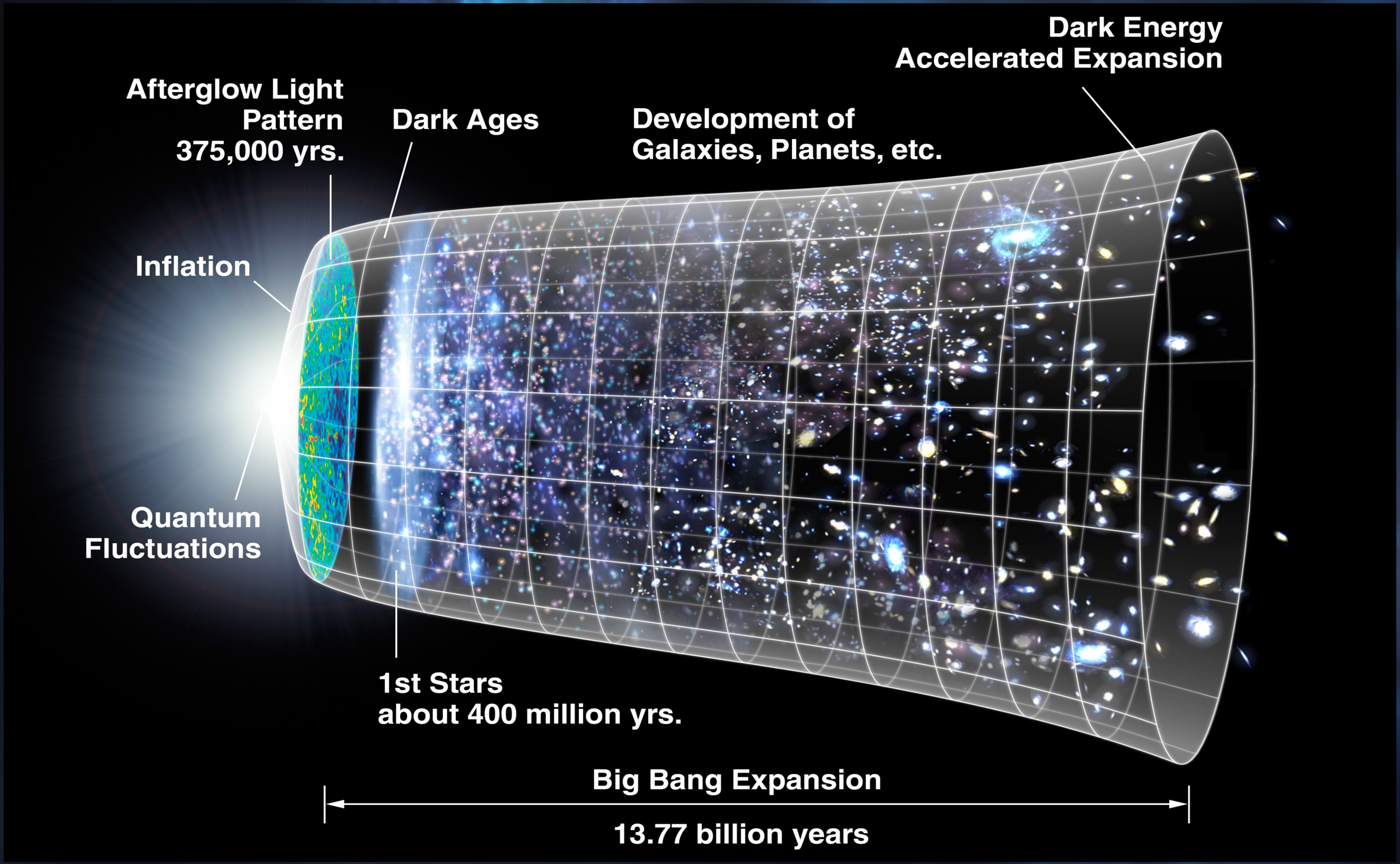
Nicolas Martin

+ 30 more people

U. TEXAS

Matthew Shetrone

Why so interesting?



BB NUCLEOSYNTHESIS

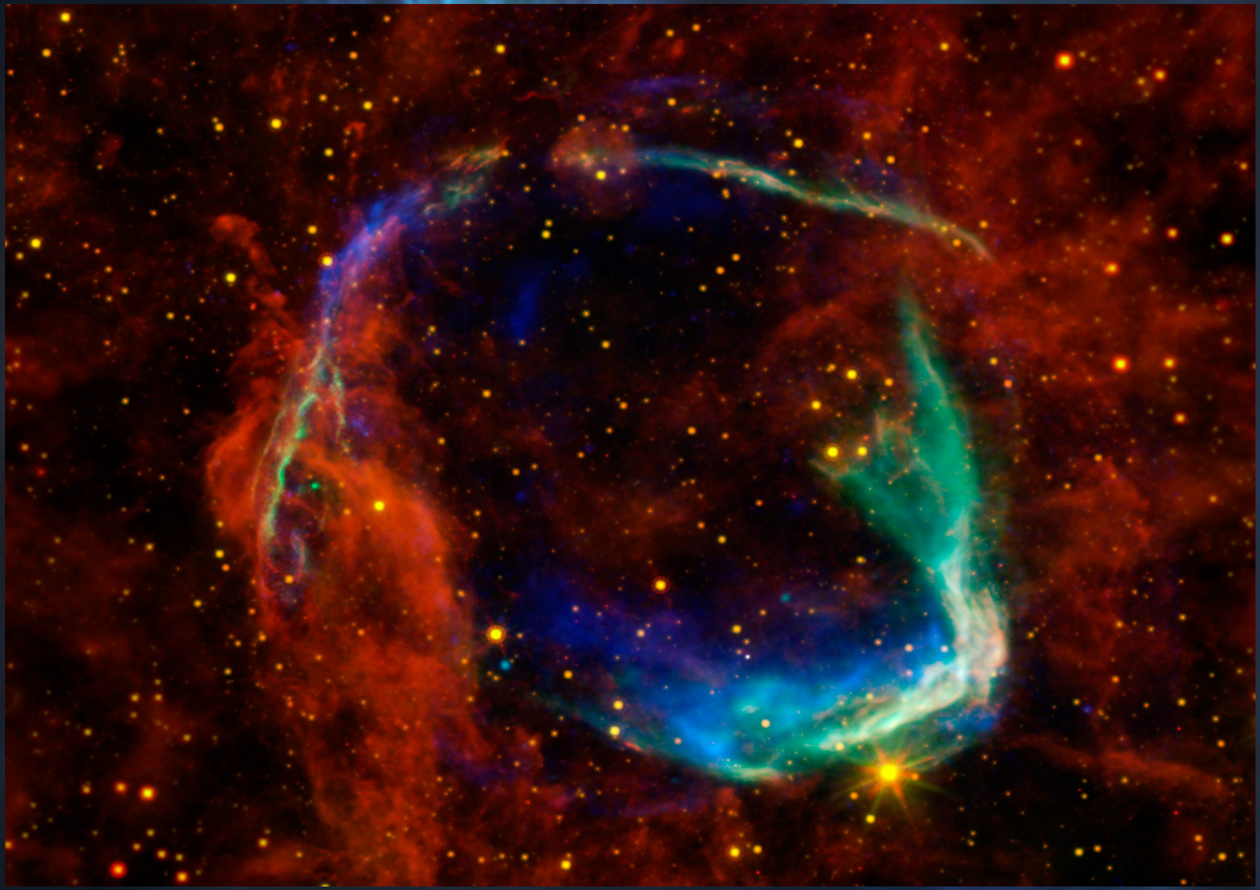
NASA

Why so interesting?

National Science Fundation

POPULATION III

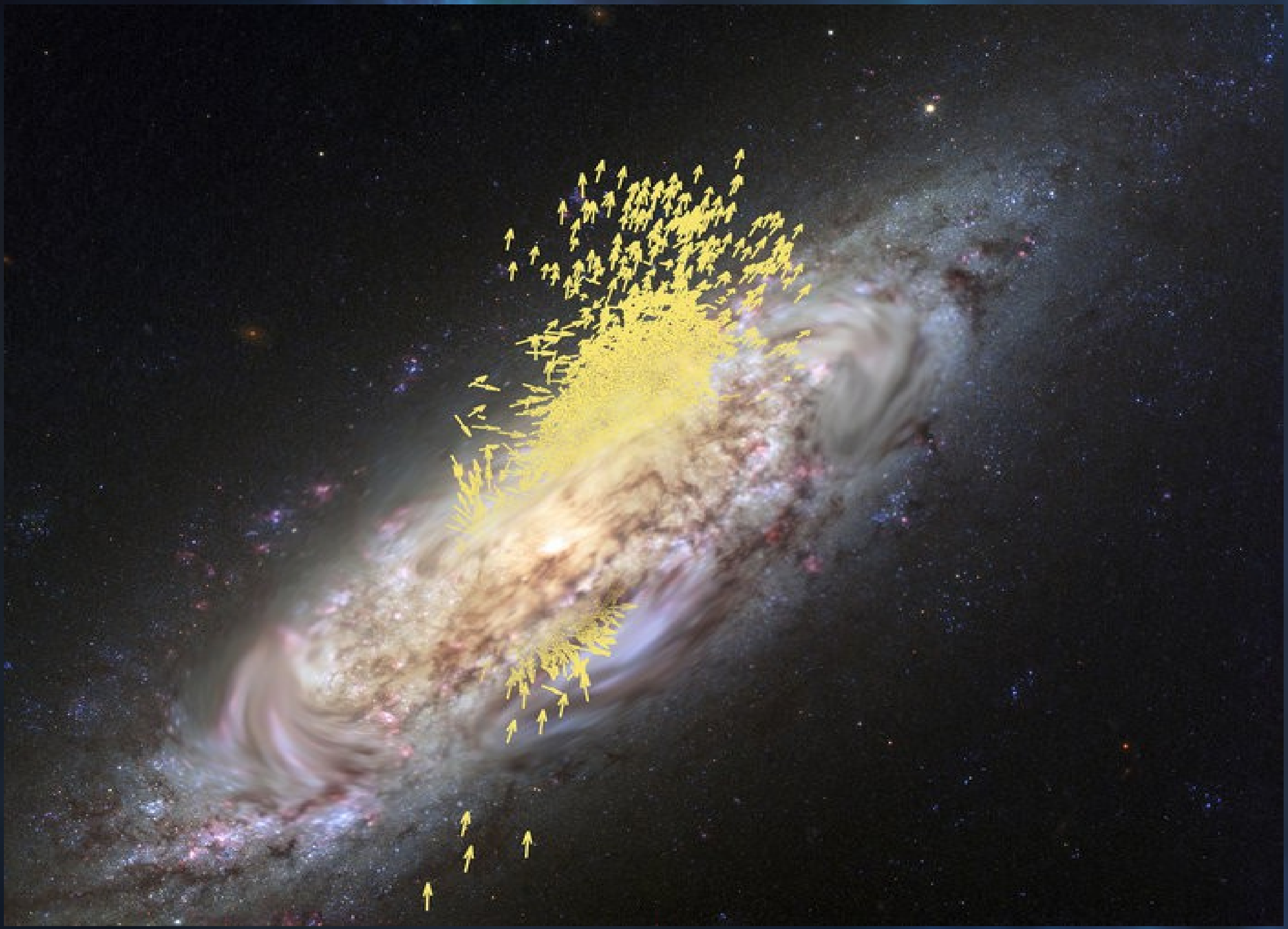
Why so interesting?



NASA

SUPERNOVA

Why so interesting?



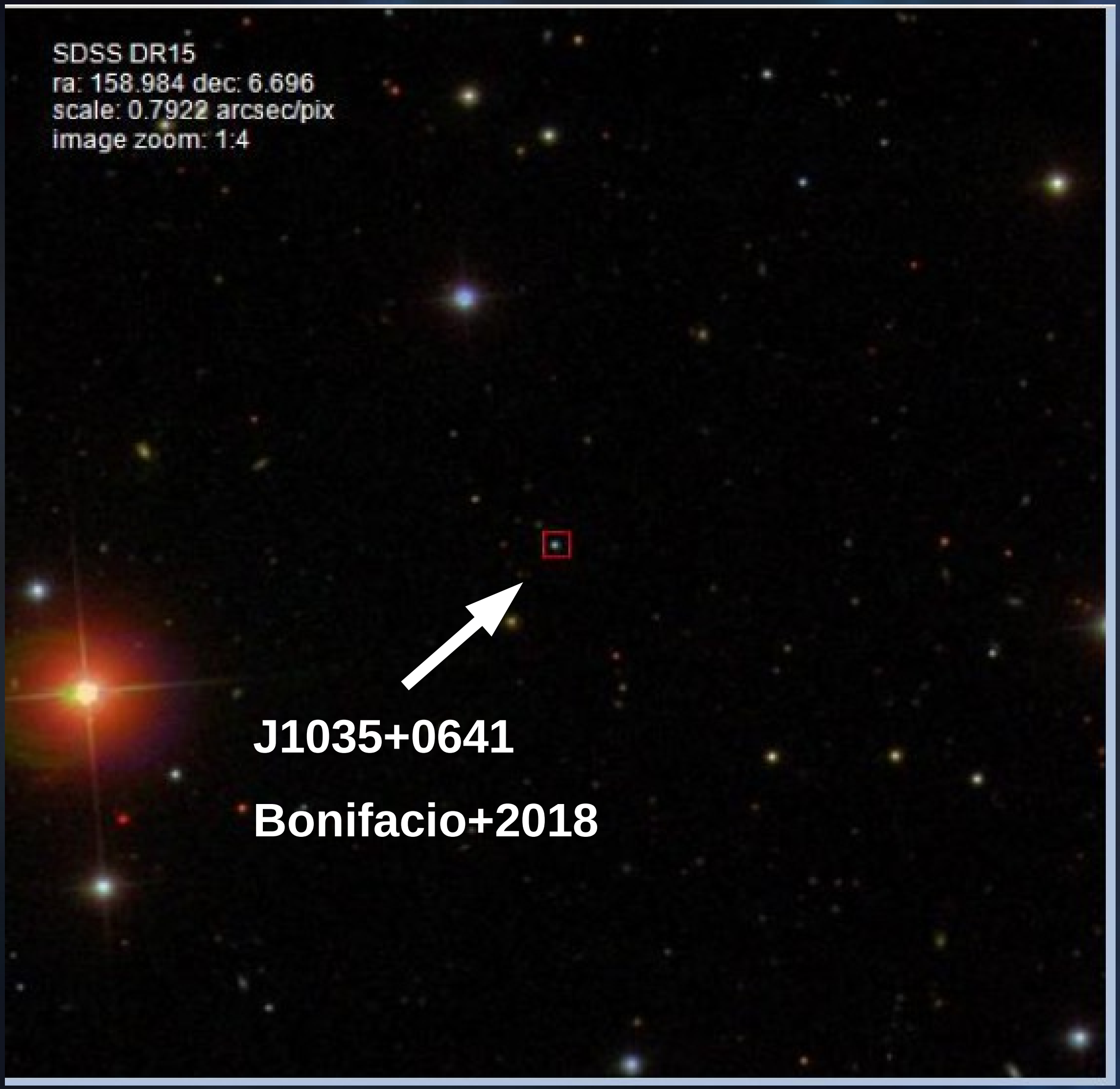
European Space Agency

MW MORPHOLOGY

Why so difficult?

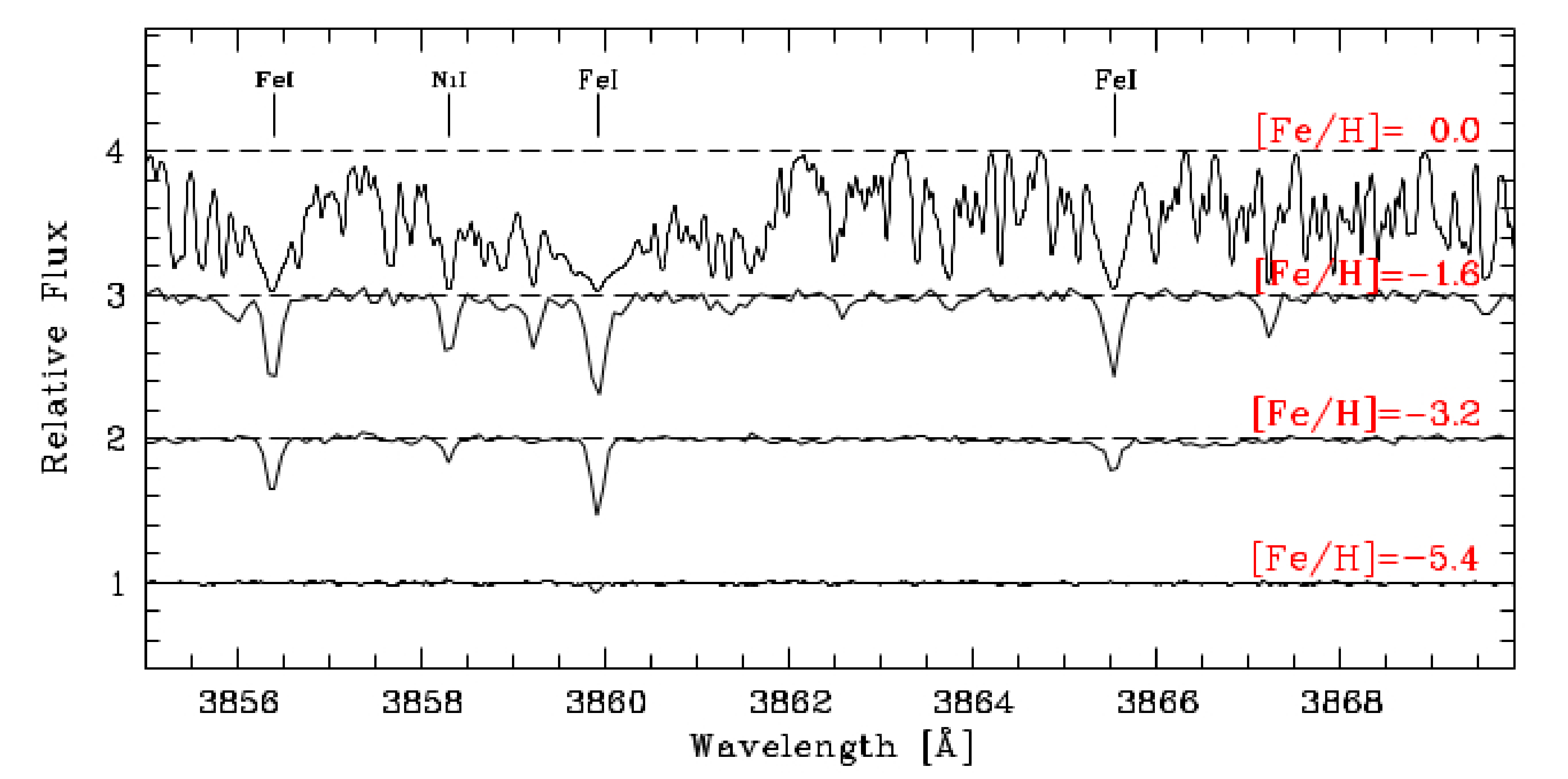
Very rare stars

Why so difficult?



Faint Objects

Why so difficult?



Frebel+ 2010

Absence of features

Why so difficult?

Gran Telescopio de Canarias (GTC)

Over-demanded facilities

Why so difficult?

Cosmological observations at high z

Two different approaches

Why so difficult?

Cosmological observations at high z

LETTER

doi:10.1038/nature25792

An absorption profile centred at 78 megahertz in the sky-averaged spectrum

Judd D. Bowman[1], Alan E. E. Rogers[2], Raul A. Monsalve[1,3,4], Thomas J. Mozdzen[1] & Nivedita Mahesh[1]

Two different approaches

Welcome to stellar archaeology

letters to nature

A stellar relic from the early Milky Way

N. Christlieb*†, M. S. Bessell‡, T. C. Beers§, B. Gustafsson*, A. Korn||, P. S. Barklem*, T. Karlsson*, M. Mizuno–Wiedner* & S. Rossi¶

** Hamburger Sternwarte, Gojenbergsweg 112, D-21029 Hamburg, Germany*
† Department of Astronomy and Space Physics, Uppsala University, Box 524, SE – 75120 Uppsala, Sweden
‡ Research School of Astonomy and Astrophysics, Mount Stromlo Observatory, Cotter Road, Weston, Australian Capital Territory 2611, Australia
§ Department of Physics and Astronomy, Michigan State University, East Lansing, Michigan 48824, USA
|| Universitäts–Sternwarte München, Scheinerstrasse 1, D-81679 München, Germany
¶ Instituto de Astronomia, Geofísica e Ciencias Atmosféricas, Universidade de São Paulo, Departamento de Astronomia, 05508-900 São Paulo, Brazil

Welcome to stellar archaeology

Up to now only 14 stars with [Fe/H]<-4.5 have been found:

- Christlieb+2012 ★
- Frebel+2005 ★
- Norris+2007 ★
- Caffau+2011 ★
- Keller+2014 ★
- Hansen+2014 ★
- Allende+2015, Frebel+2015 ★
- Bonifacio+2015 ★
- Bonifacio+2015, Caffau+2016 ★
- Bonifacio+2015 ★
- DA+2018a ★
- DA+2018b ★
- Starkenburg+2018 ★
- Nordlander+2019 ★

Welcome to stellar archaeology

Photometric Searches

HK objective-prism survey (Beers, Preston & Shectman 1985)

Hamburg ESO survey (Christlieb, Wisotzki & Graßhoff 2002) ★ ★ ★ ★

CaHK filter (Anthony-Twarog et al. 2000, Koch et al. 2016)

SkyMapper (e.g. Keller 2007) ★ ★

Best and brightest (Schlaufman & Casey 2014)

Pristine Project (Starkenurg & Martin 2017) ★

Welcome to stellar archaeology

Spectroscopic Searches

BOSS-GALAH-LAMOST-SEGUE-RAVE

TOPOS (Caffau+2013)

SDSS (Aoki+2013, DA+2016)

LAMOST (Li+2015)

Observations: 14 ★ ★

Med-res spectroscopy: 2.3SSO, 3.6ESO, 2.3ANU, XSHO, KPNO, GTC, WHT

14 Stars with a mean magnitude ~16.5 V

High-res follow-up: UVES@VLT; HDS@SUBARU; MIKE@Magellan; HIRES@Keck

136 hours in a 6-10 class telescopes only for discovery papers!!

Observations: 14 ★ ★

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136 hours in a 6-10 class telescopes only for discovery papers!!

HORuS

Now Available at 10.4m GTC!!!

SPANISH CAT DEADLINE: 2nd October

Discovery Papers: 14 ★ ★

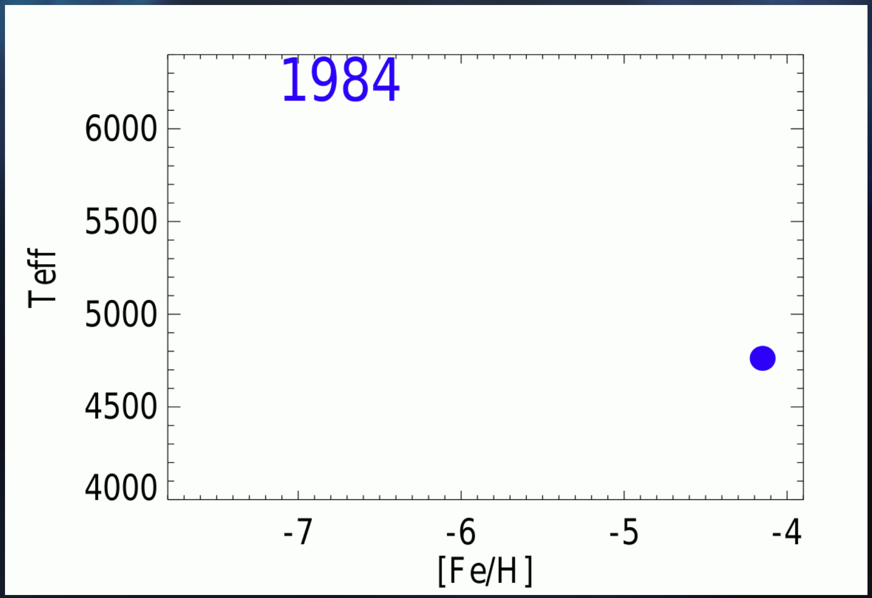
14(+2) discovery papers with ~ 28 cites/year/star

High impact journals: Nature 4x ★ ; A&A 4x ★ ; ApJ 4x ★ ; MNRAS 2x ★

92 authors from tens of institutions!!

7 Indiana Stellar Jones with 5 or more ★ !!!

T. BEERS
M. BESSEL
P. BONIFACIO
E. CAFFAU
N. CHRISTLIEB
A. FREBEL
J. NORRIS



A paradigm: HE 1327+2326

Frebel+2005: the discovery letter

Nucleosynthetic signatures of the first stars

Anna Frebel[1], Wako Aoki[2], Norbert Christlieb[2,3], Hiroyasu Ando[2], Martin Asplund[1], Paul S. Barklem[4], Timothy C. Beers[5], Kjell Eriksson[4], Cora Fechner[3], Masayuki Y. Fujimoto[6], Satoshi Honda[2], Toshitaka Kajino[2], Takeo Minezaki[7], Ken'ichi Nomoto[8], John E. Norris[1], Sean G. Ryan[9], Masahide Takada-Hidai[10], Stelios Tsangarides[9] & Yuzuru Yoshii[7]

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A paradigm: HE 1327+2326

Frebel+2005:

Aoki+2006: d

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Frebel+2008:


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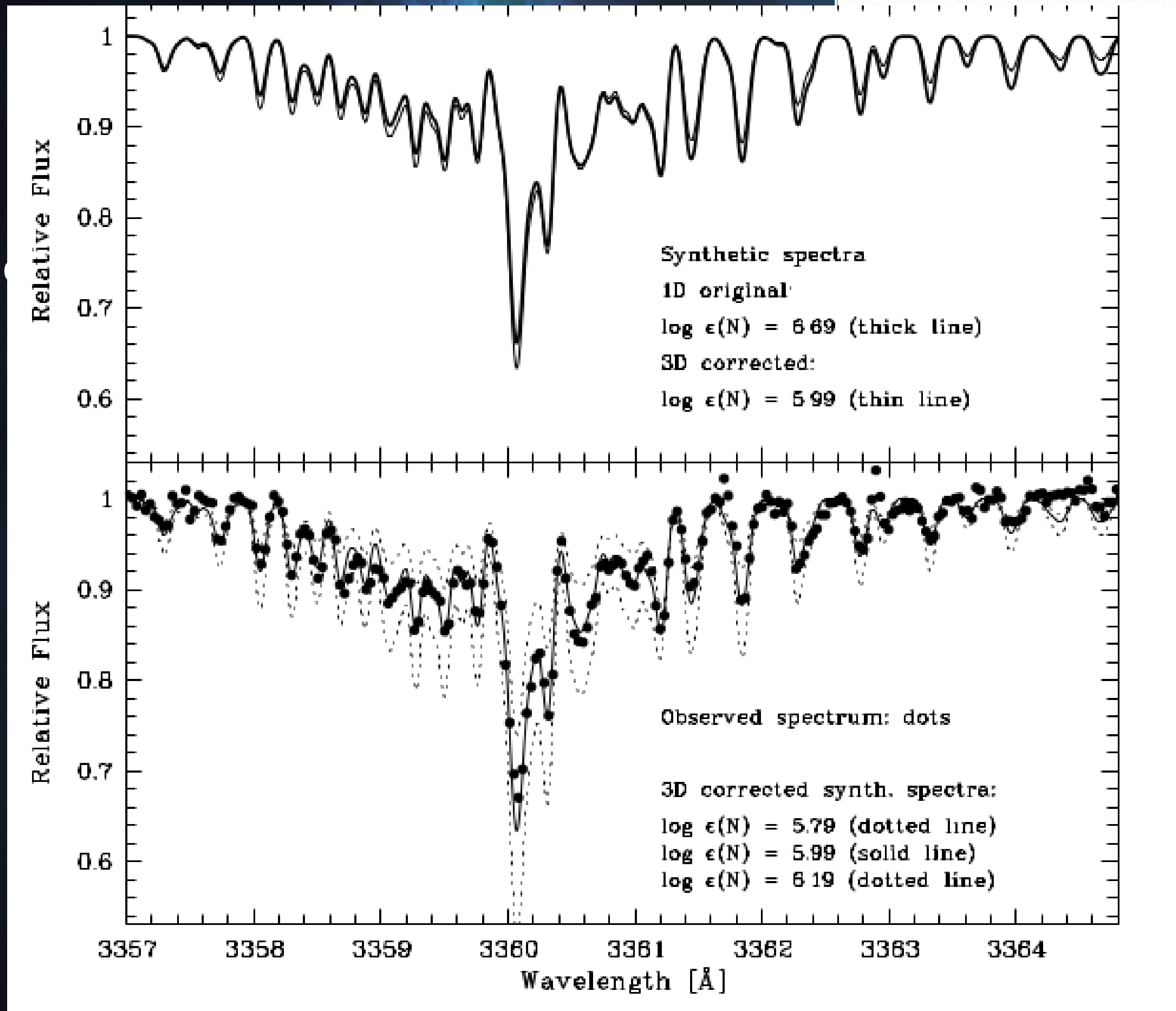

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A paradigm: HE 1327+2326

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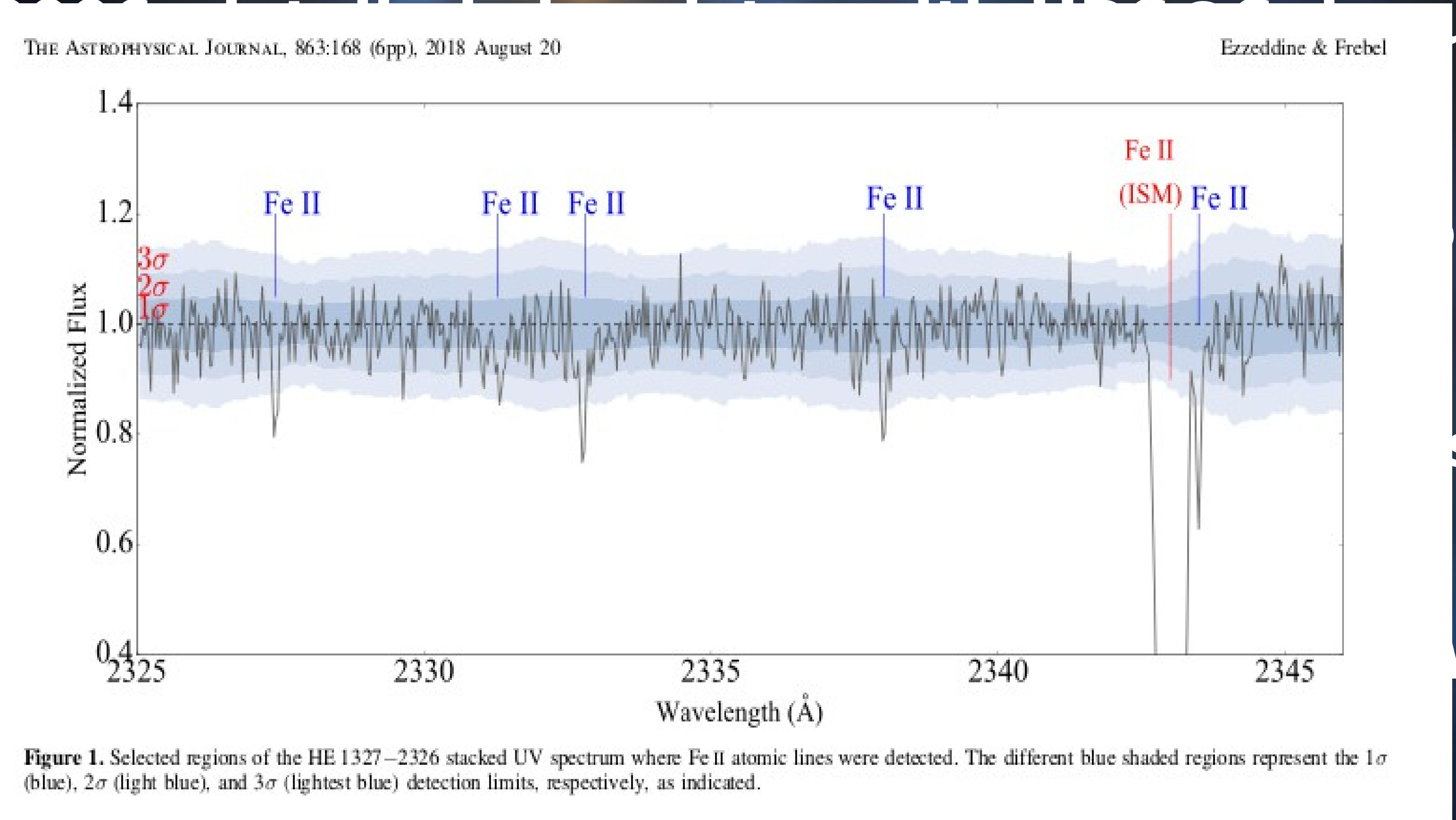
Aoki+2 … u

Frebel … VLT

Frebel … s

DA+20 … WHT



THE ASTROPHYSICAL JOURNAL, 863:168 (6pp), 2018 August 20 Ezzeddine & Frebel

Figure 1. Selected regions of the HE 1327−2326 stacked UV spectrum where Fe II atomic lines were detected. The different blue shaded regions represent the 1σ (blue), 2σ (light blue), and 3σ (lightest blue) detection limits, respectively, as indicated.

Ezzeddine&Frebel 2018: UV observations with COS@HST

The star should not exist: SDSS 1029+1729

LETTER

doi:10.1038/nature10377

An extremely primitive star in the Galactic halo

Elisabetta Caffau[1,2], Piercarlo Bonifacio[2], Patrick François[2,3], Luca Sbordone[1,2,4], Lorenzo Monaco[5], Monique Spite[2], François Spite[2], Hans-G. Ludwig[1,2], Roger Cayrel[2], Simone Zaggia[6], François Hammer[2], Sofia Randich[7], Paolo Molaro[8] & Vanessa Hill[9]

Caffau+2011: discovery letter

Caffau+2012: Detailed chemical signature, kinematics,...

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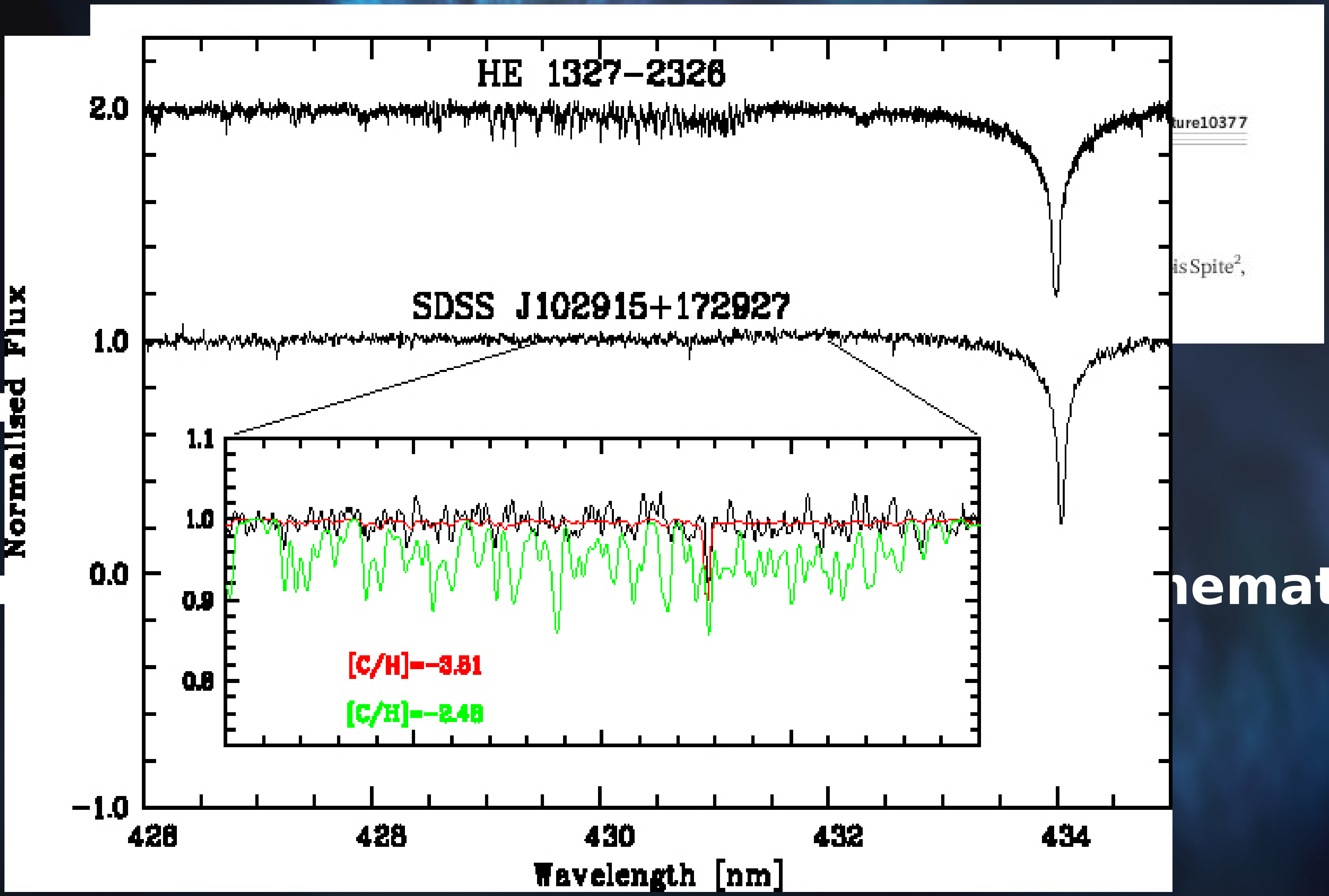


Caffau

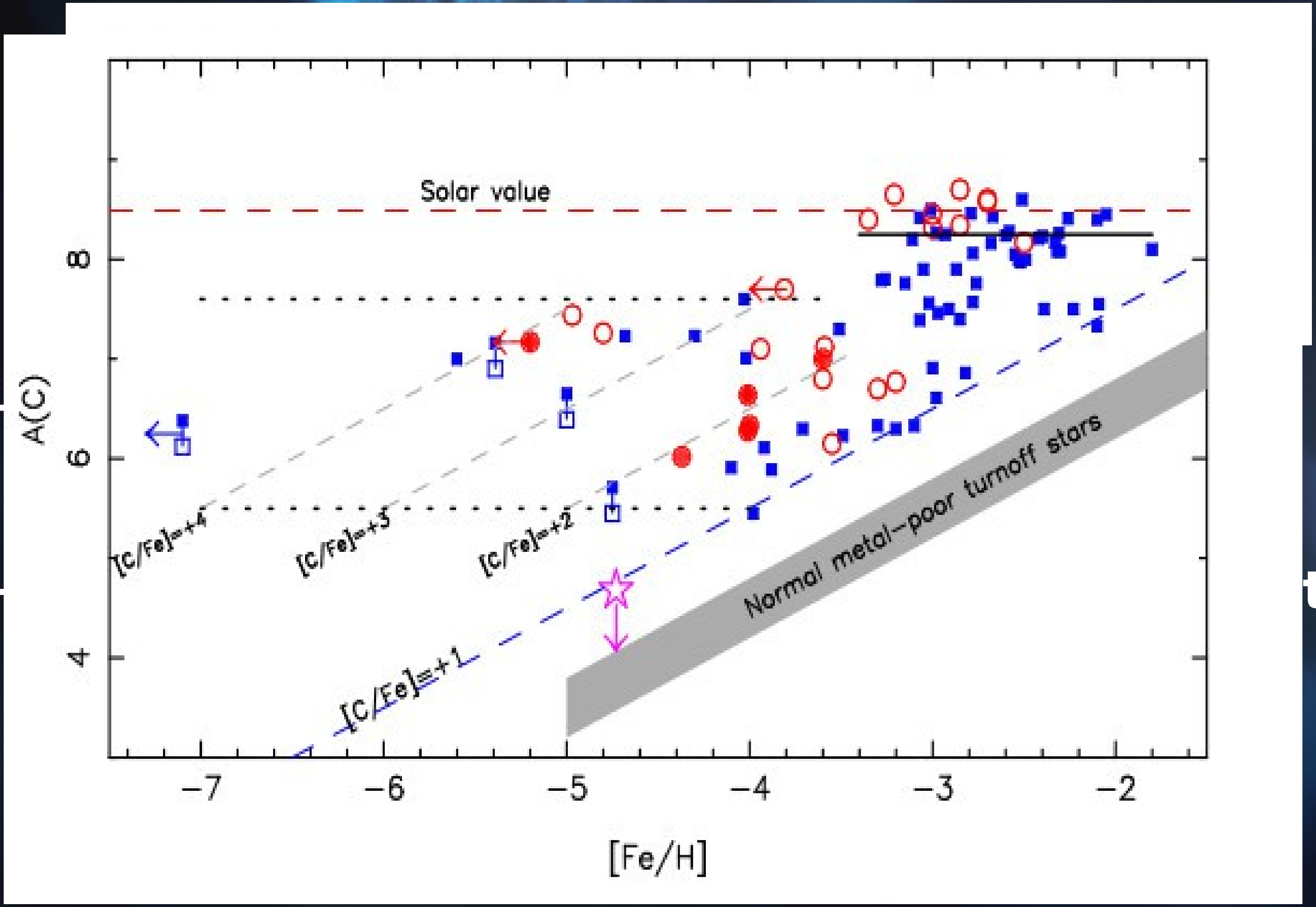
Caffau ... **nematics,...**

The star should not exist: SDSS 1029+17291

Caffau-

Caffau-

tics,...



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Caffau+2011: discovery letter

Caffau+2012: Detailed chemical signature, kinematics,...

DA+2017: New med-res observations with ISIS@WHT

Bonifacio+2018: Confirmation it is a dwarf star with Gaia

2-Looking for the Most Metal-Poor Stars with Large Surveys

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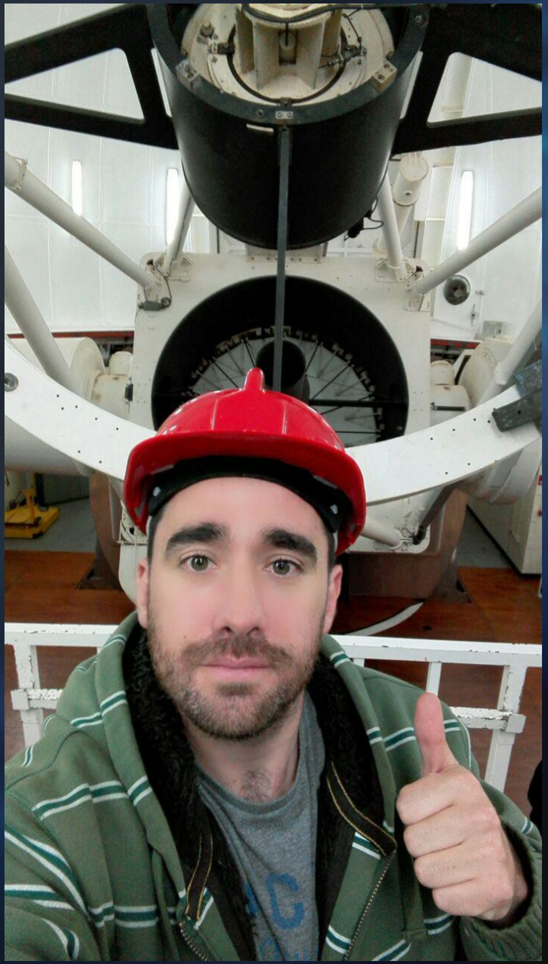
8-10 UMP stars

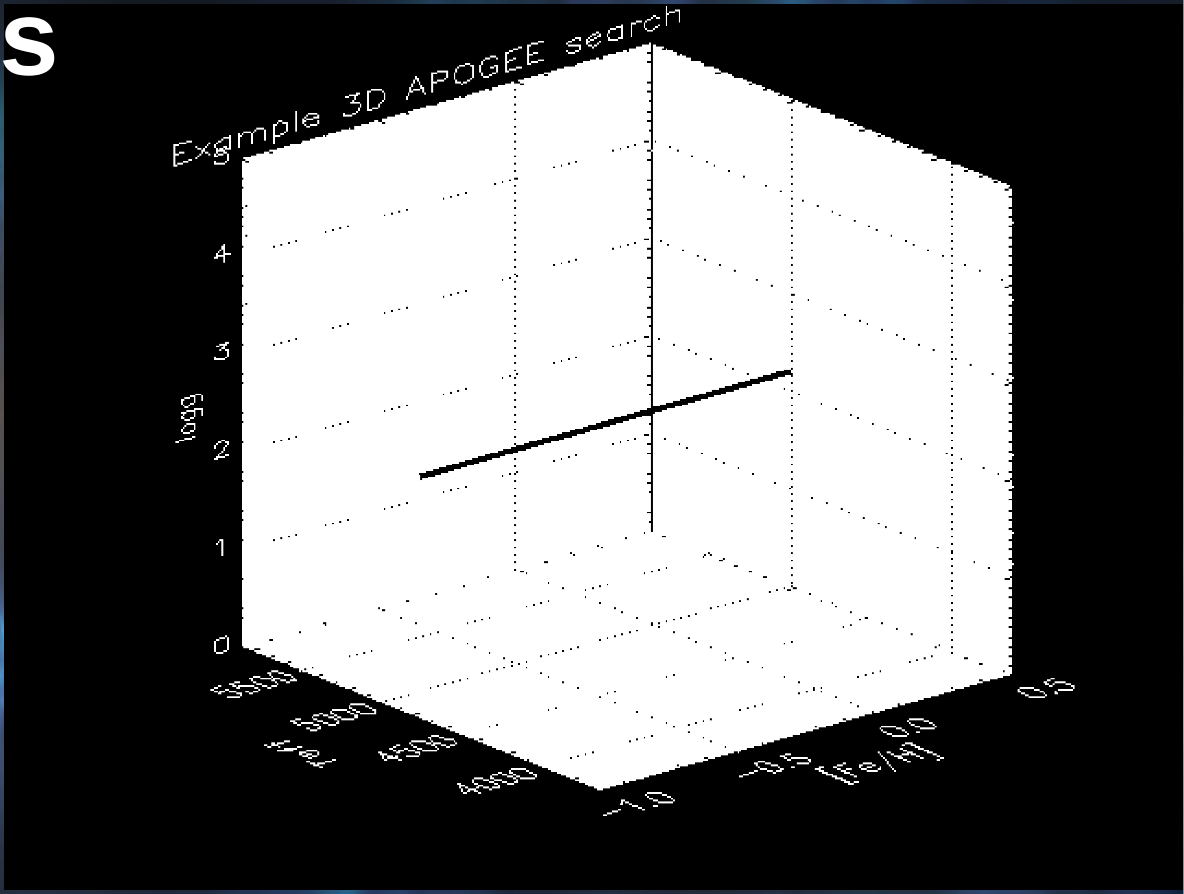
~500 candidates to observe with ISIS at WHT or with OSIRIS at GTC

~1000 with IDS at INT

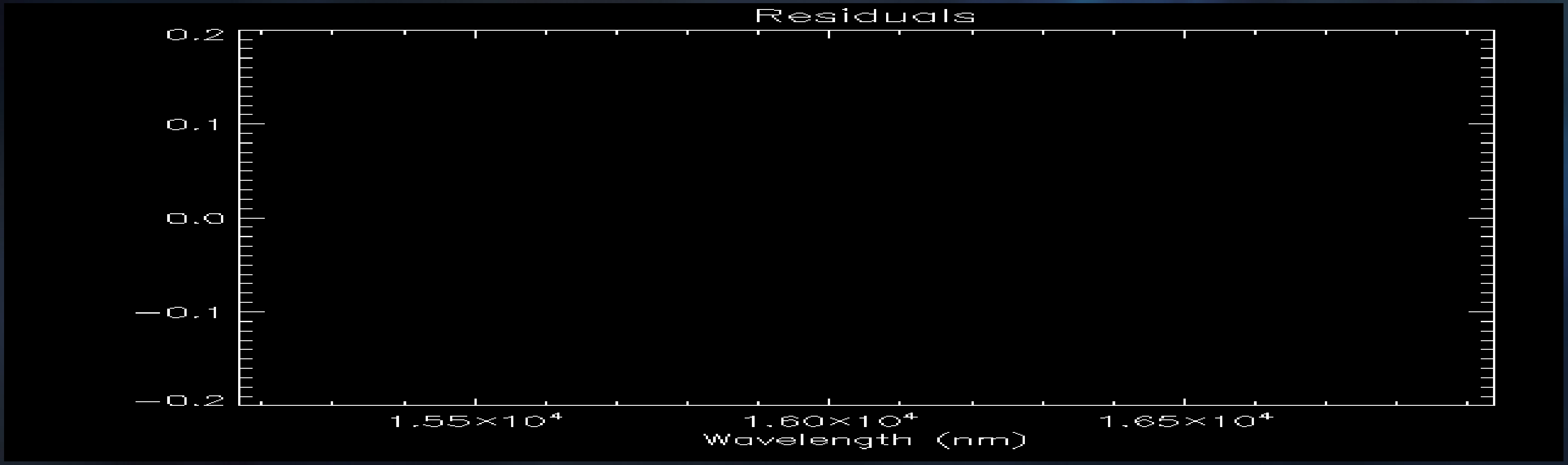


~10,000,000 spectra from SDSS and LAMOST or photometric candidates from Pristine and J-plus

2-Looking for the Most Metal-Poor Stars with Large Surveys

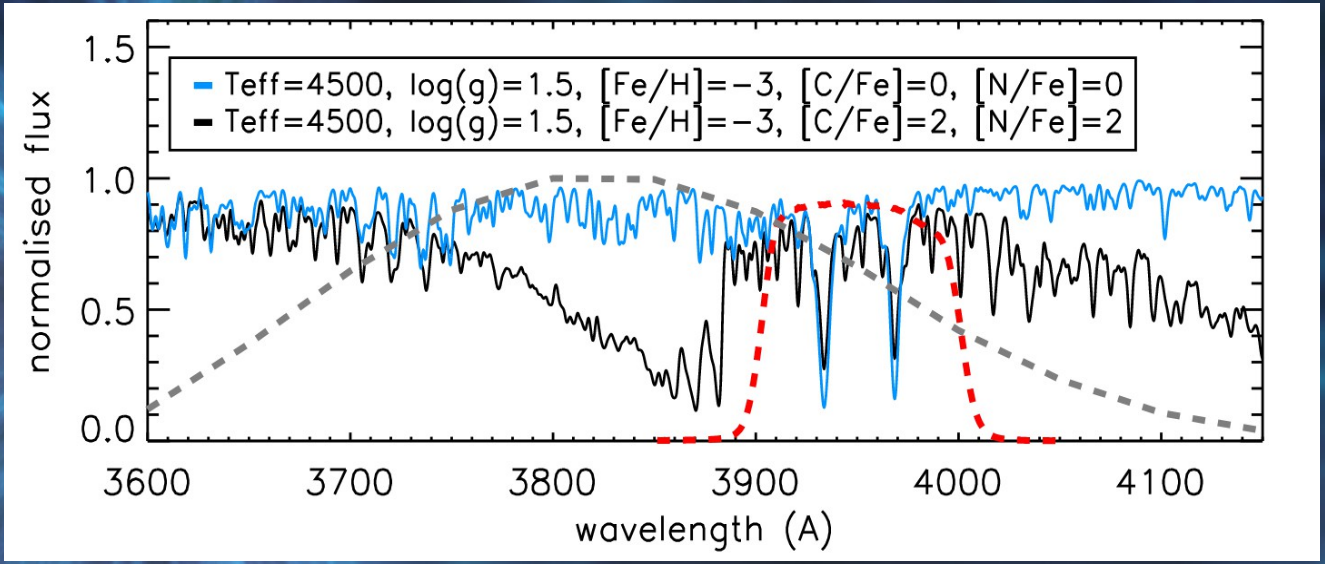


Spectroscopic analysis with FERRE & FESWI



3- Follow-up Spectroscopy with Pristine Candidates

Starkenburg+ 2017



See next talk by Else Starkenburg

PRISTINE

3- Follow-up Spectroscopy with Pristine Candidates

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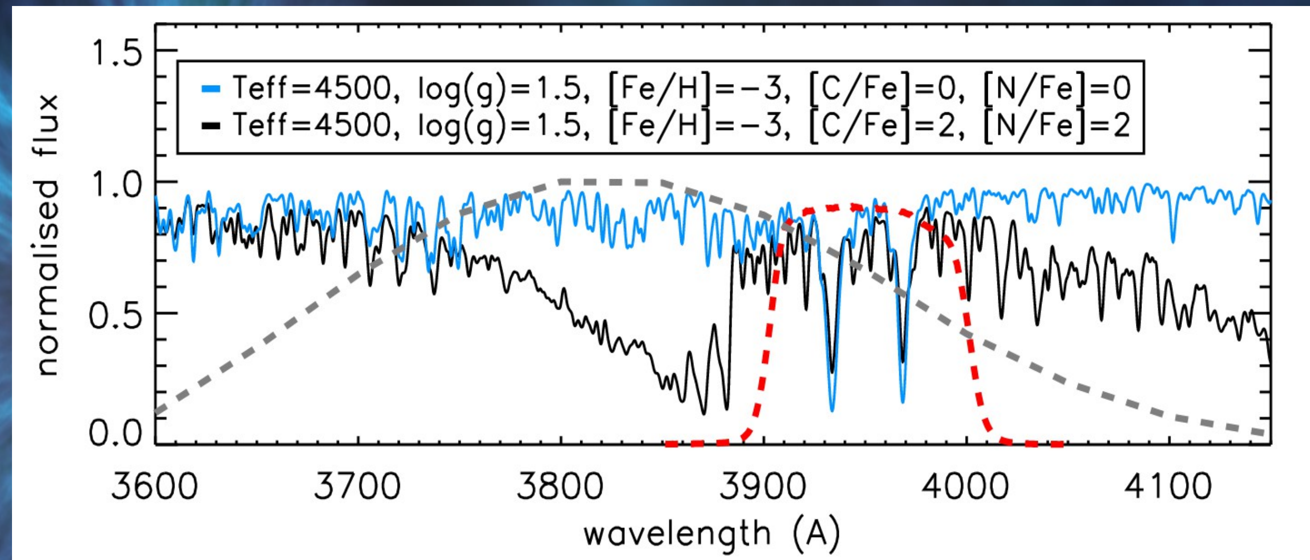
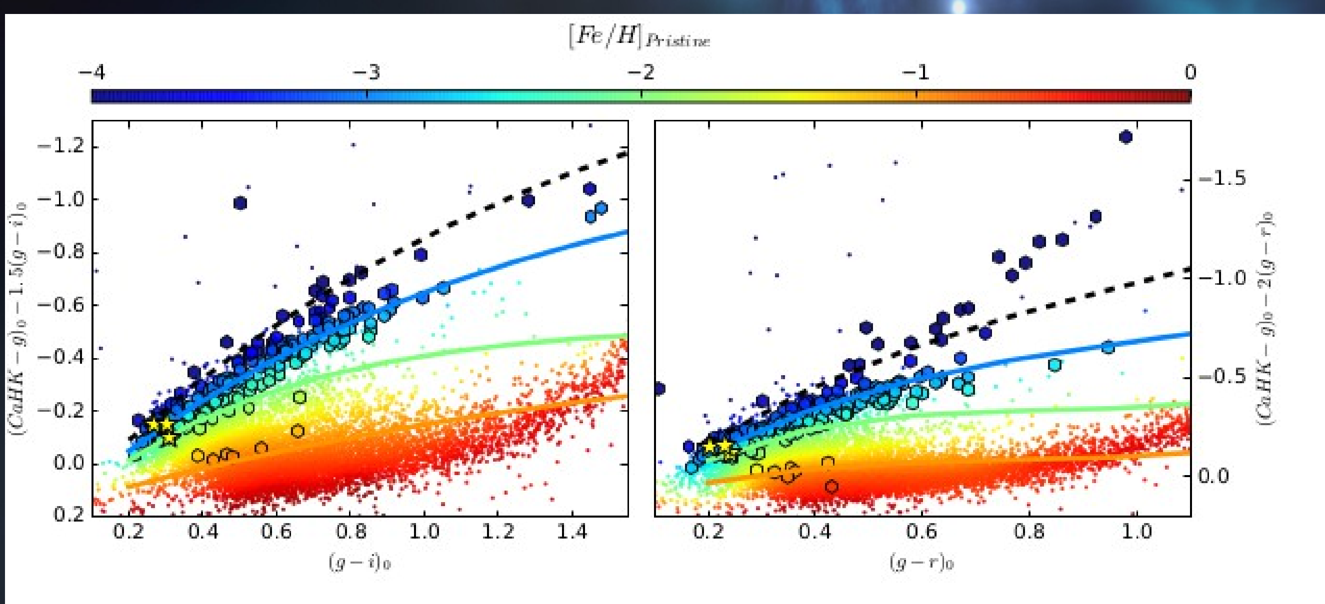


Youakim+ 2017



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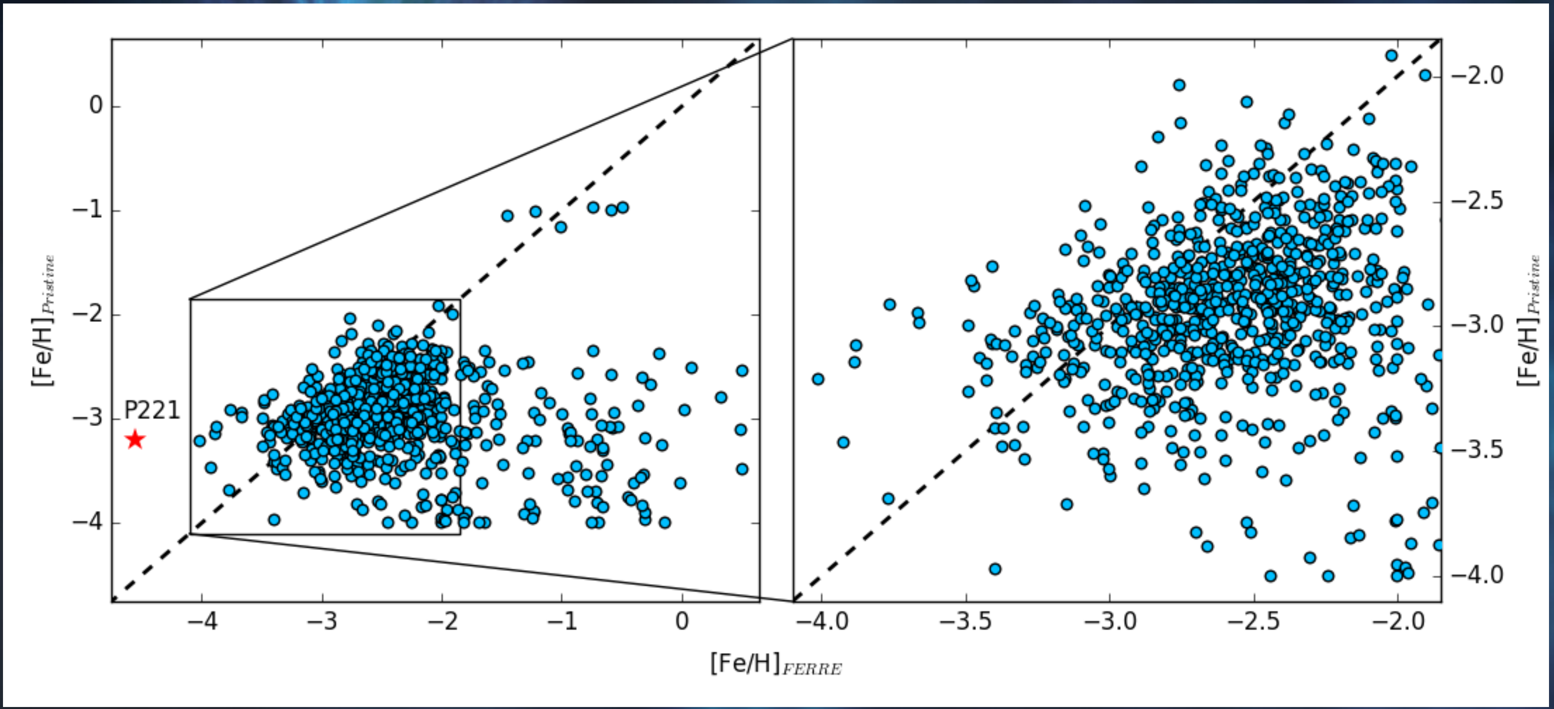
3- Follow-up Spectroscopy with Pristine Candidates

Aguado, Youakim+ 2019 (Submitted)



~1100 medium-resolution spectra with IDS, ISIS and EFOSC

~180 observing nights at INT, WHT and NTT & 23 observers

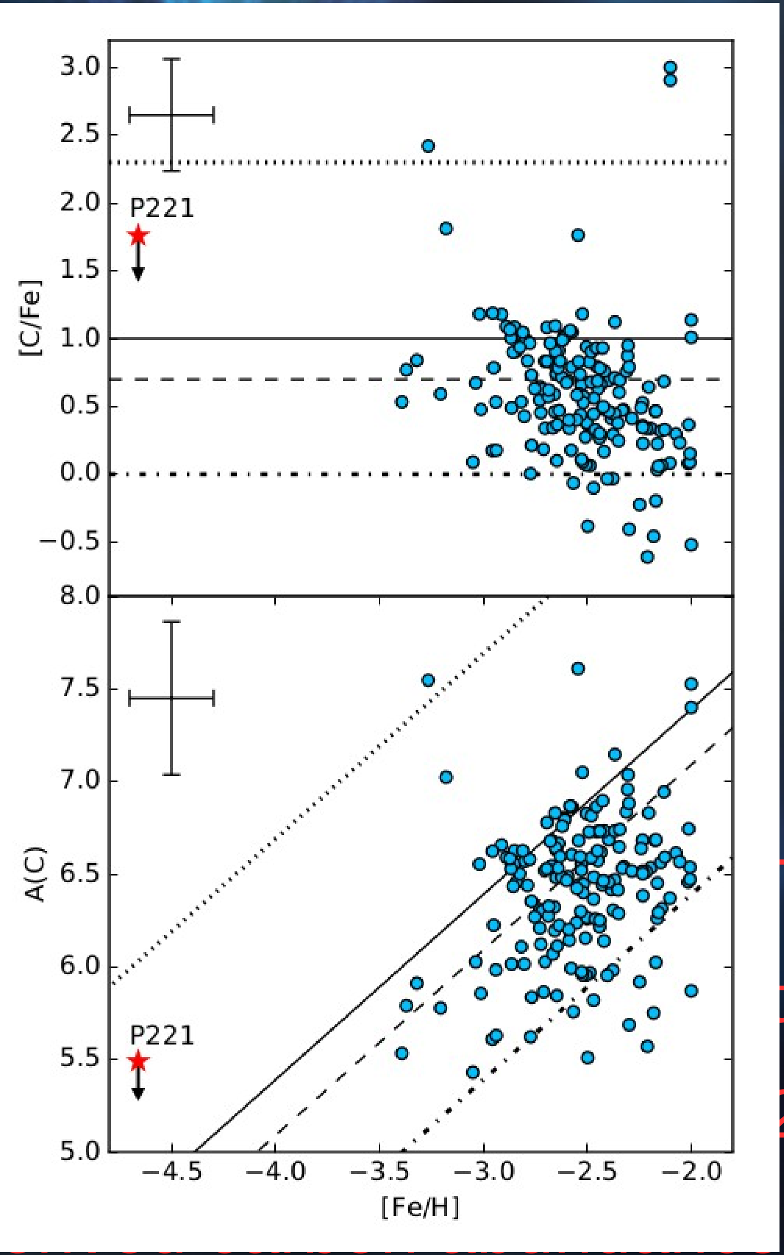
The discovery of P221.8781+9.7844 by Starkenburg+2018

56% and 23% successful ratio in [Fe/H]<-2.5 and [Fe/H]<-3.0

~170 stars with derived carbon abundance

3- Follow-up Spectroscopy with Pristine Candidates

Aguado, Youakim+ 2019 (Submitted)



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The discovery of … tarkenburg+2018

56% nad 23% su… 2.5 and [Fe/H]<-3.0

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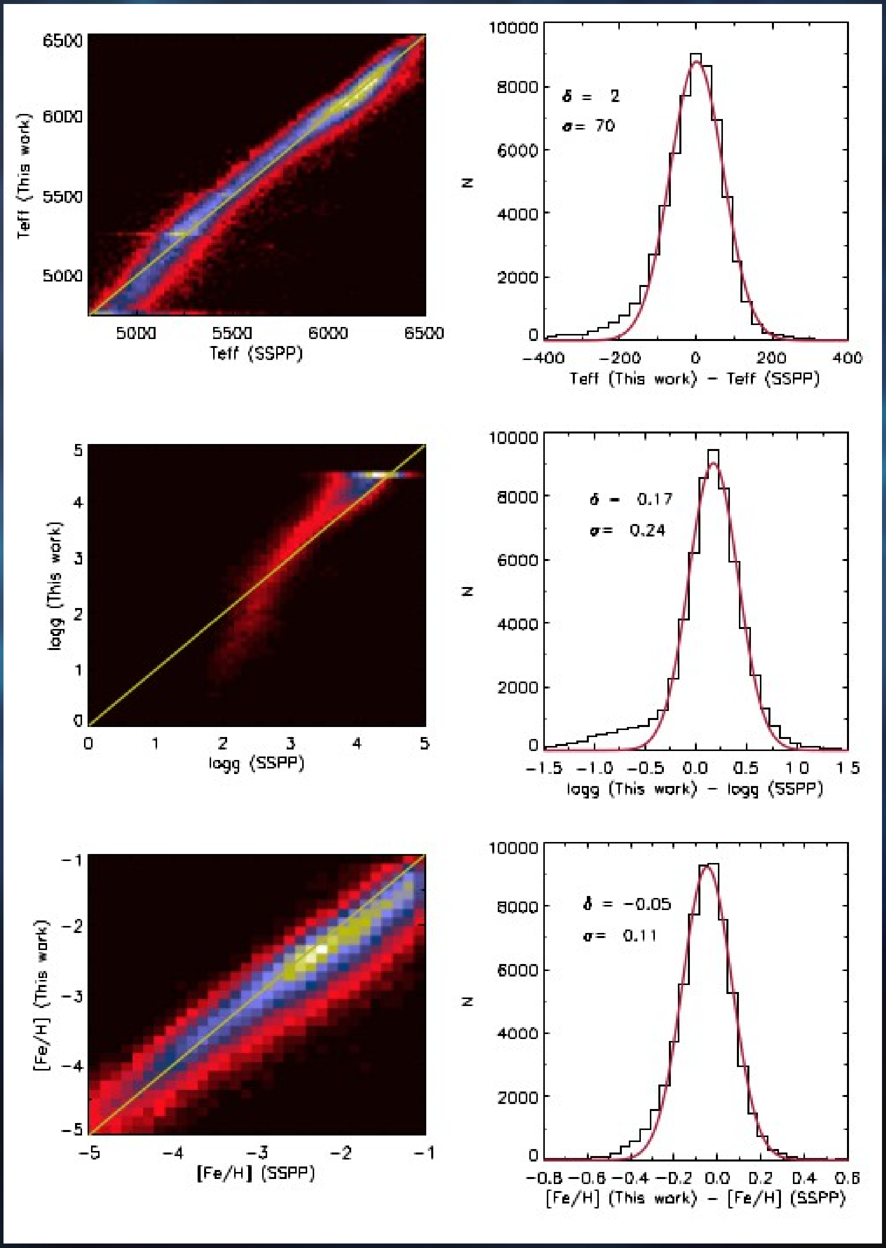
4-Follow-up Spectroscopy with SDSS and LAMOST candidates

~80 medium-resolution high S/N spectra with ISIS and OSIRIS

We recover Teff and [FeH] for several well known UMP stars

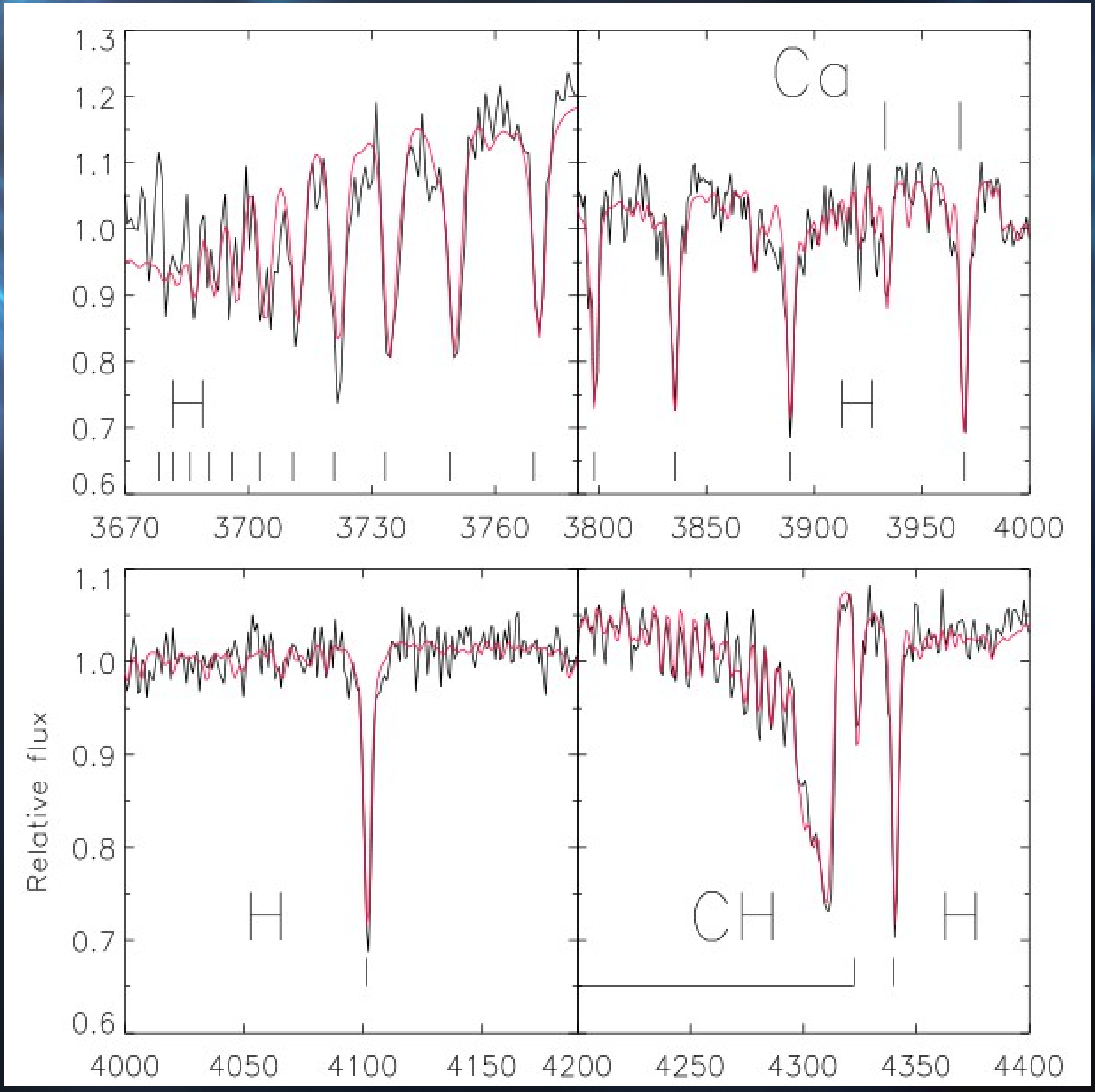


Allende Prieto+ 2014

4-Follow-up Spectroscopy with SDSS and LAMOST candidates

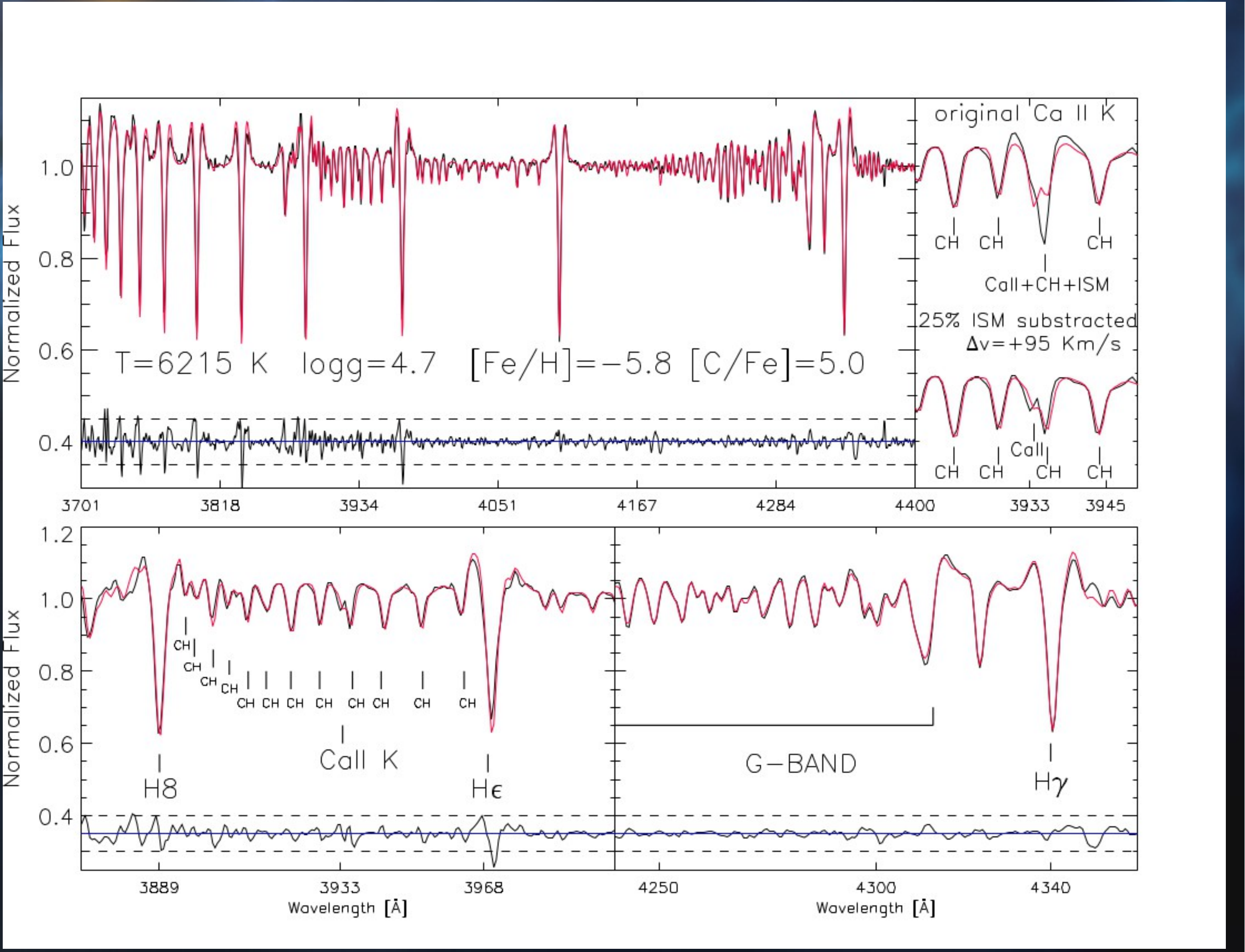
The discovery of J1313-0019: Allende Prieto+2015

Also see Frebel+2015, DA+17b



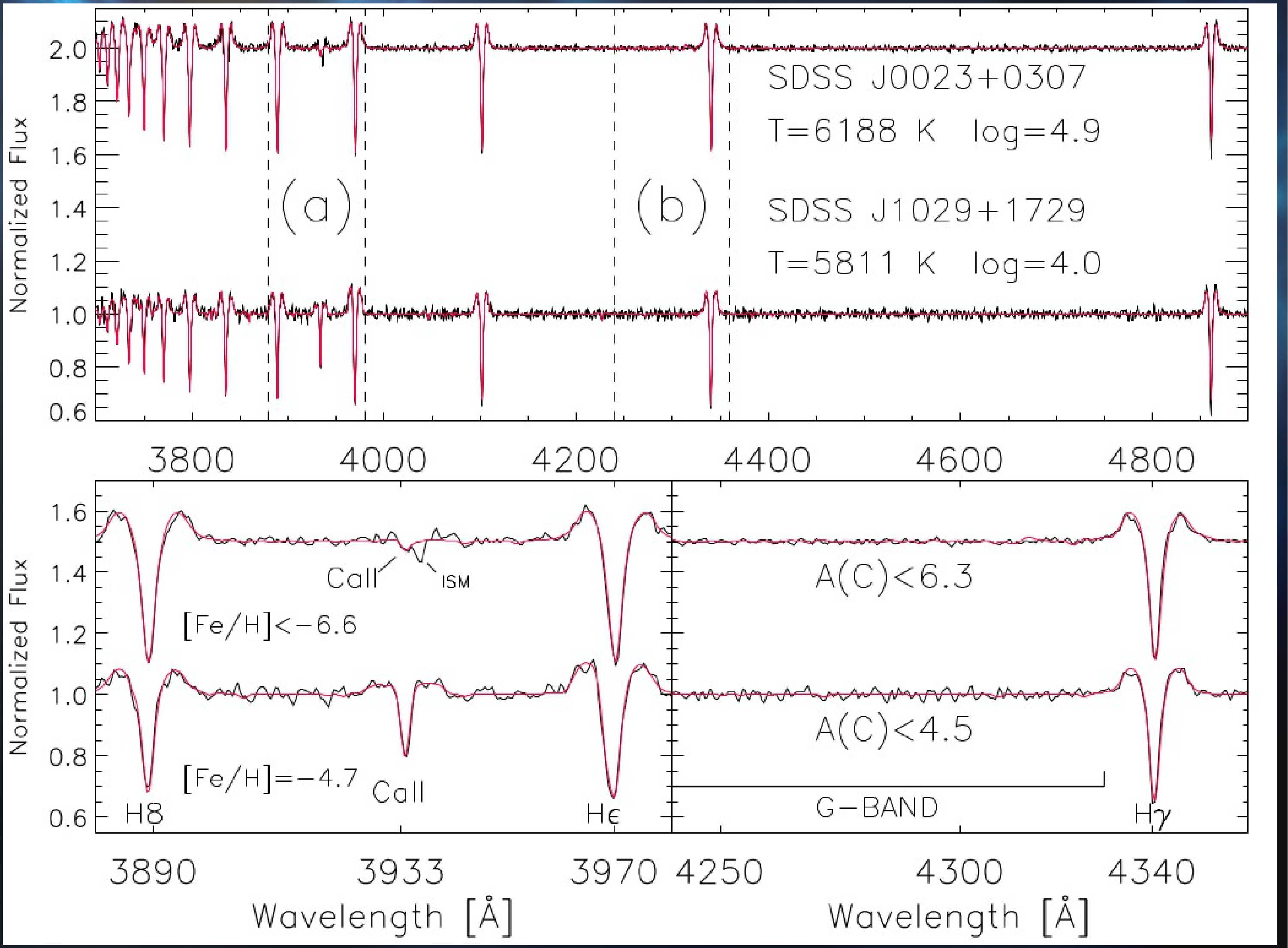
4-Follow-up Spectroscopy with SDSS and LAMOST candidates

The discovery of J0815+4729: DA+2018a



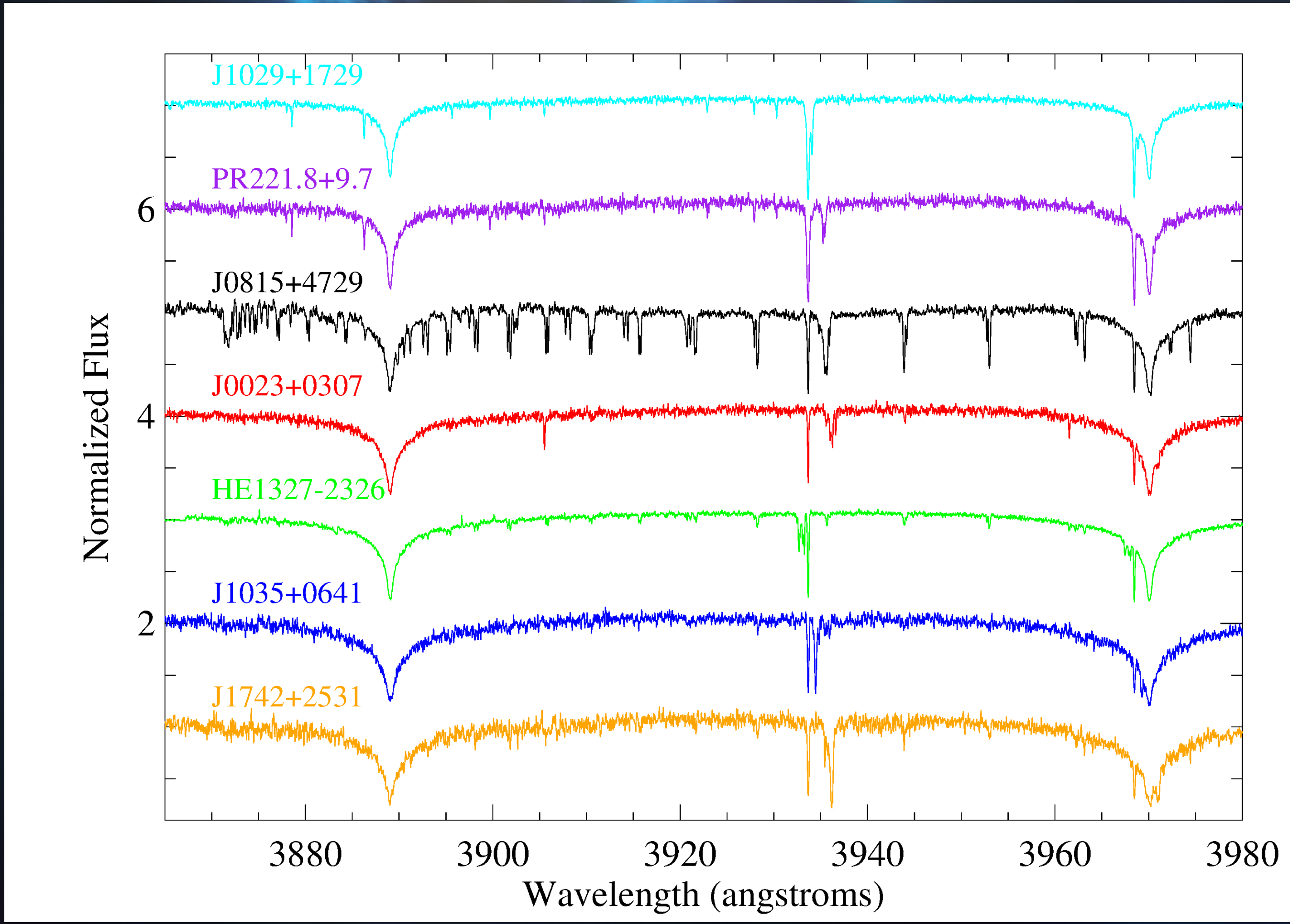
4-Follow-up Spectroscopy with SDSS and LAMOST candidates

The discovery of J0023+0307: DA+2018b



4-Follow-up Spectroscopy with SDSS and LAMOST candidates

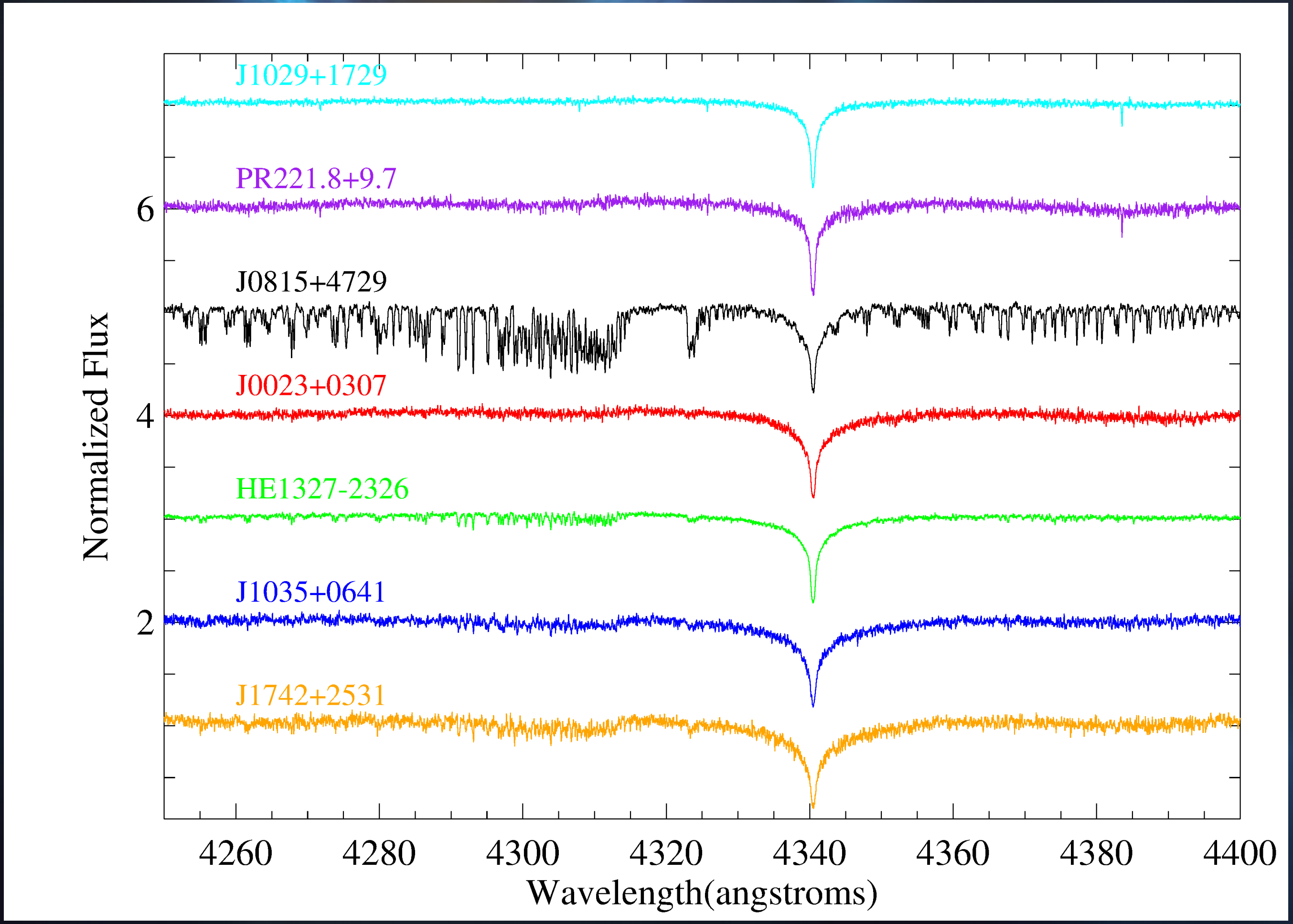
Very high CNO abundances in J0815+4729: González Hernández+2019 (In prep)



González Hernández+2019 (in Prep)

4-Follow-up Spectroscopy with SDSS and LAMOST candidates

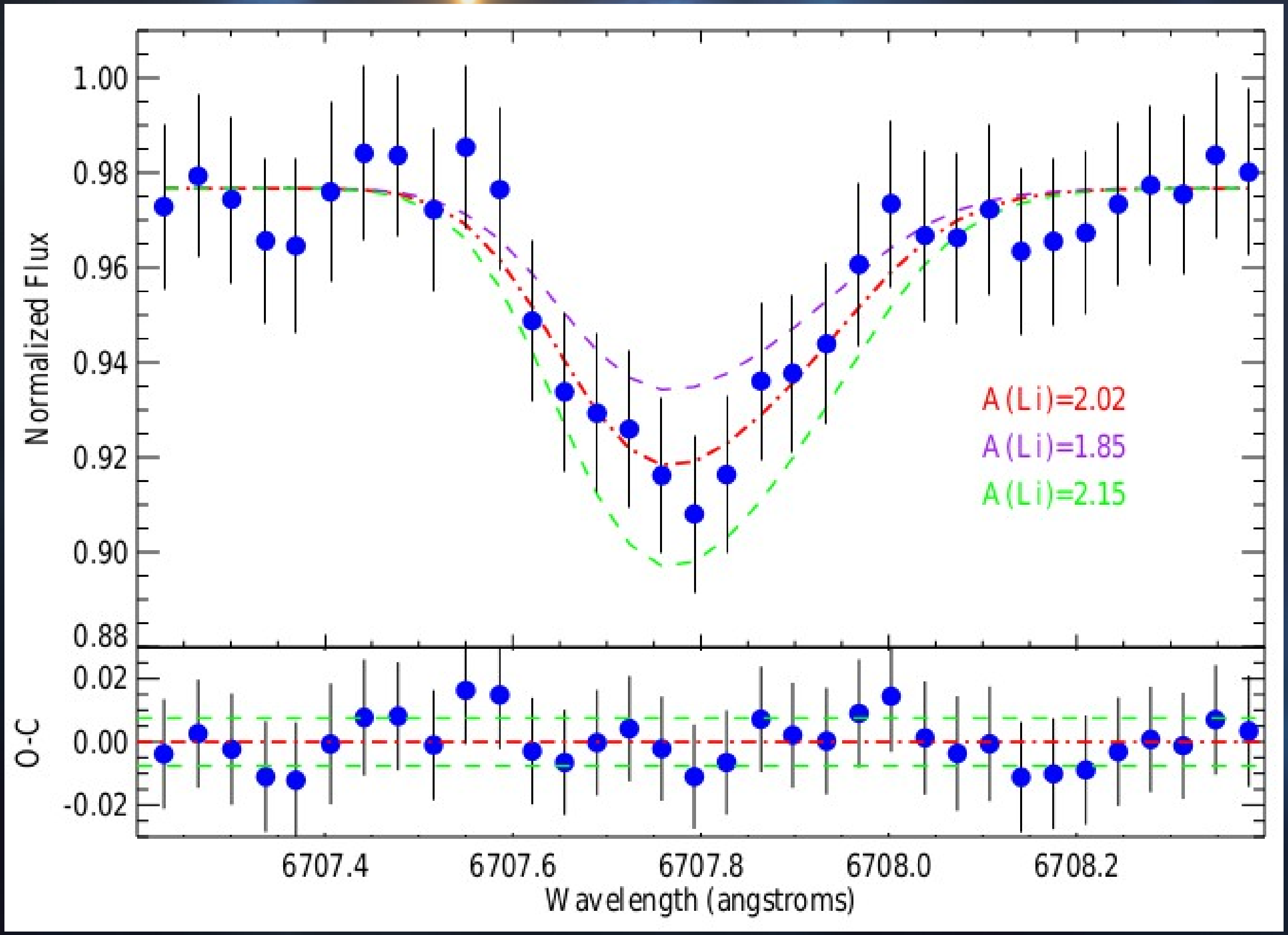
Very high CNO abundances in J0815+4729: González Hernández+2019 (In prep)



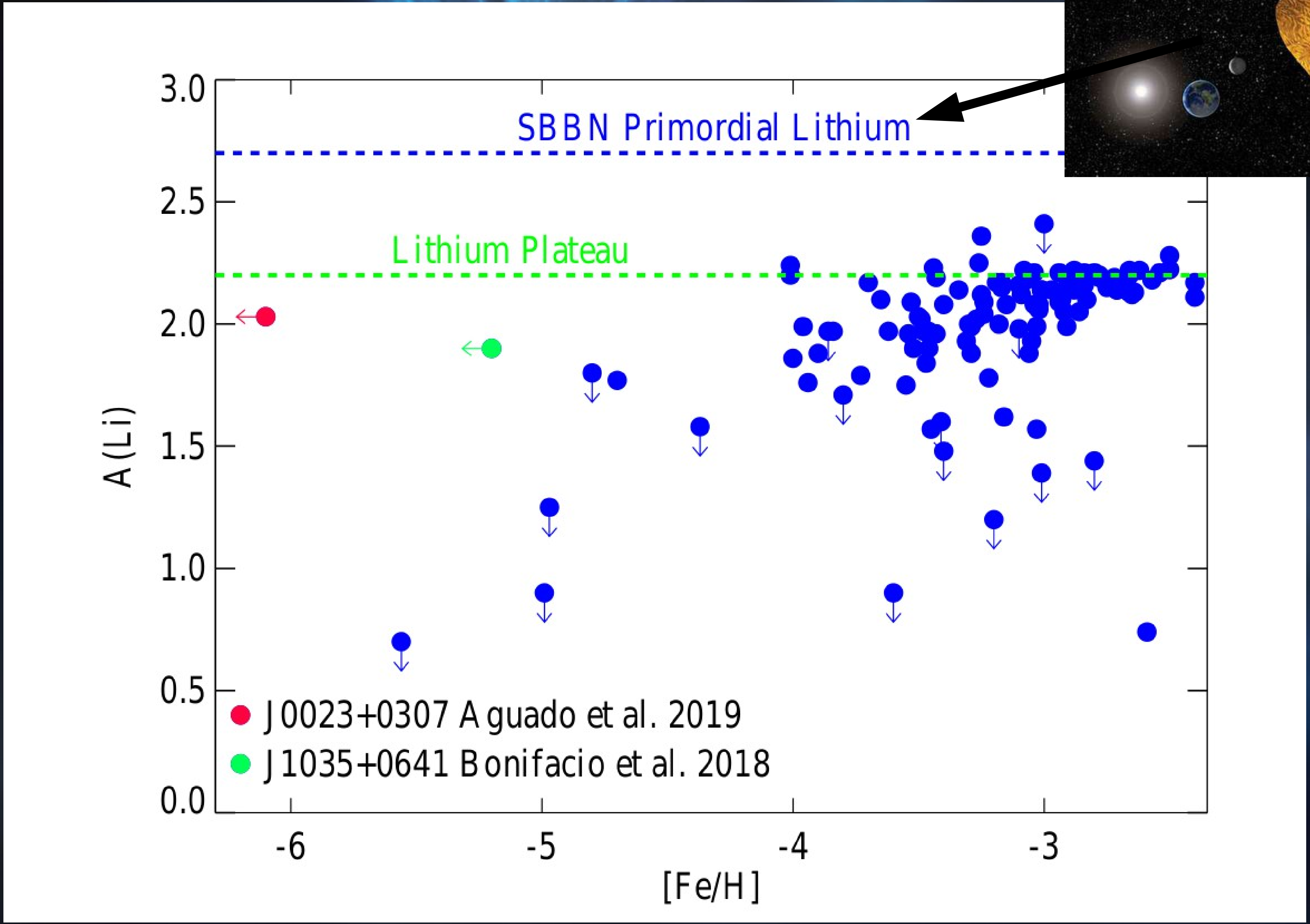
González Hernández+2019 (in Prep)

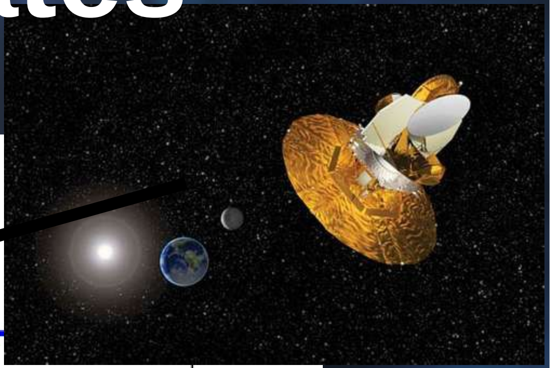
4-Follow-up Spectroscopy with SDSS and LAMOST candidates

Back to the lithium plateau with J0023+0307: DA+2019



4-Follow-up Spectroscopy with SDSS and LAMOST candidates



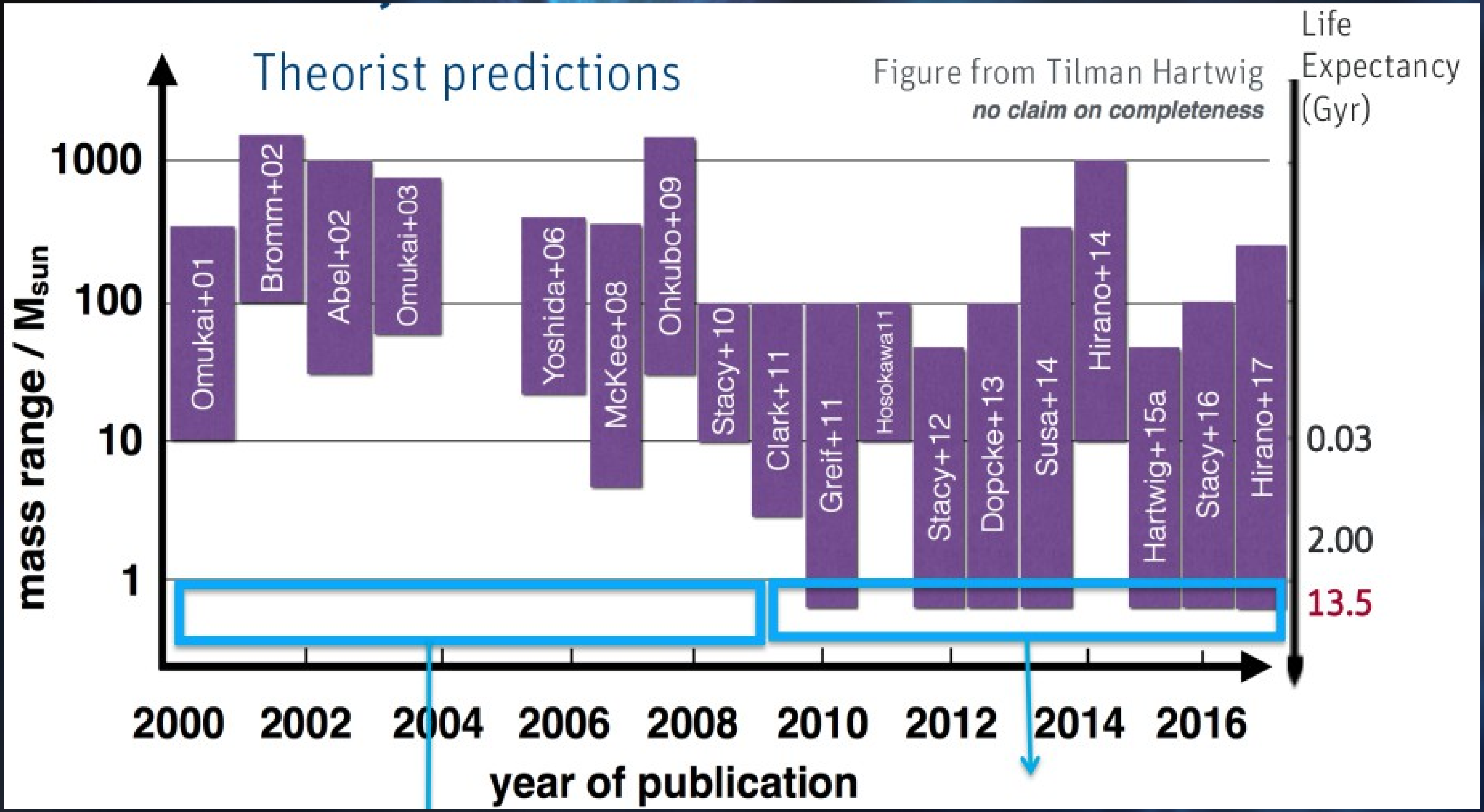


Summary

- Metal-poor stars are key for understanding several open questions in astrophysics
- To find them a large observational effort is required
- New UMP stars have been found during the last years
- With the FERRE code we are able to look into not only spectroscopic but also photometric surveys
- With next generation of large spectroscopic surveys such as WEAVE, DESI, 4MOST, … together with Gaia the field will be revolutionized!

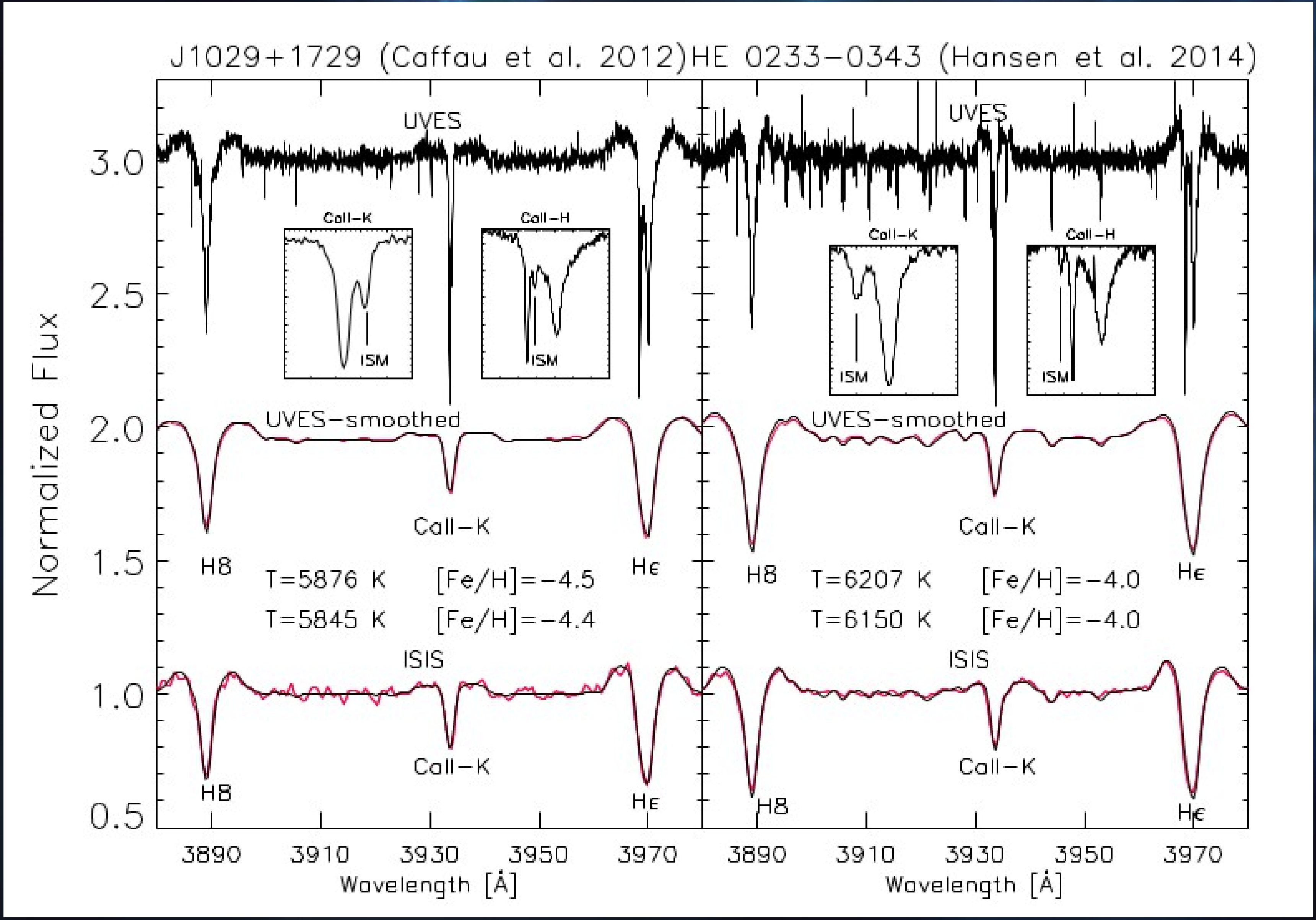
Thank You!

The Early Universe



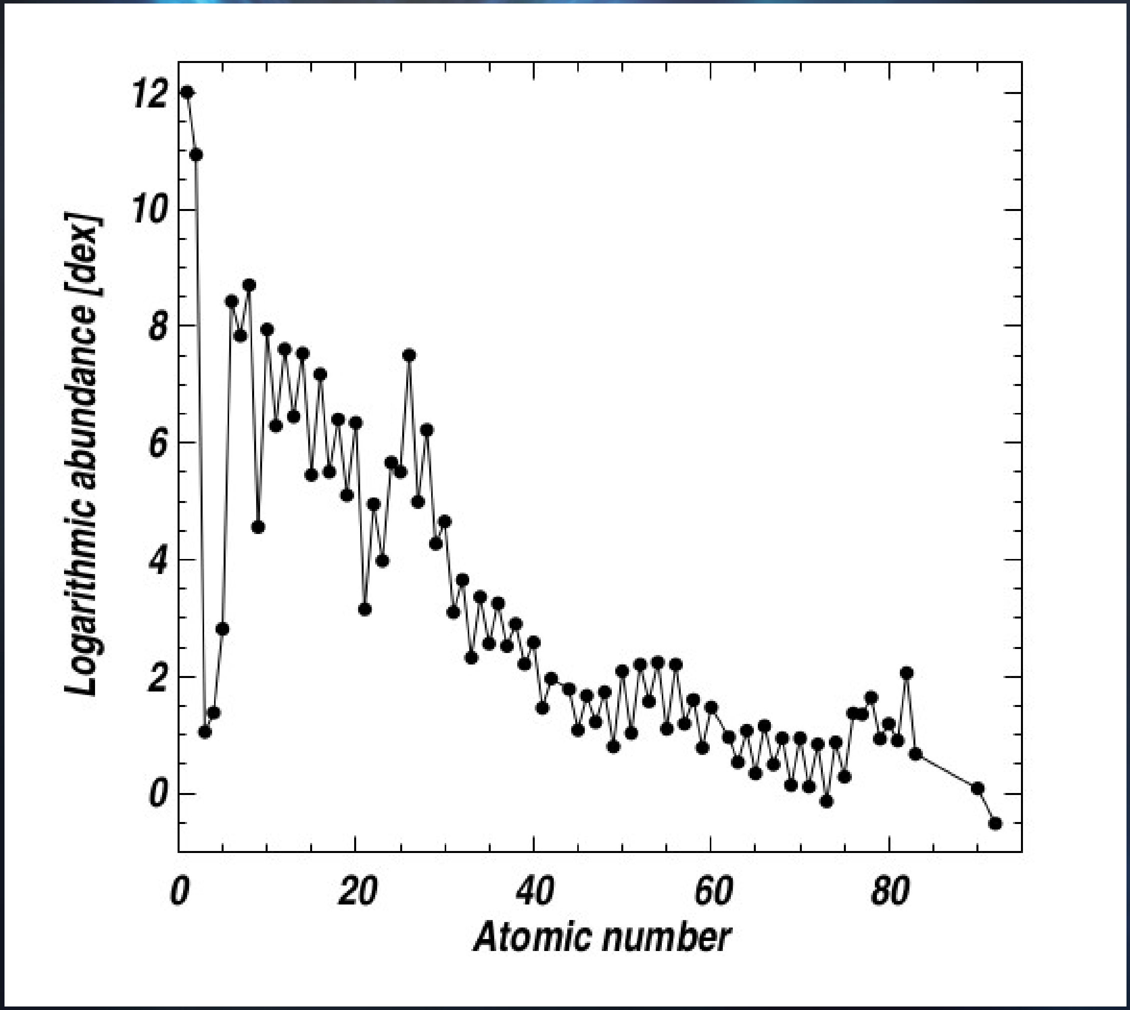
Hartwig, Starkenburg

Other known UMP stars



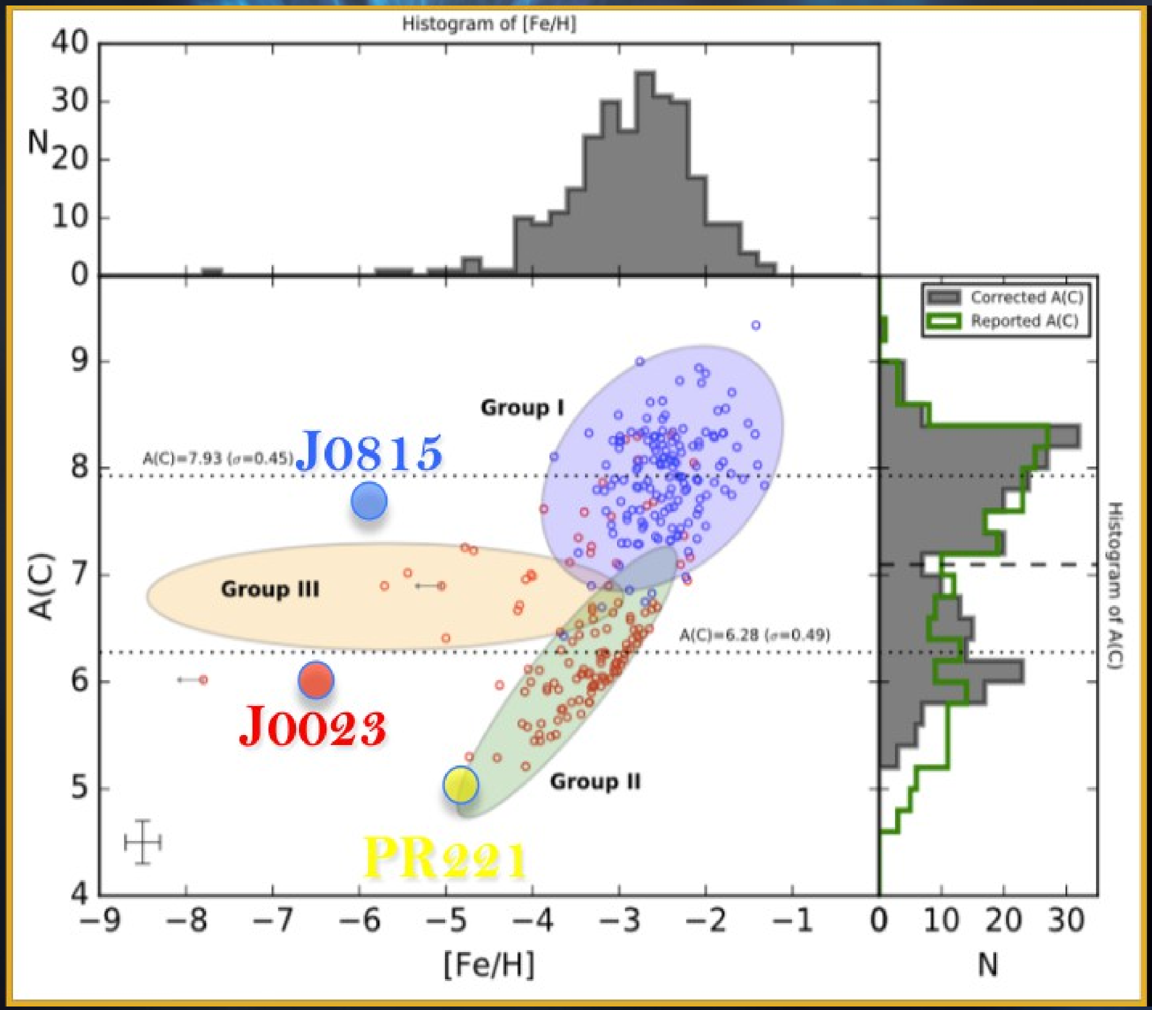
Aguado+ 2017

The solar composition



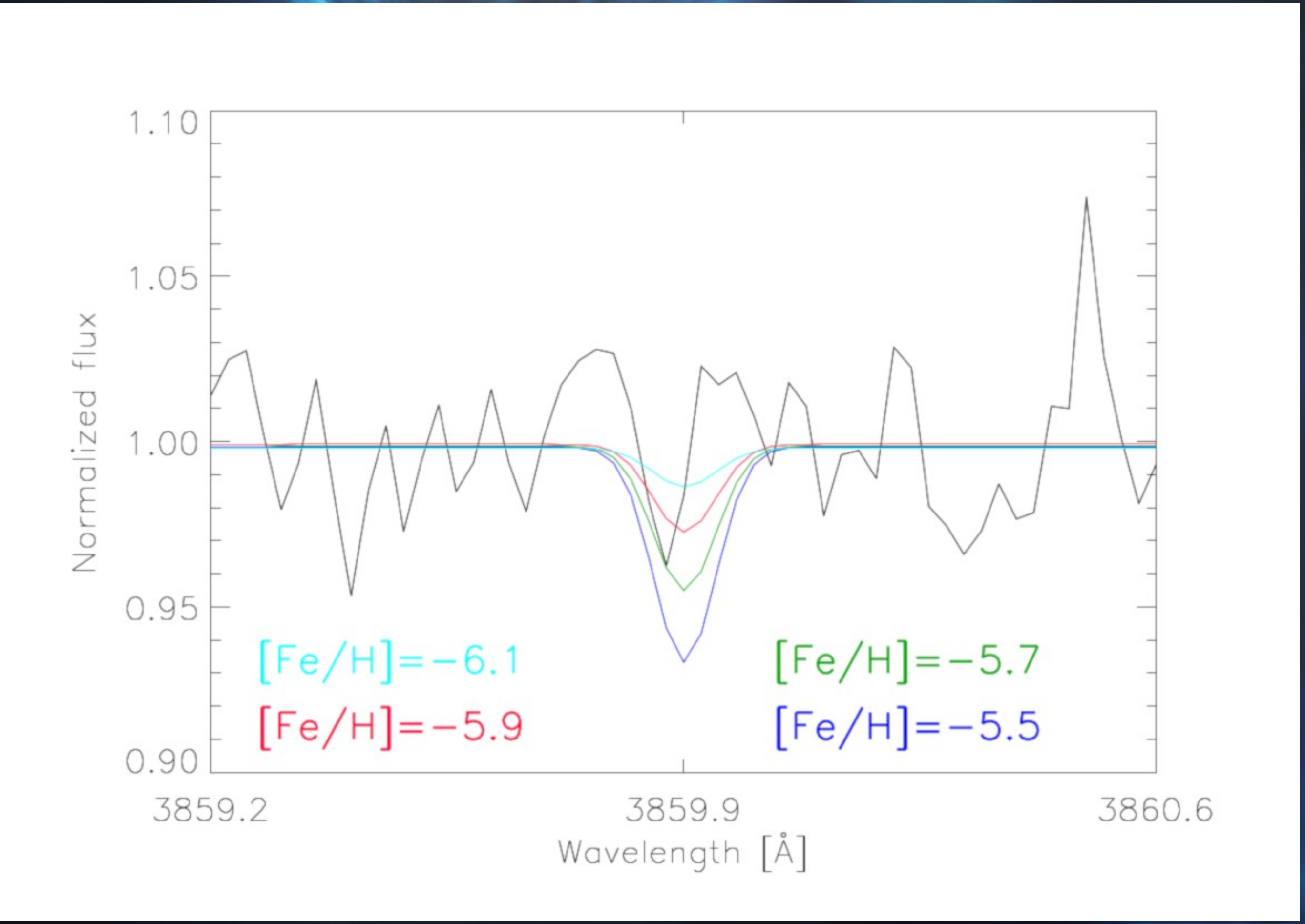
Asplund+ 2009

The A(C) vs [Fe/C] diagram



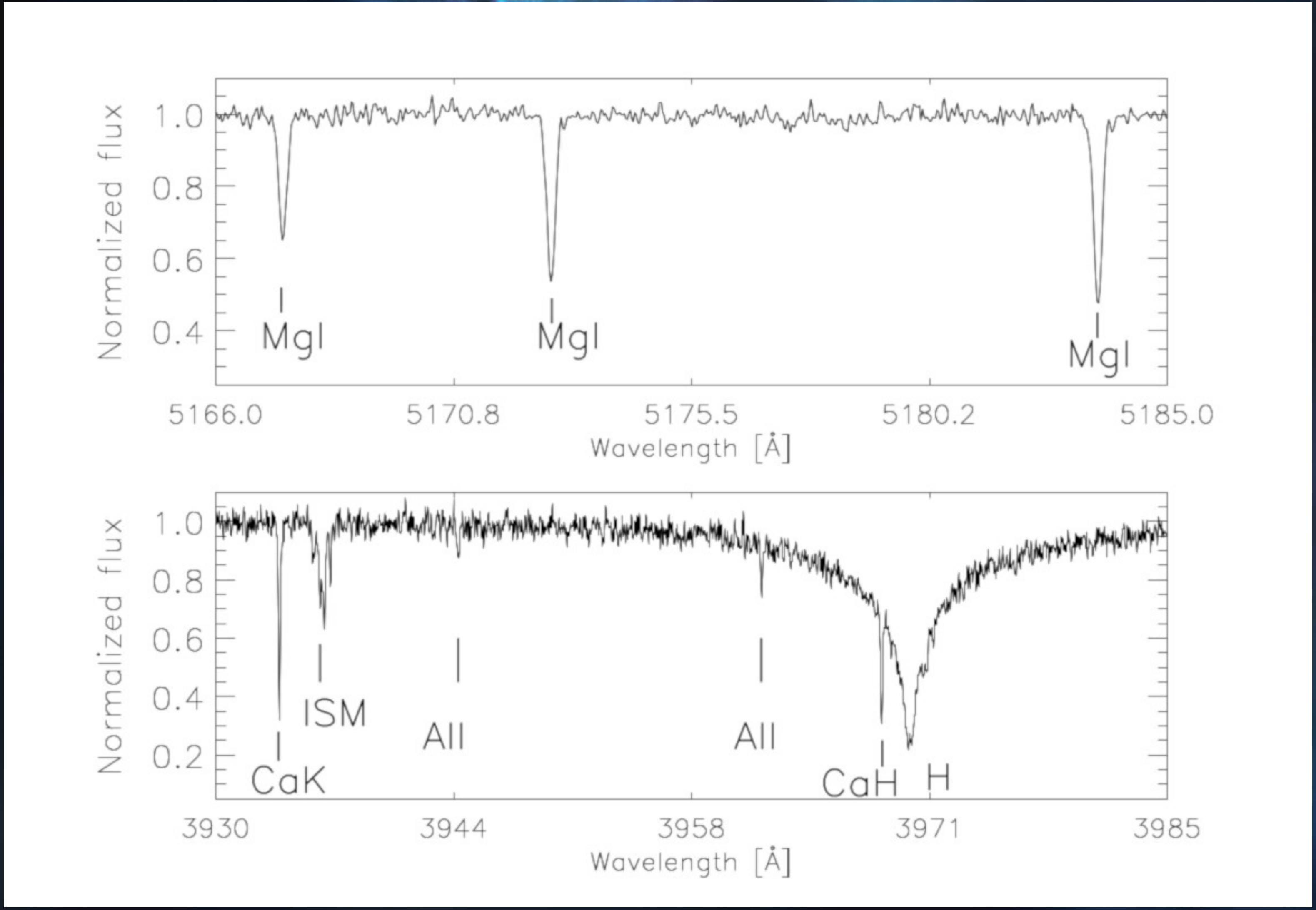
Yoon+ 2016

Iron in J0023+0307



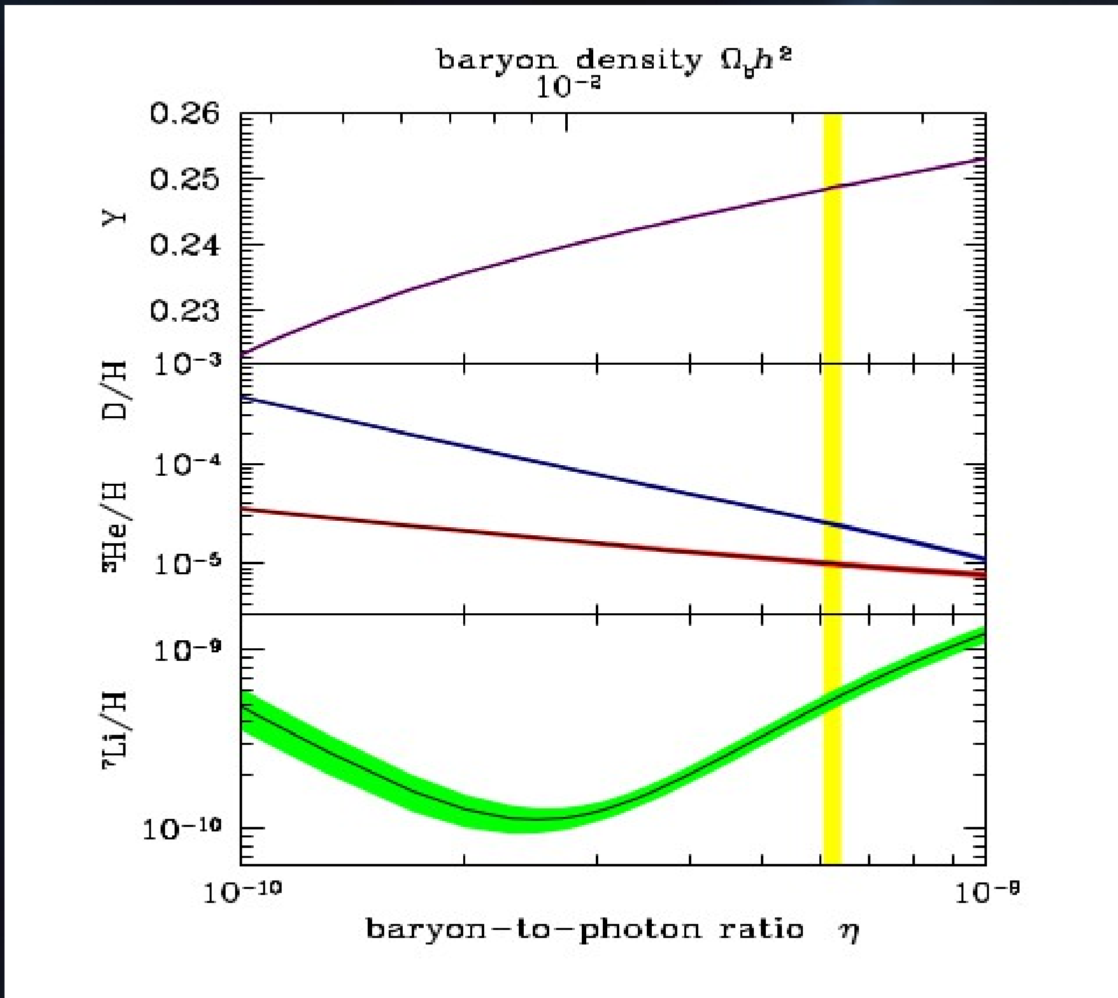
DA+2019

Chemistry in J0023+0307

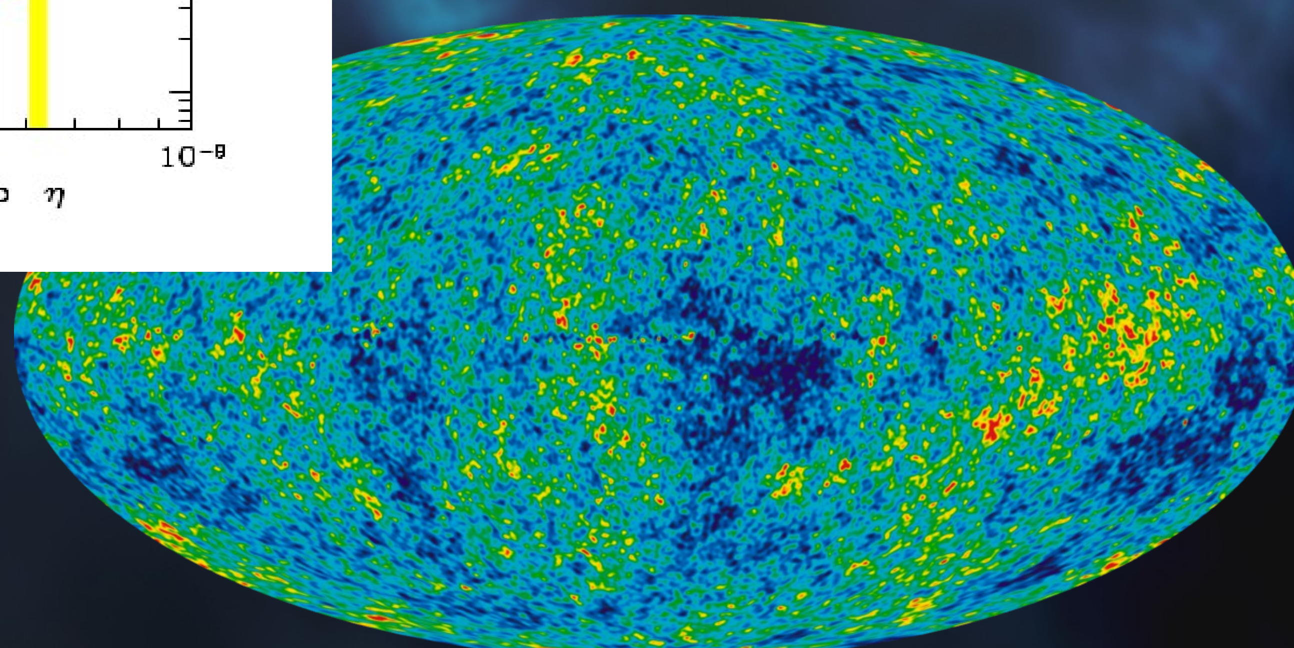


DA+2019

The lithium in J0023+0307

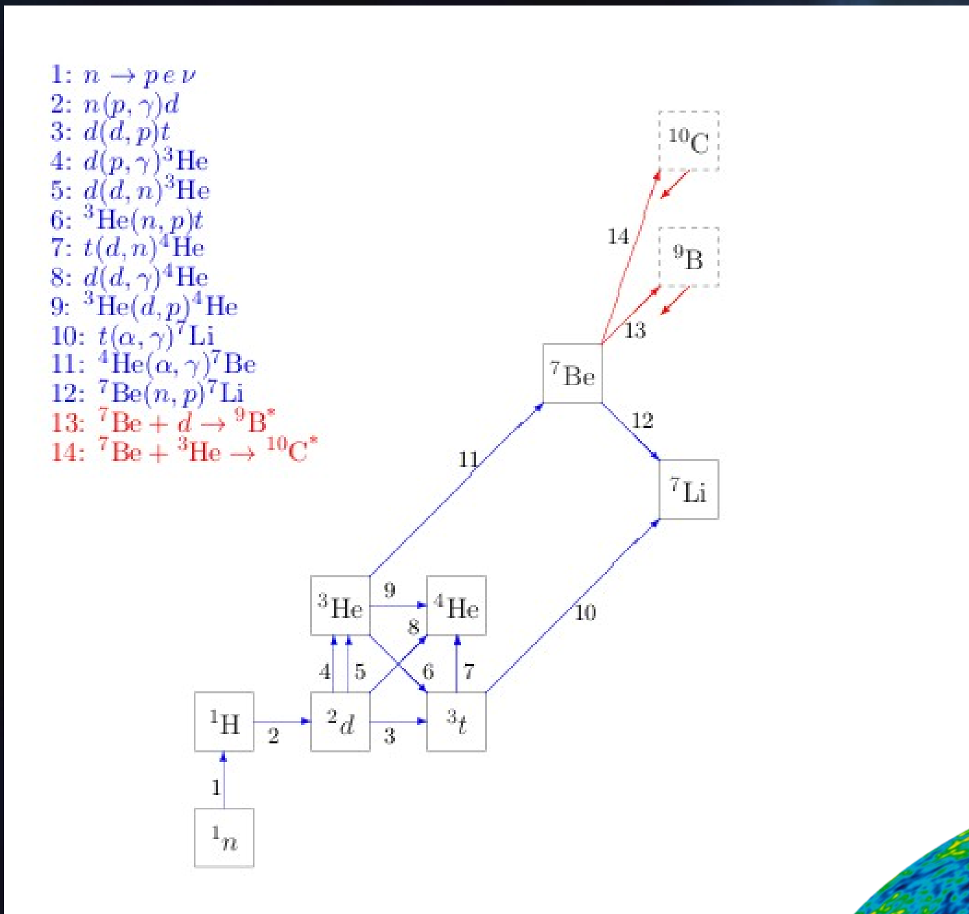


CMB+BBN



Fields 2012

The lithium in J0023+0307



Fields 2012

CMB+BBN