Stellar Genealogy

Rare Gems in the Milky Way as Probes of the Chemical evolution of the Universe

Vinicius Placco

NSF NOIRLab

Stellar Genealogy

How to find what you are *not* looking for: the search for low-mass Pop. III stars

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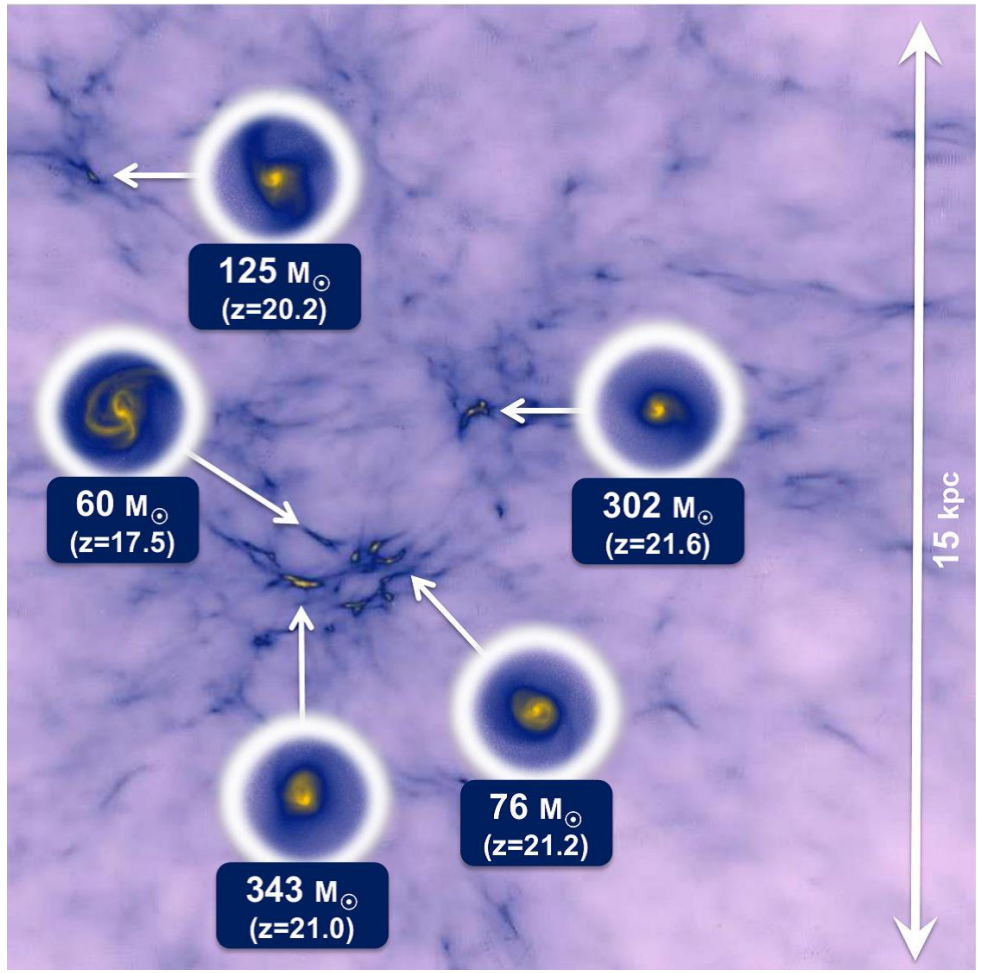
finding a needle in a haystack

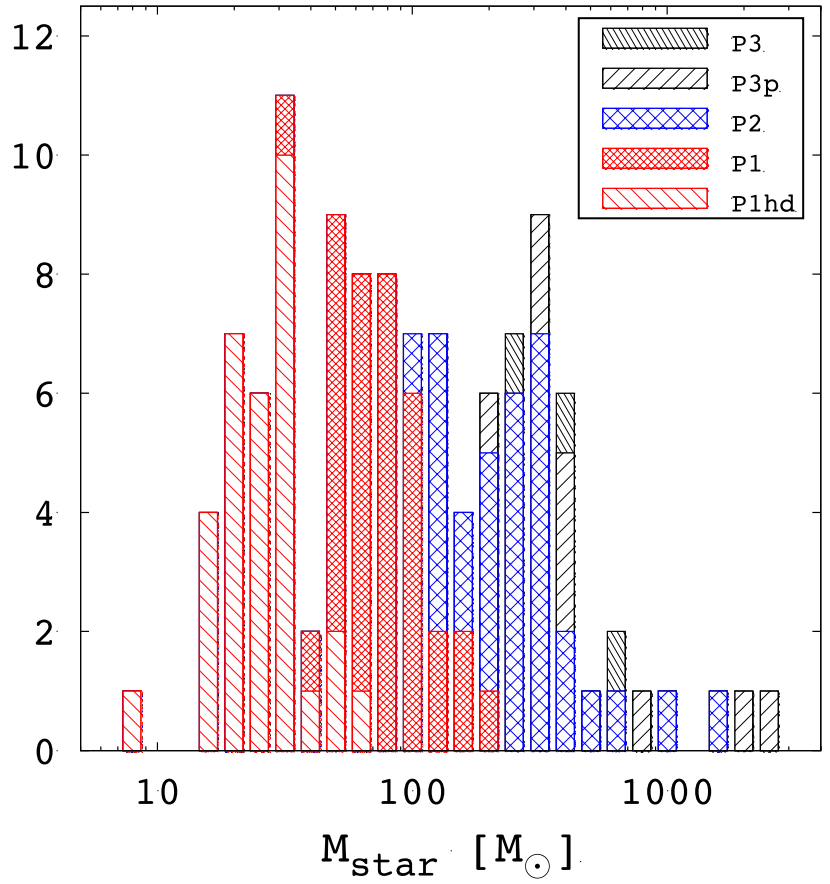
finding if there is a needle in a haystack

Outstanding questions

1. Does the needle exist?
2. How does it look like?
3. How do you find it?
4. What else will you find?
5. If you find it:
    1. What can you learn?
    2. How do you know it is it?
    3. How do you find more?
6. If you don’t find it, what can you learn?

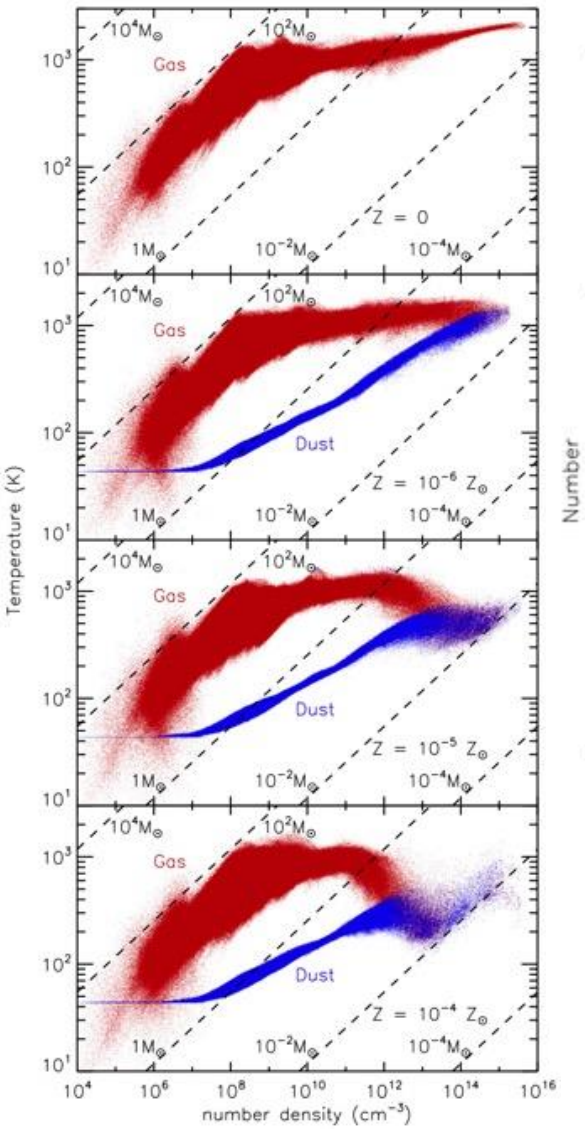
The first 100 stars formed in the universe

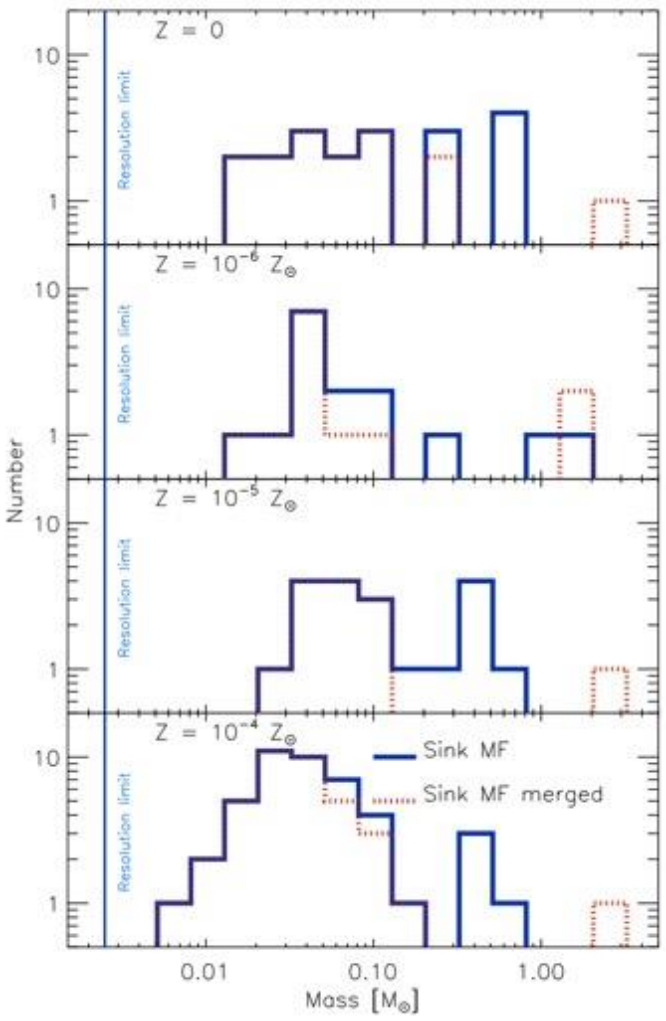




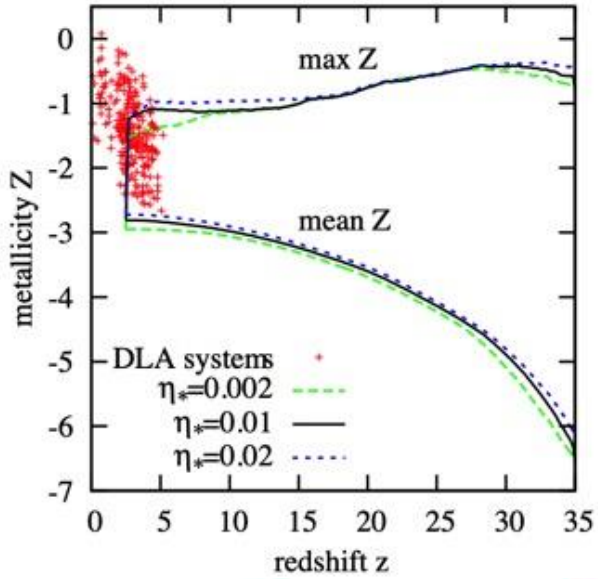
Hirano+2014

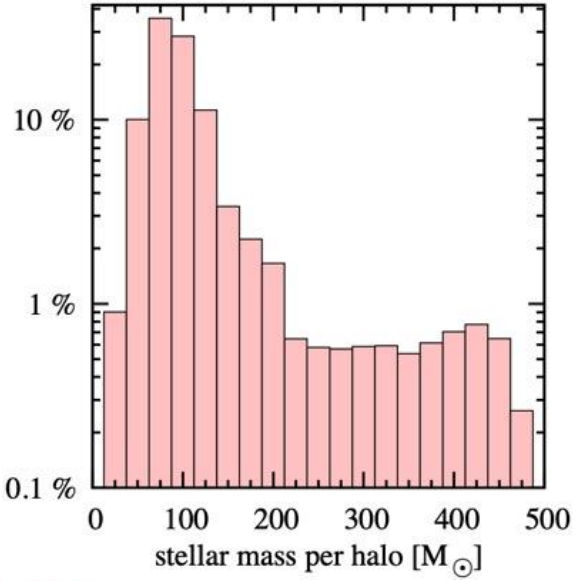
When do the first stars form → as early as z = 20—30!

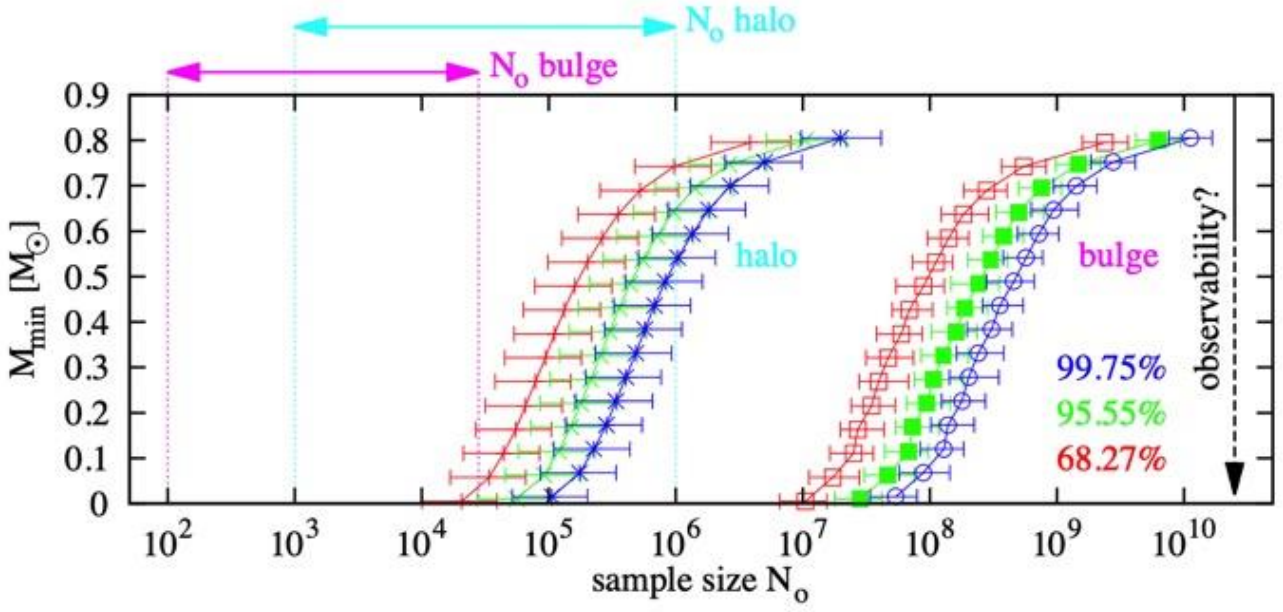




Can we observe "Pop III survivors" at z = 0?
Maybe…



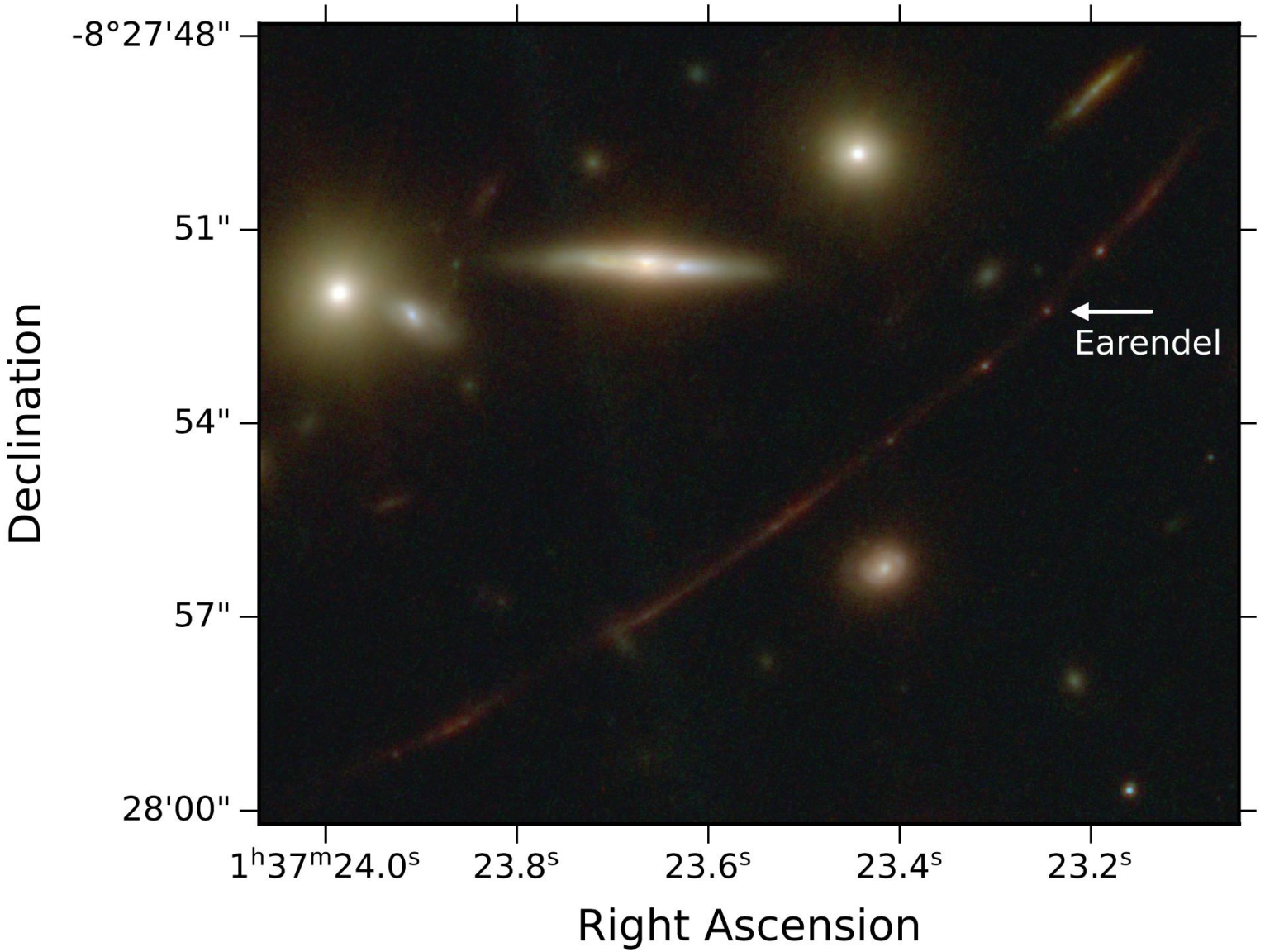


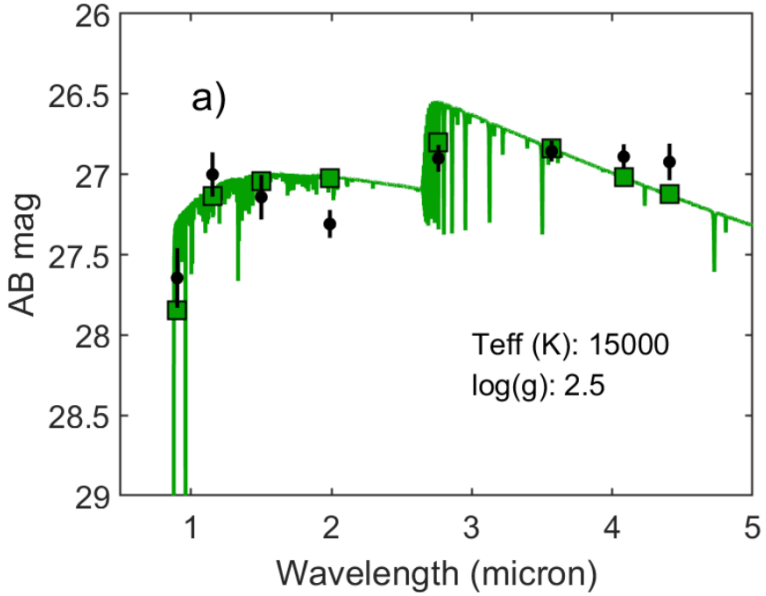


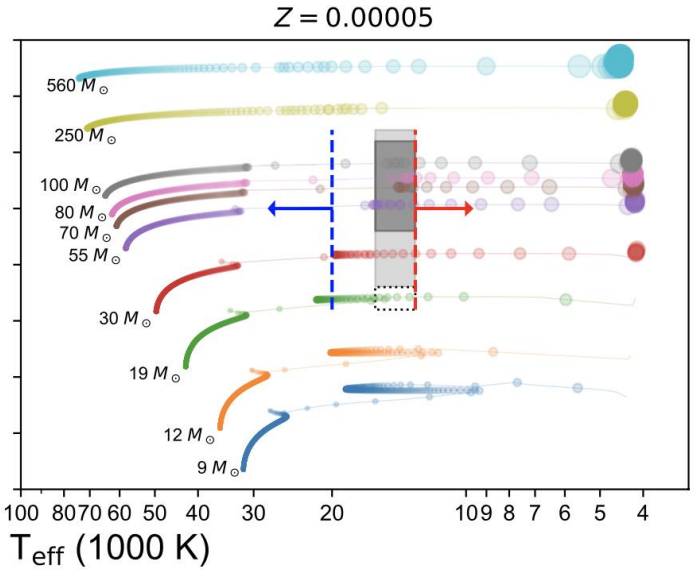
Credit: Dopcke+2013

Credit: Hartwig+2015

Pop III in situ? Luminous Blue Variable at $z \sim 6.2$

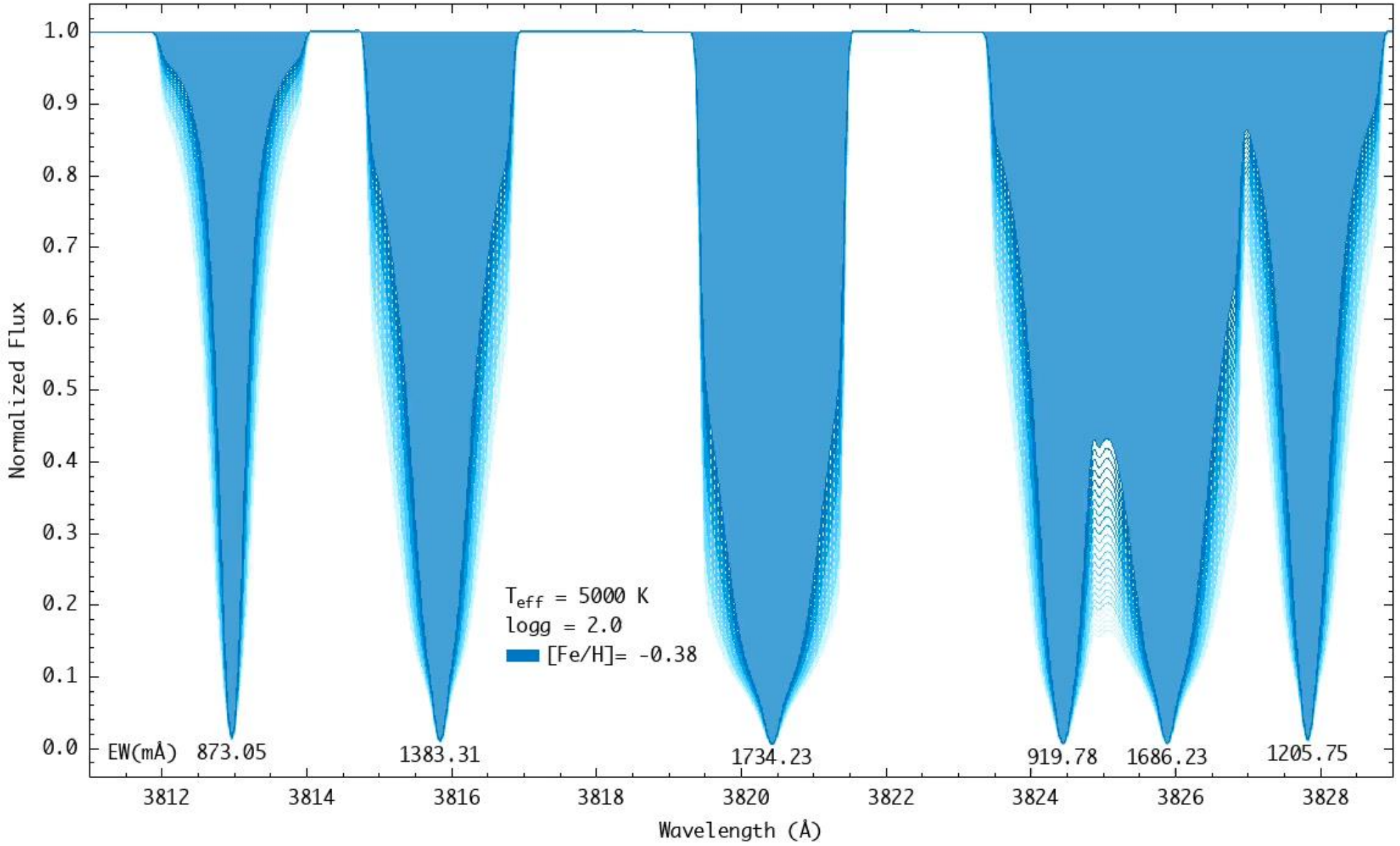






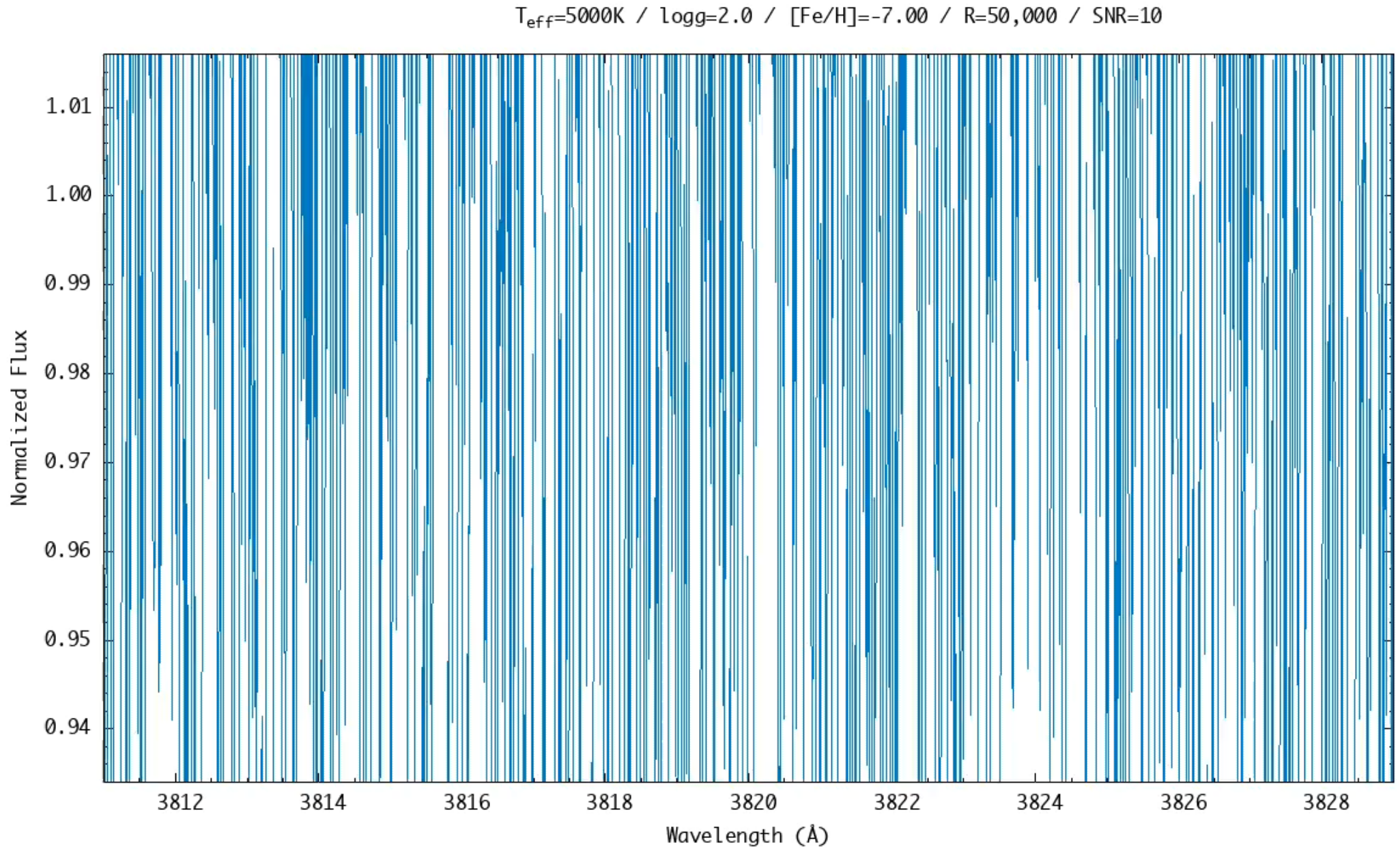
Credit: Welch+2022

How do you find a low-mass Pop. III star? Spectral signatures



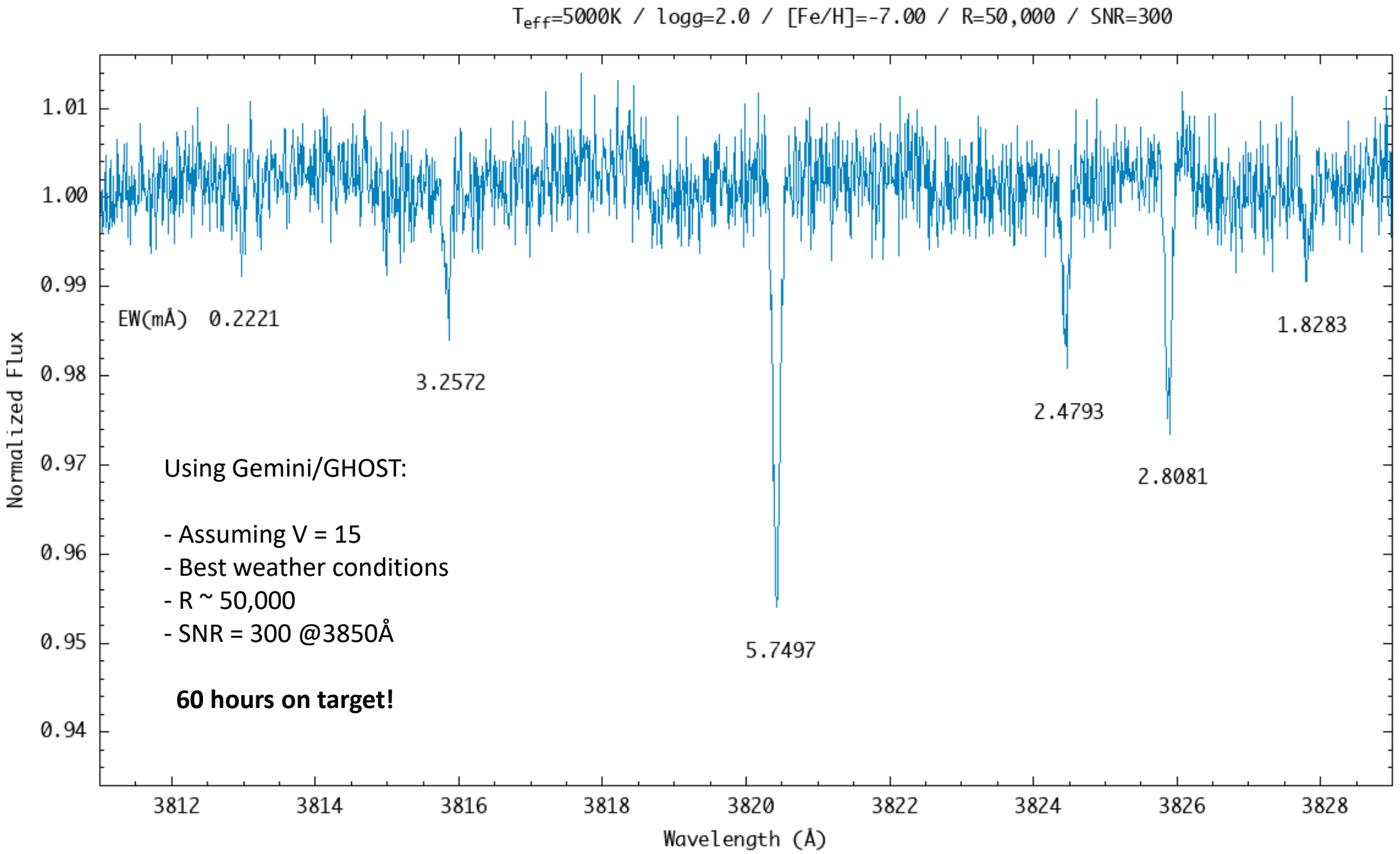
Credit: V. Placco

How do you find a low-mass Pop. III star? Real spectra have noise…



Credit: V. Placco

The Observational Cost



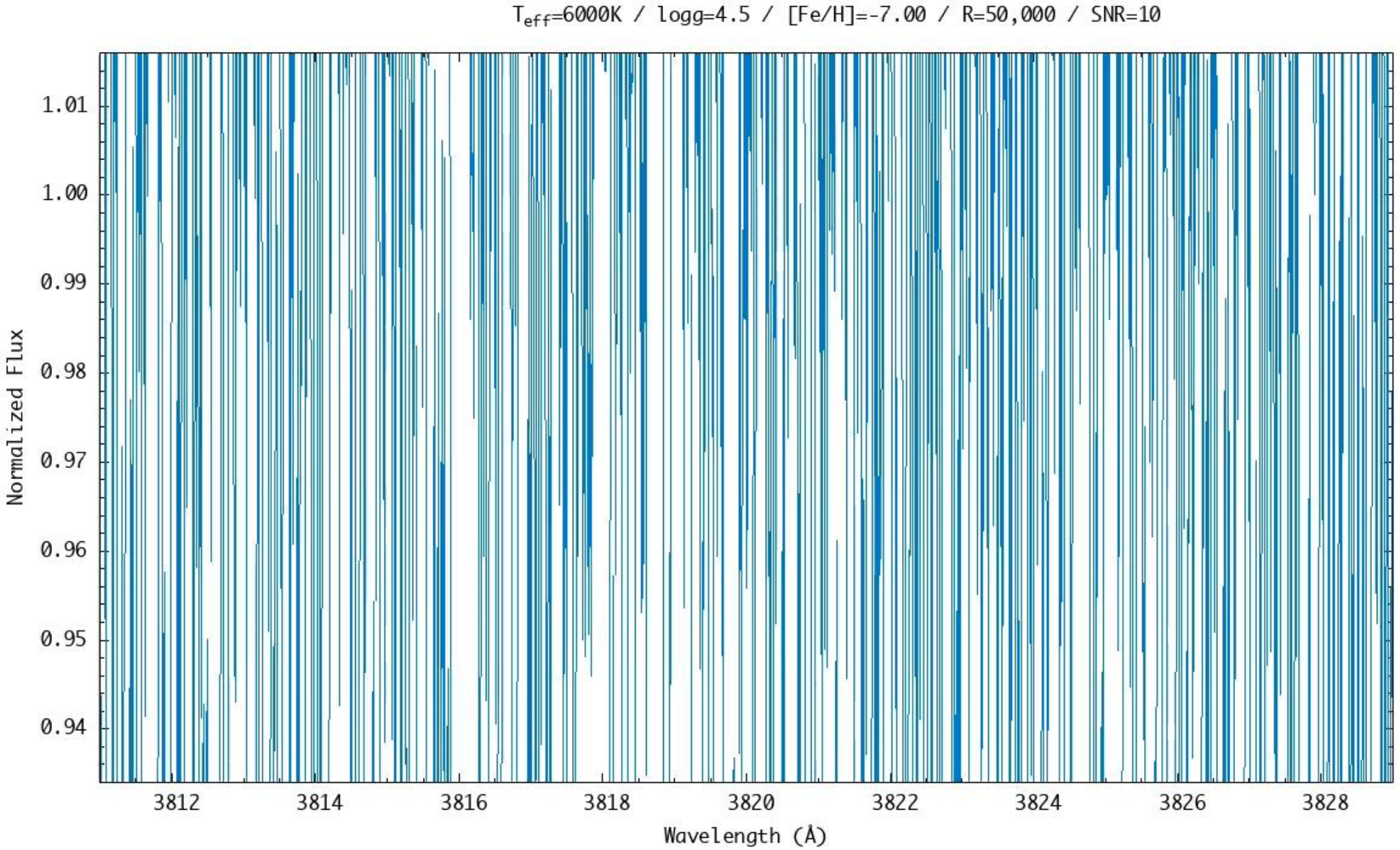
Using Gemini/GHOST:

- Assuming V = 15
- Best weather conditions
- R ~ 50,000
- SNR = 300 @3850Å

60 hours on target!

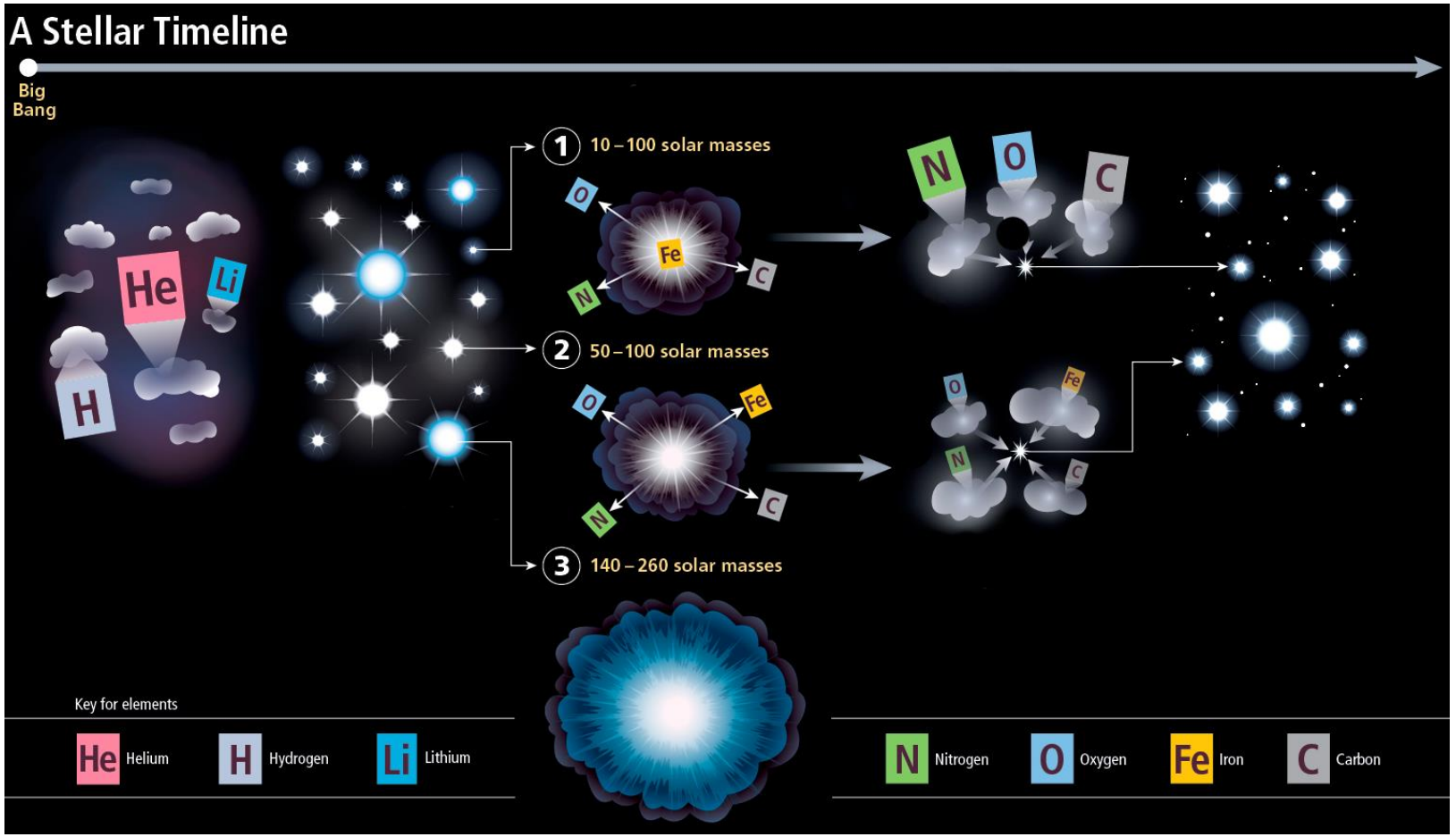
Credit: V. Placco

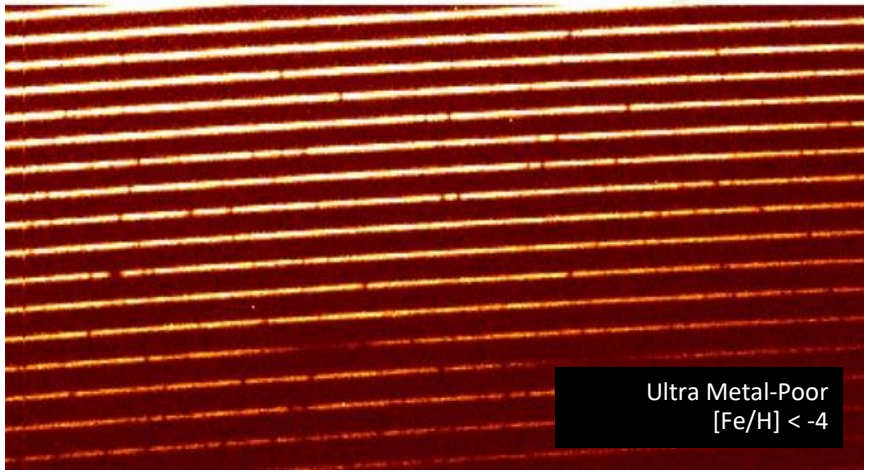
How do you distinguish between “low-metal” and “no-metal”?



Credit: V. Placco

“Near field cosmology” (a.k.a. the next best thing)





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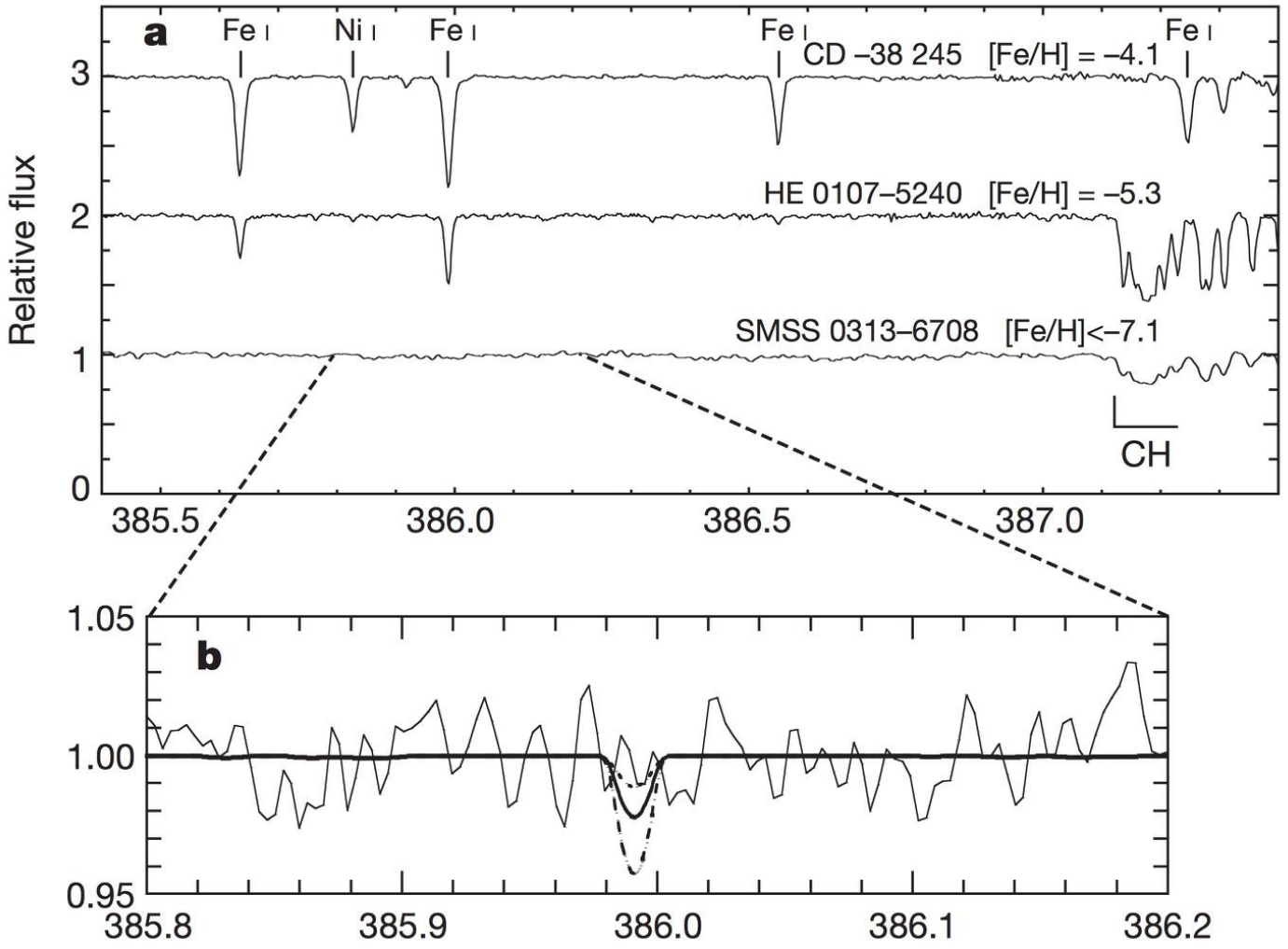
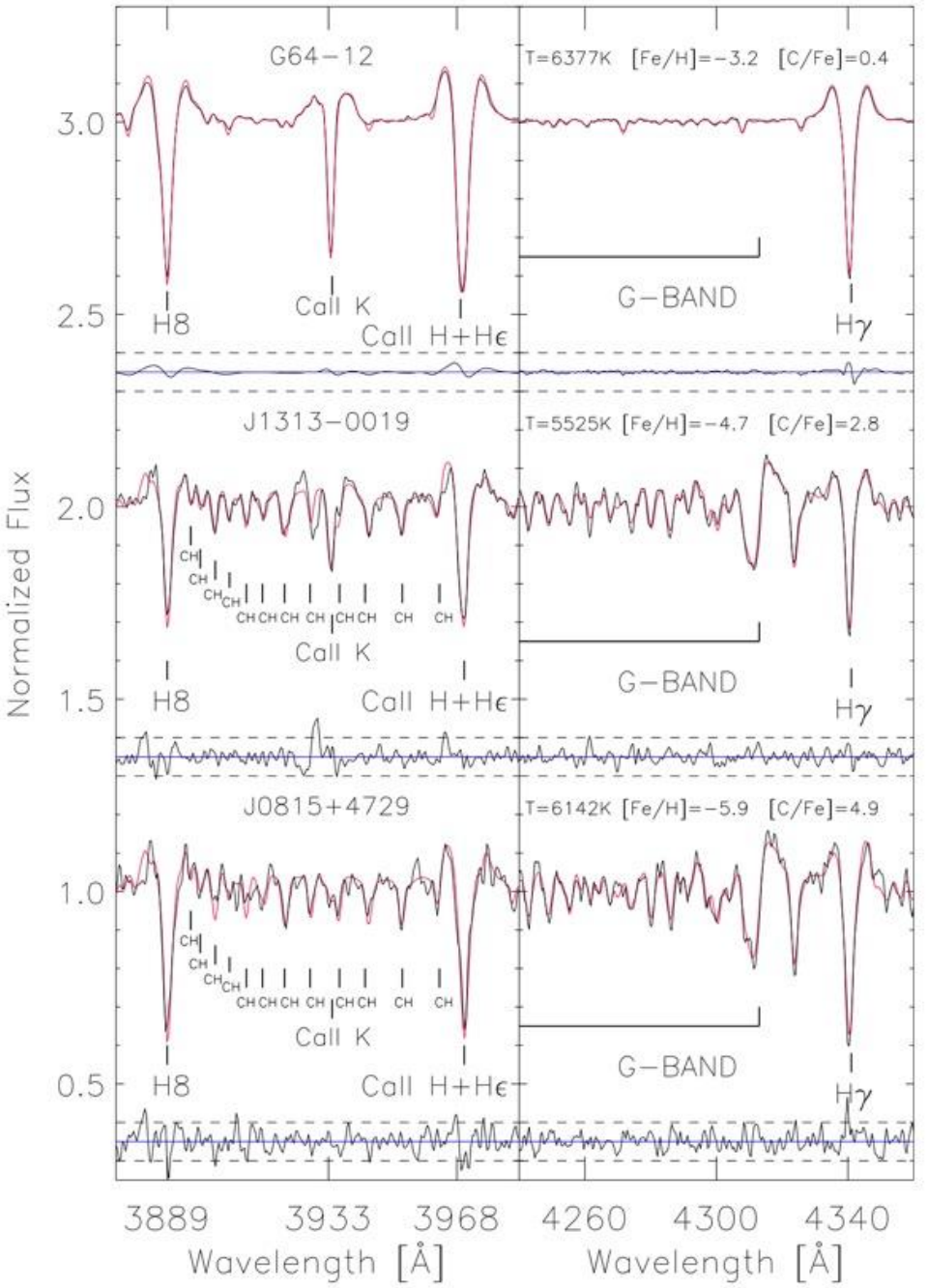
Credits: Discover Magazine / Elisa Arizono / Erika Holmbeck

Finding low-metallicity stars



Keller+2014



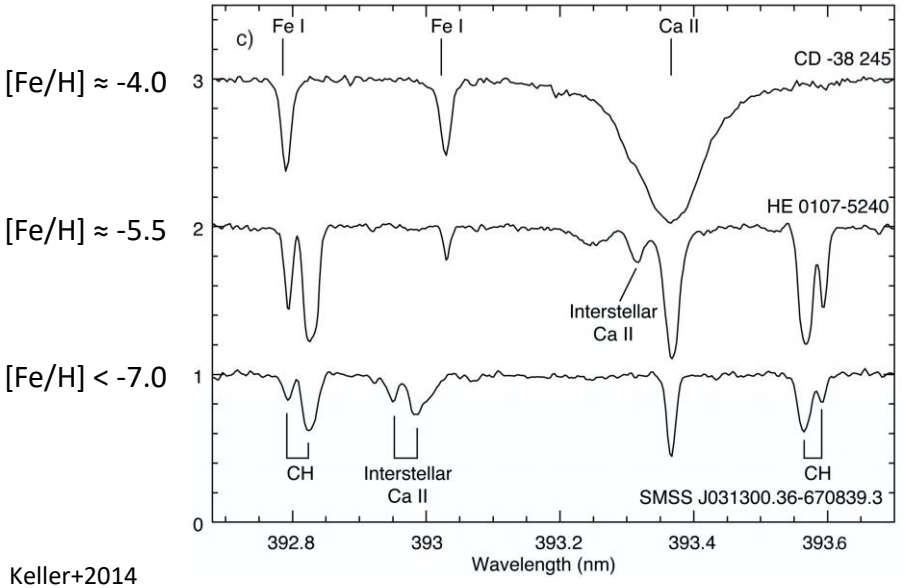
Aguado+2018

Finding low-metallicity stars → look for carbon

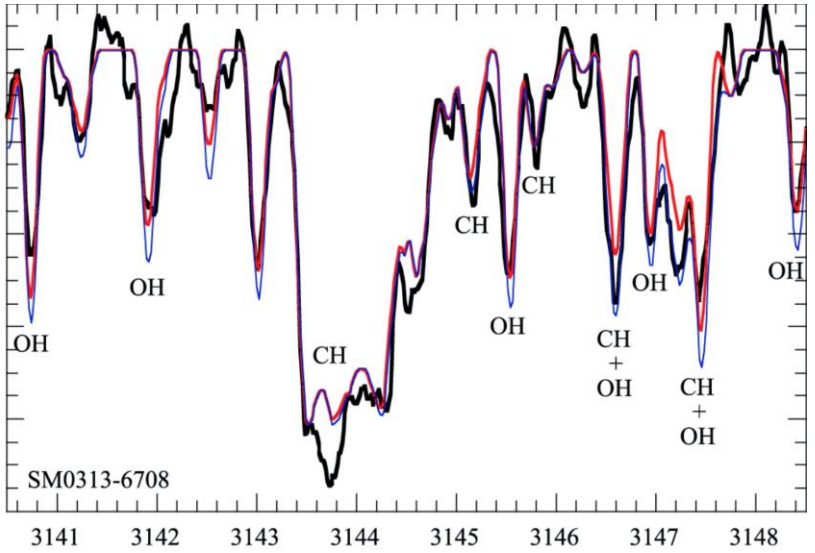
[Fe/H] ≈ -4.0

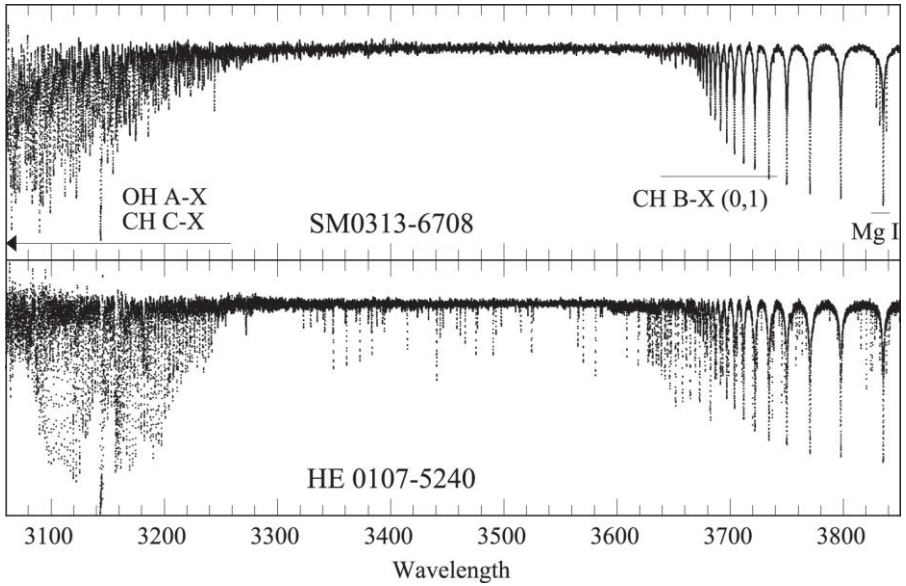
[Fe/H] ≈ -5.5

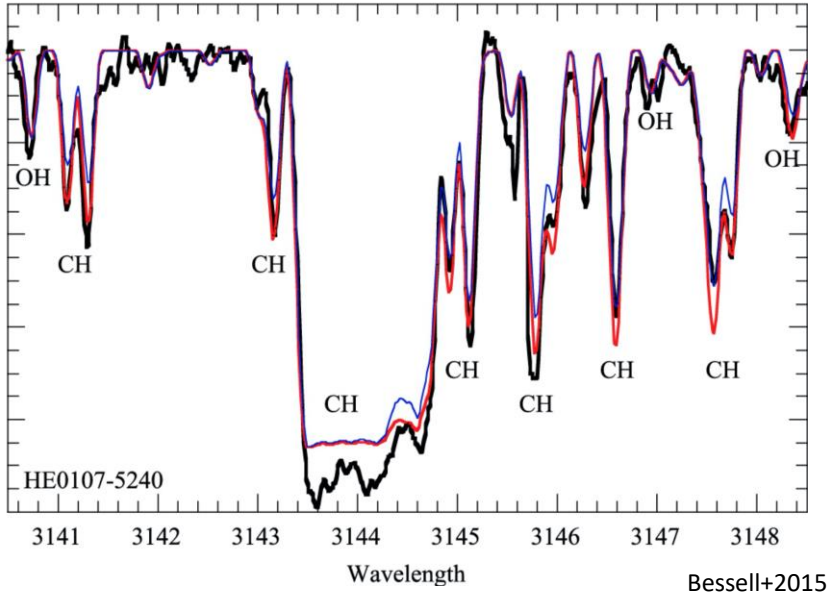
[Fe/H] < -7.0



Keller+2014







Bessell+2015

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Carbon is a key ingredient

THE

ASTROPHYSICAL JOURNAL

AN INTERNATIONAL REVIEW OF SPECTROSCOPY
AND ASTRONOMICAL PHYSICS

VOLUME IX MARCH 1899 NUMBER 3

ON THE SPECTRA OF STARS OF CLASS III *b*.

By N. C. Dunér.

Furthermore, since the greatest telescopes in the world have entered this field, it can hardly be of further interest to continue these investigations in a climate so unsuitable as that of Upsala for astronomical observations. But since in the course of the observations already made certain new details have been discovered in the spectra of stars of class III *b*, and since these confirm the results published by Professor Hale in the Astrophysical Journal, Vol. VIII, No. 4, I beg leave to present them here.

BD. + 85°332 (9.2^m).

Rg (peculiar color) = 6.8 Sp. III *b!!* 3 zones, the green one brightest, the blue not faint. Band 9 strong and broad, 6 rather faint. Band 4 suspected on one occasion. (Ss I, Ss III 96.8.14, 96.8.31, 96.9.9.)

THE CHEMICAL COMPOSITION OF TWO CH STARS, HD 26 AND HD 201626*

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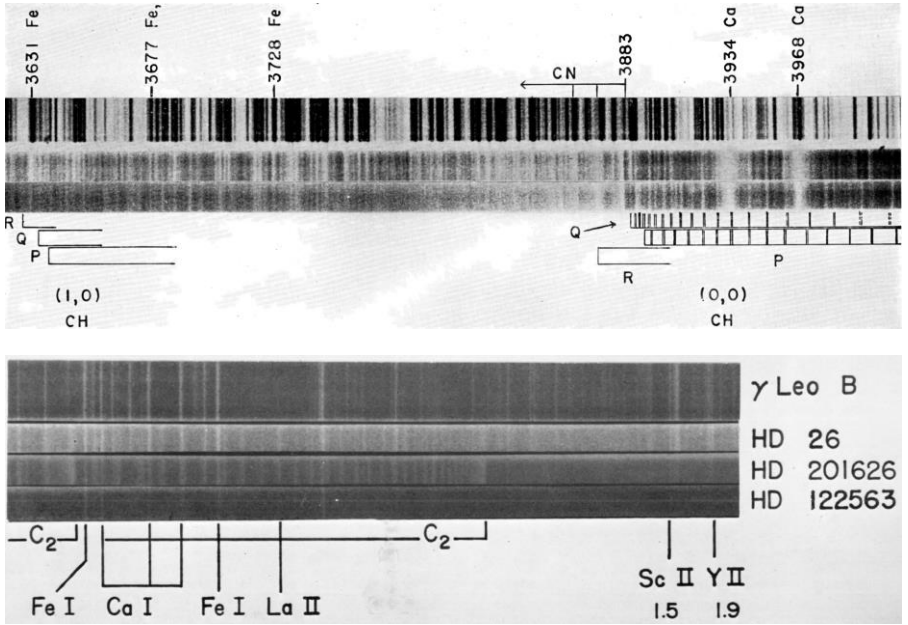
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology

Received December 17, 1963

ABSTRACT

The high-velocity CH stars appear to be deficient in metals but rich in carbon and heavy elements. By a comparative curve-of-growth analysis using the G8 III star ε Virginis as a standard, we have found that the CH stars, HD 26 and HD 201626, are metal-poor by factors of 5 and 30, respectively. Both stars show a carbon-to-iron ratio 5 times higher than ε Vir. There is no evidence for the presence of C^{13}. In addition, both show an excess of Ba, La, Ce, and Nd with respect to Fe, by factors of about 20. Eu is enhanced by only a factor of 5 in HD 26, and by less than 2 in HD 201626. Except for their general metal deficiency these stars have relative abundances of C:Fe:Ba very similar to the population I Ba II star, HD 46407.



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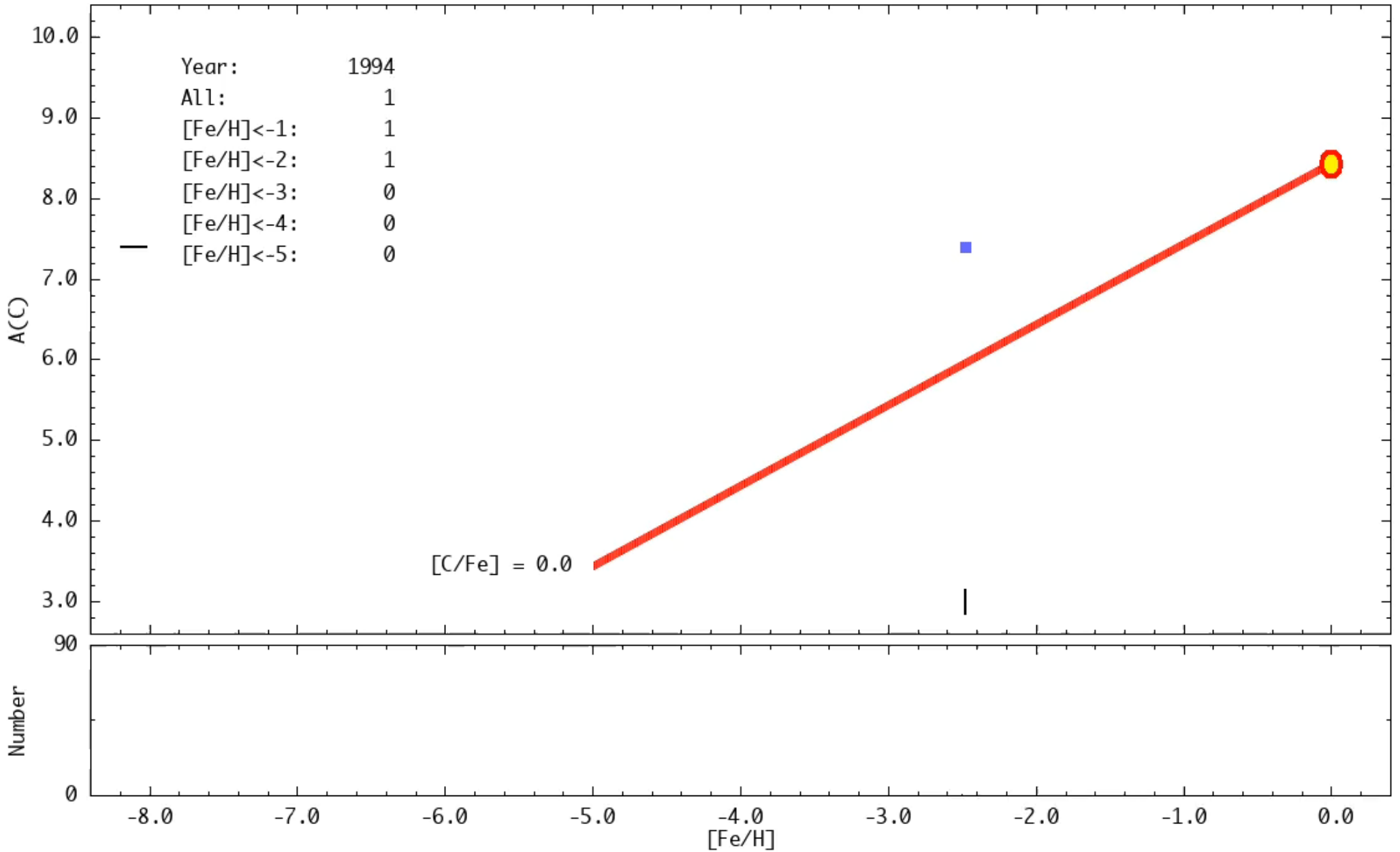
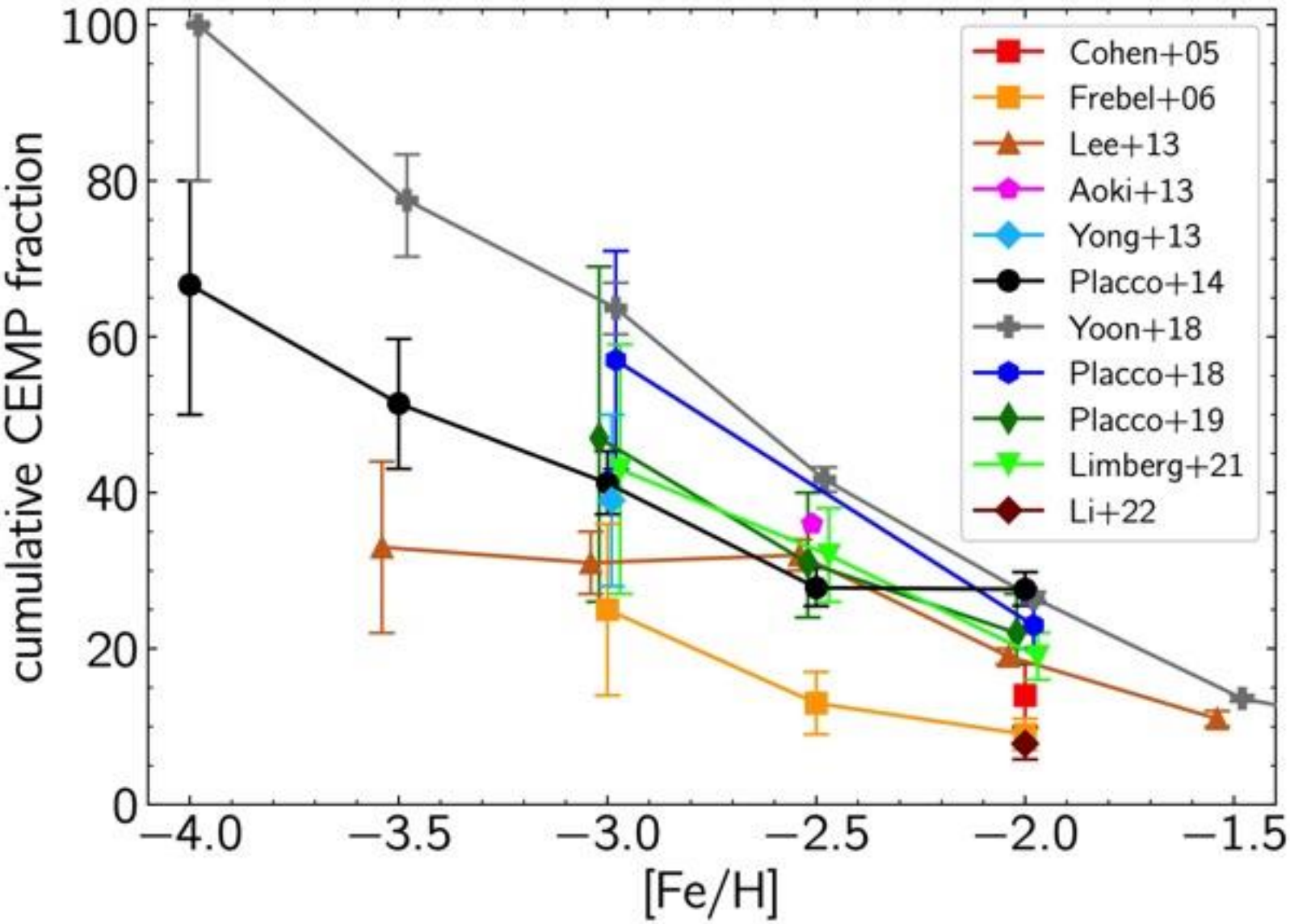
Carbon: empirical evidence



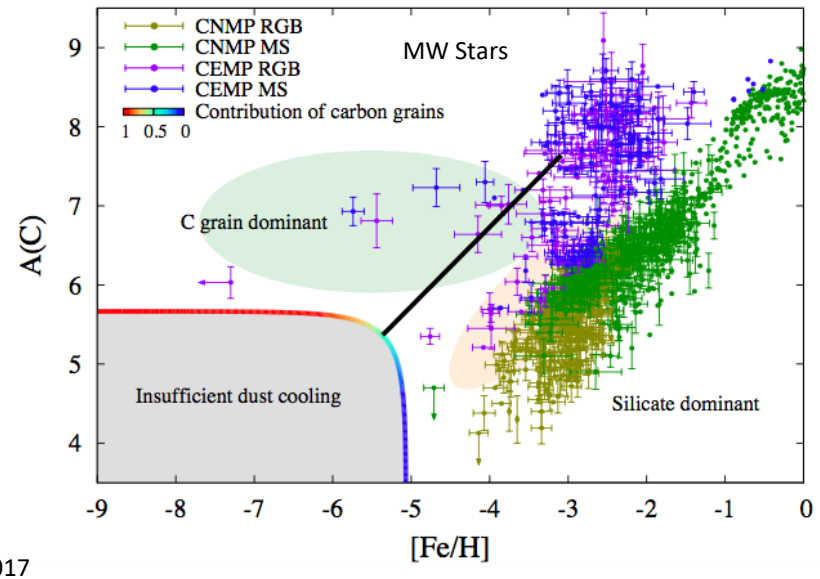
Credit: V. Placco/SAGA database

Carbon: empirical evidence

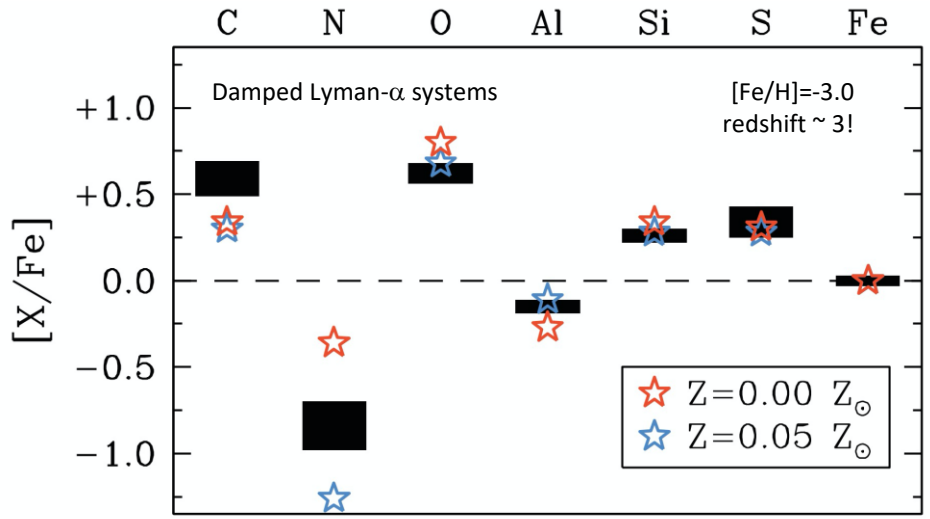


Arentsen, Placco+2022

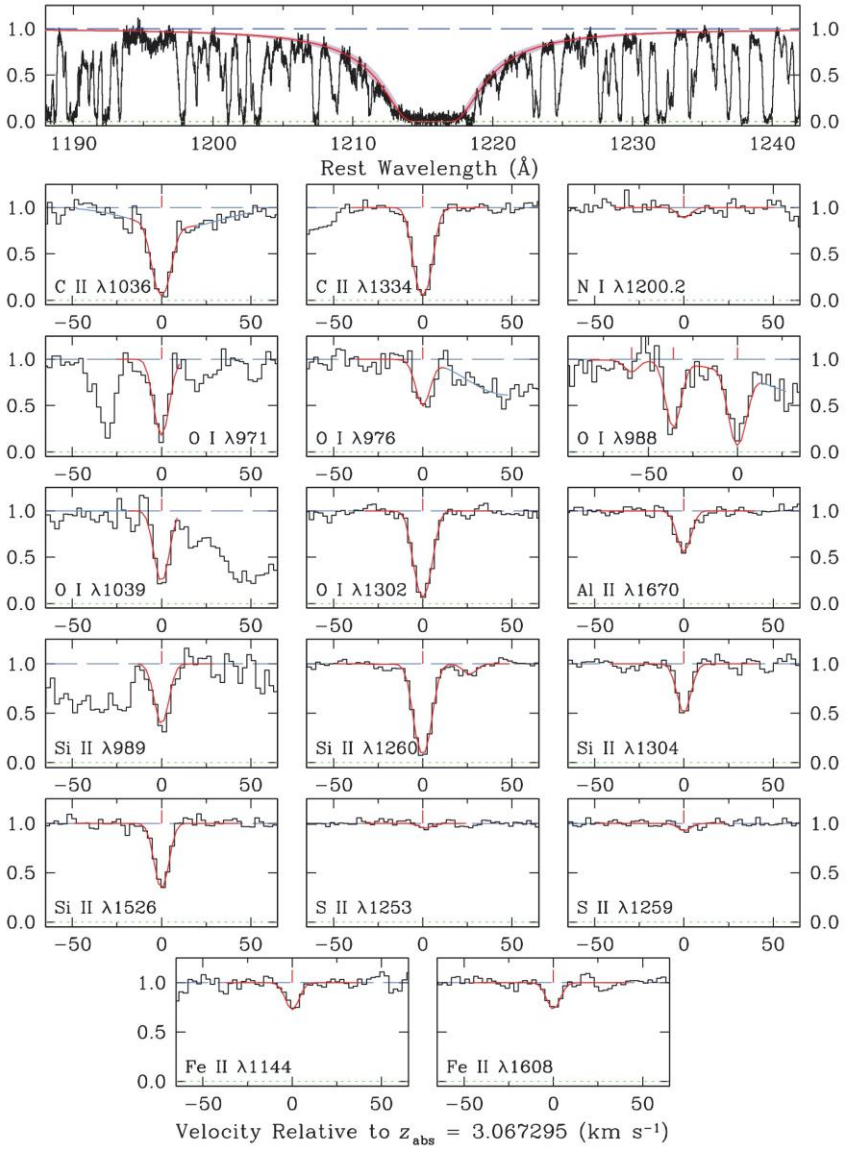
Carbon: “near-field” meets “far-field” cosmology



Chiaki+2017



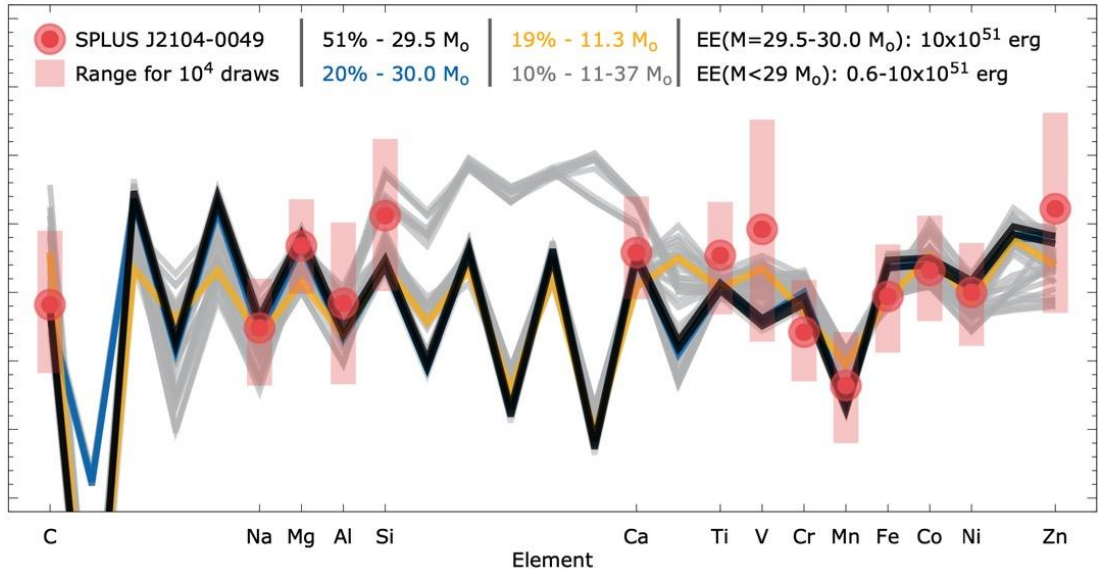
Cooke+2011



Cooke+2013/2017

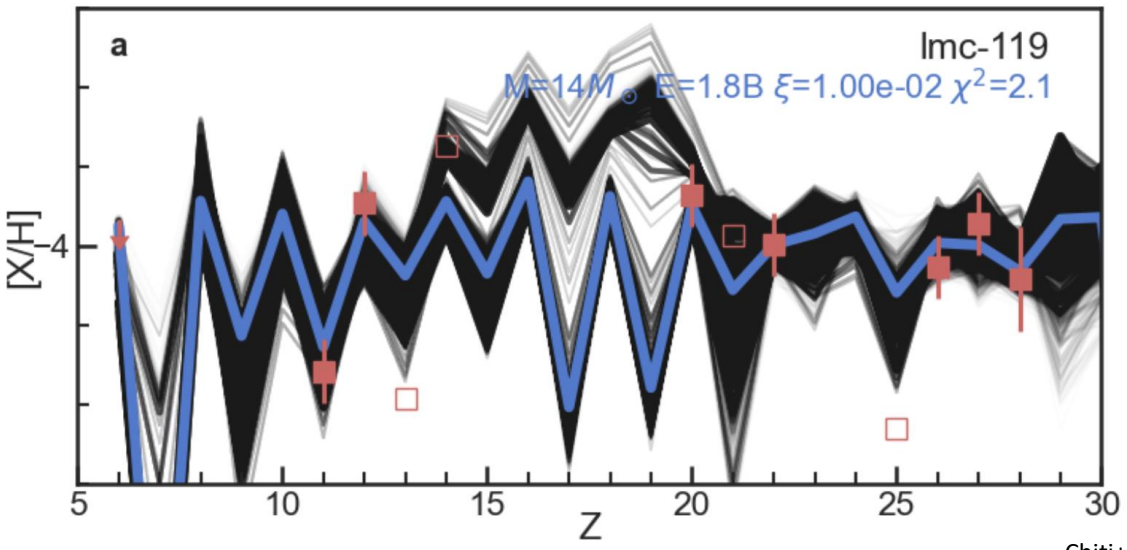
What about the progenitor population?

Milky Way Halo



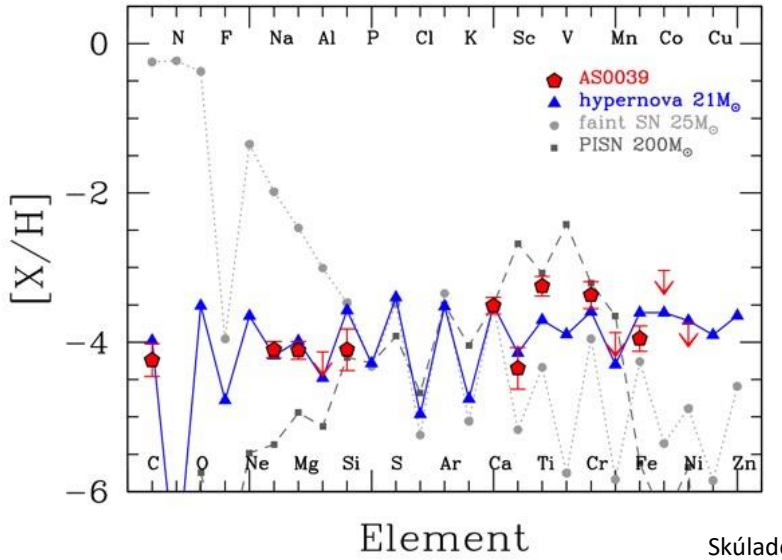
Placco+2021

Large Magellanic Cloud



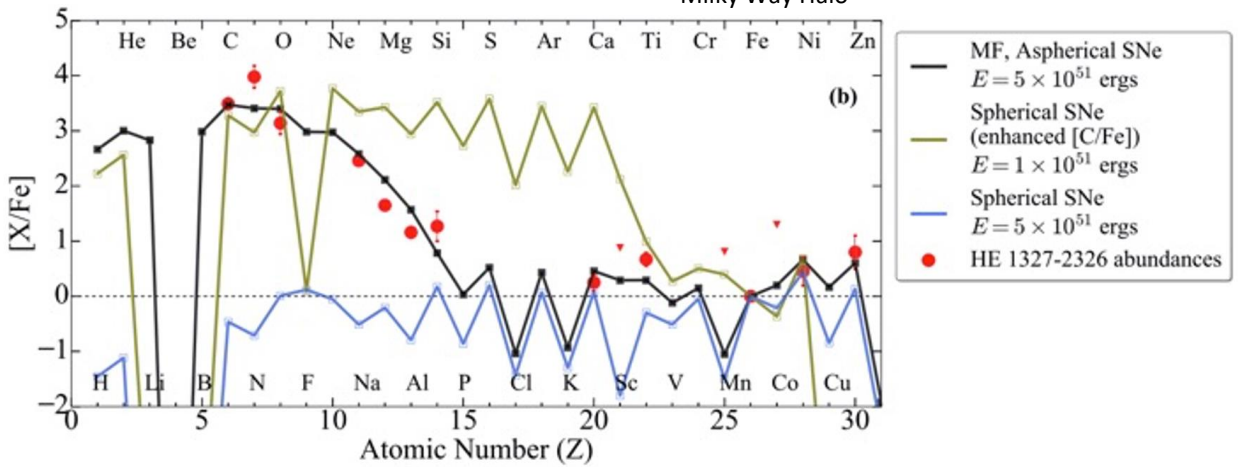
Chiti+2024

Sculptor



Skúladóttir+2021

Milky Way Halo



Ezzeddine+2019

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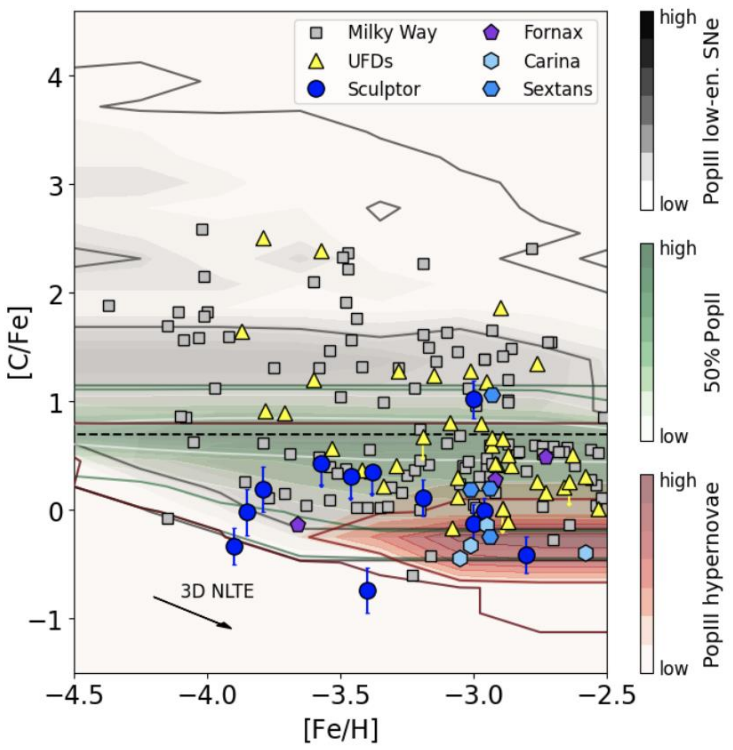
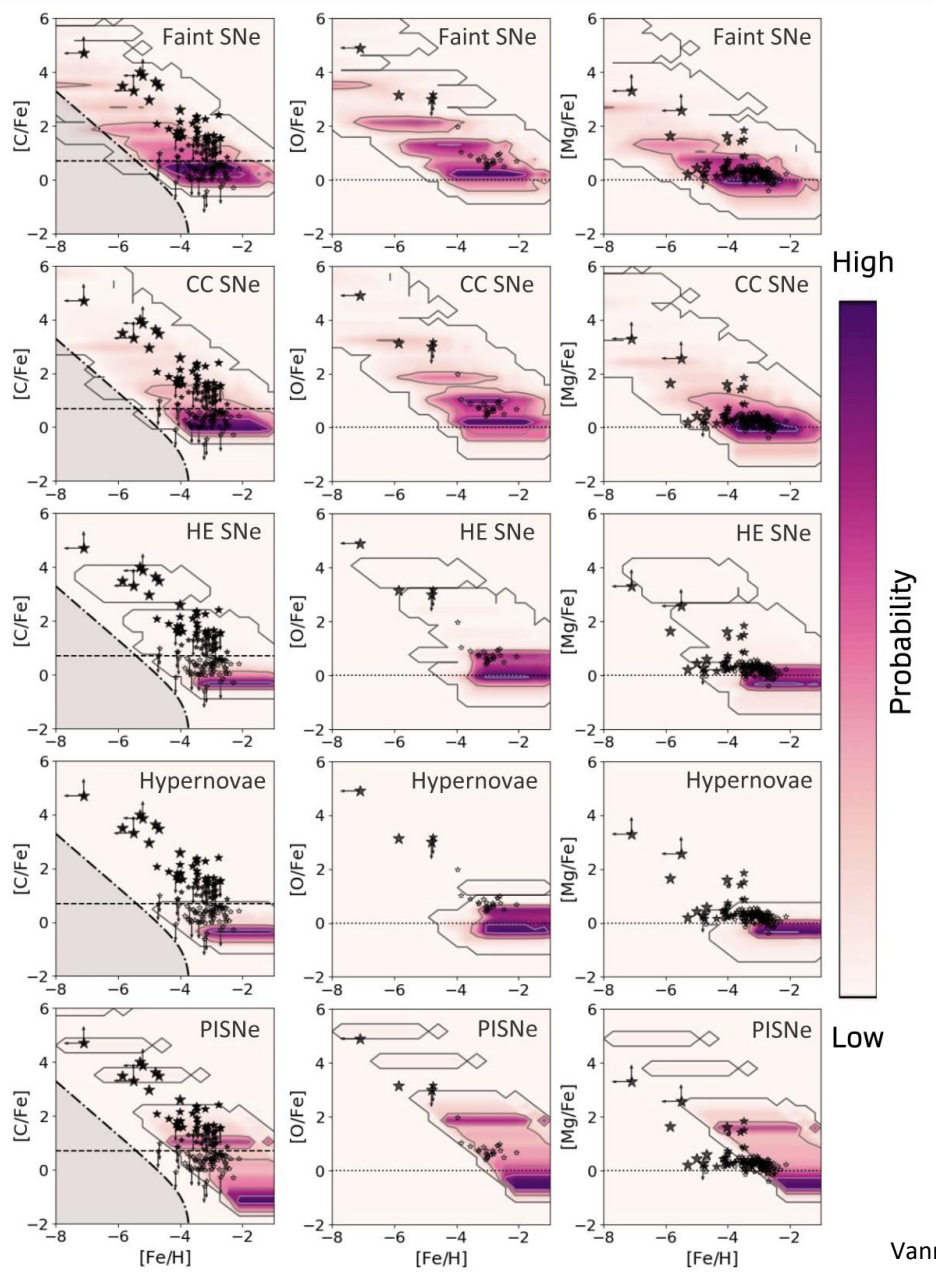
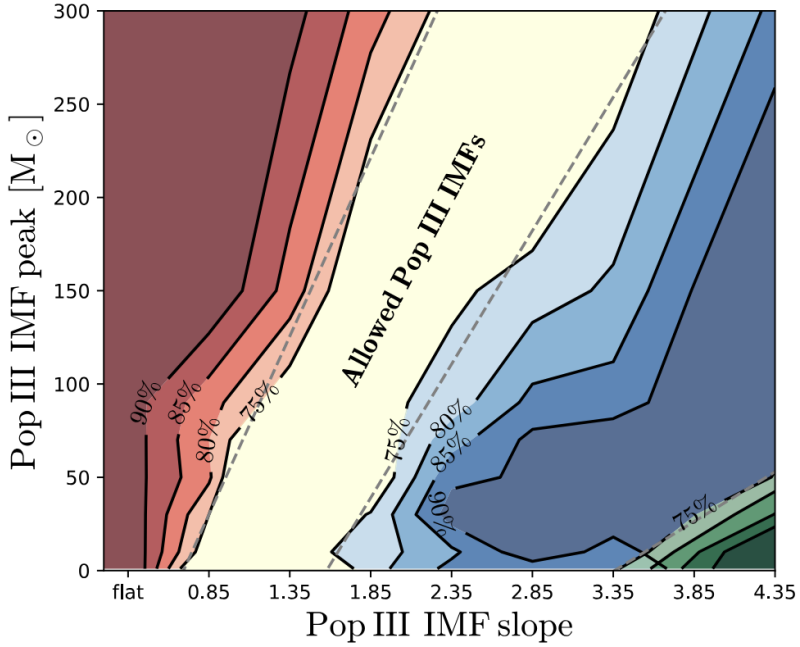
Can we really say something about the primordial IMF?



Skúladóttir+2024



Vanni+2024



Koutsouridou, Salvadori, Skúladóttir 2024

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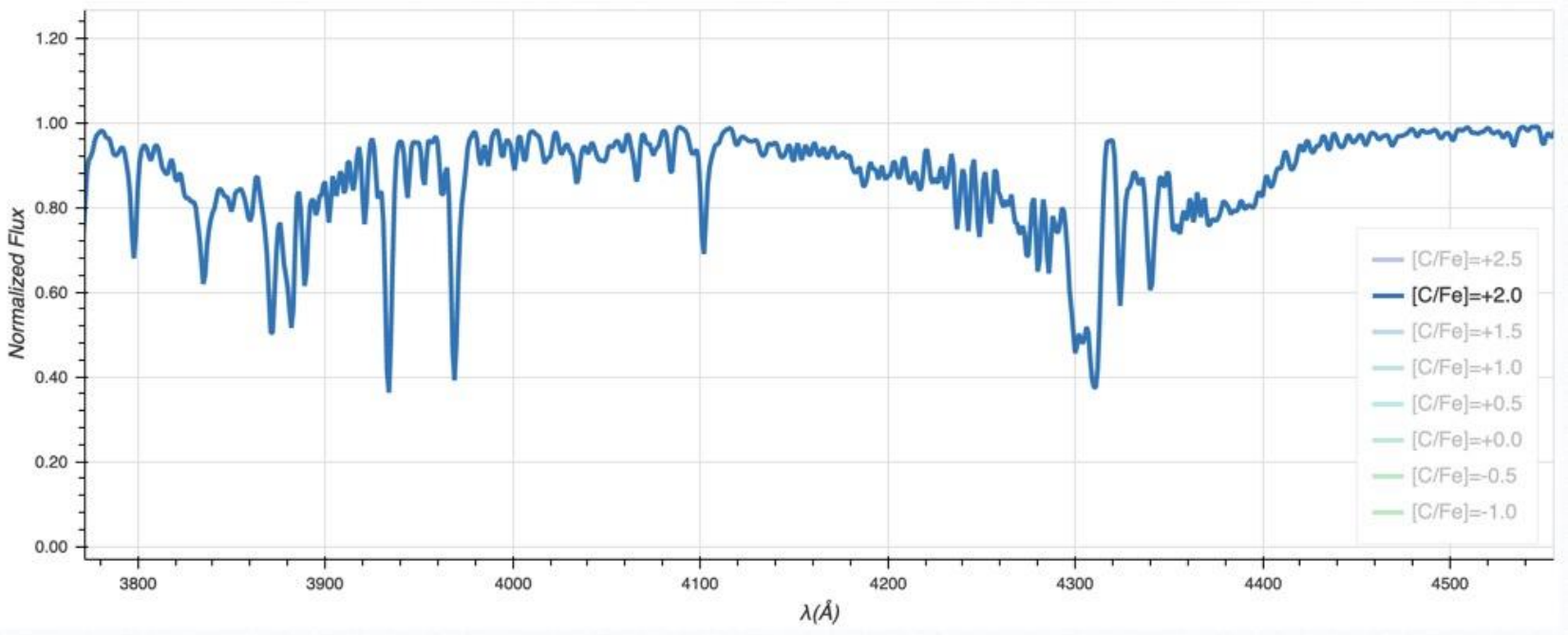
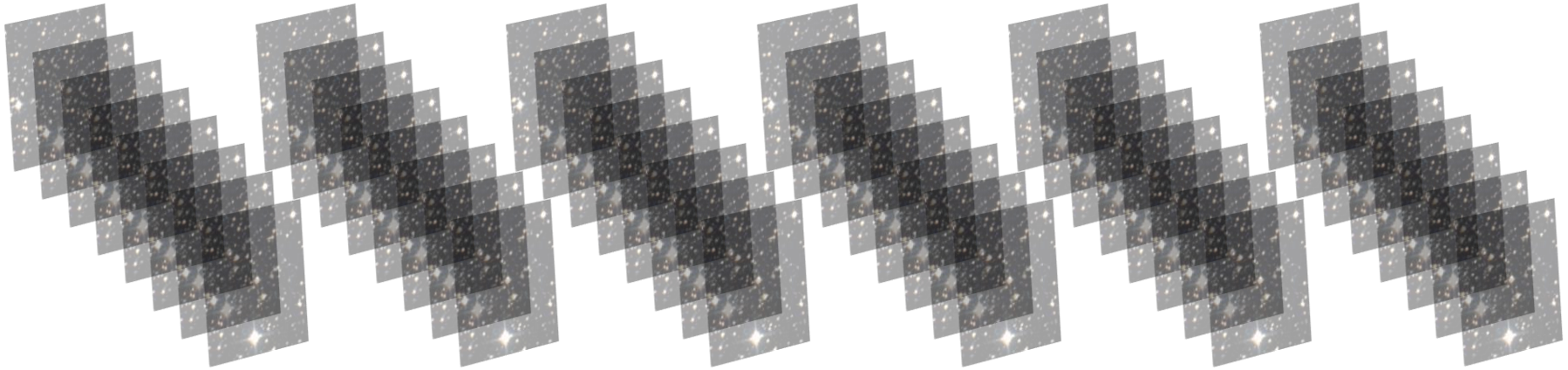
[Fe/H]<-4 is hard to find → *one* V<18 for every 100^2 degrees

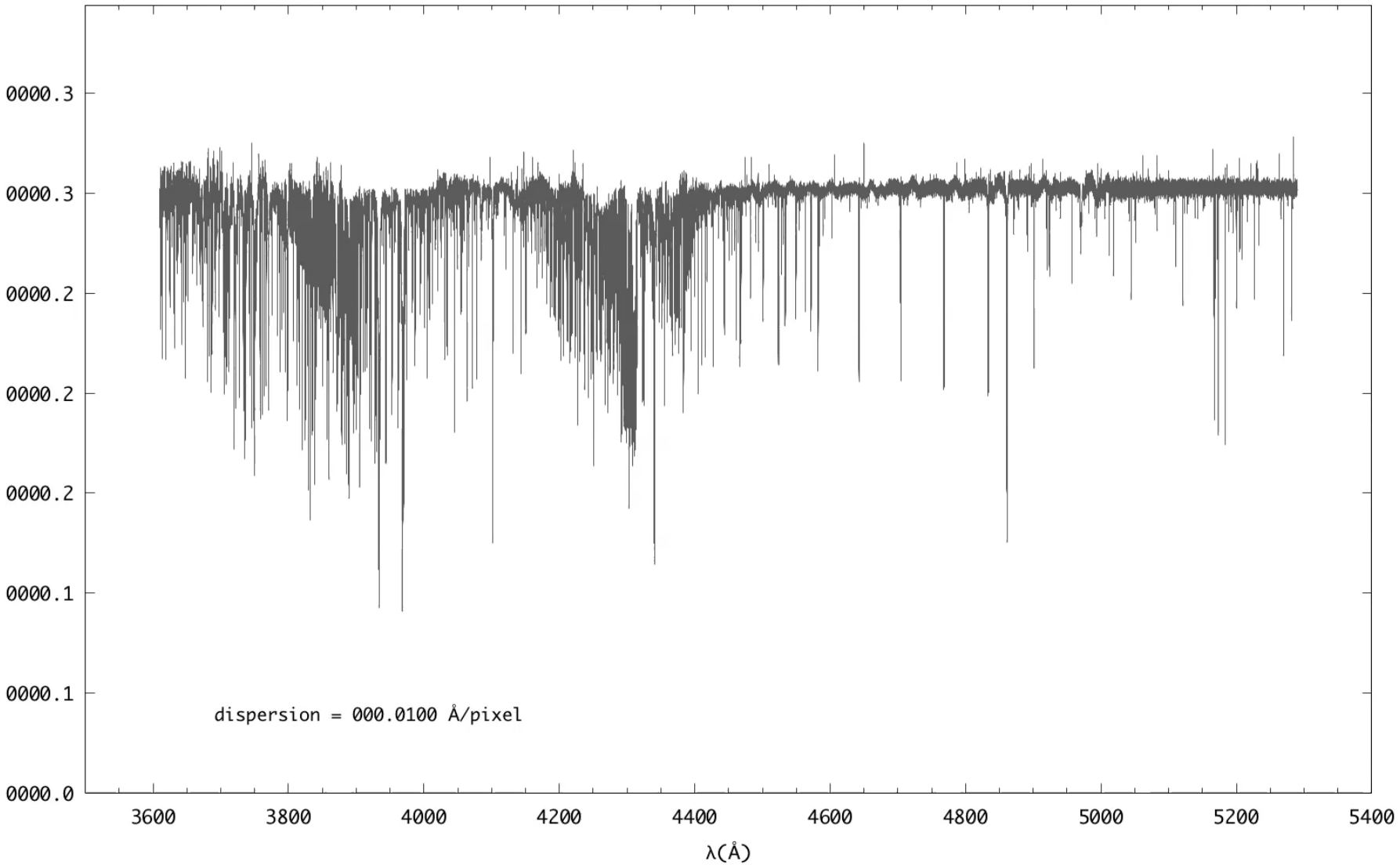
If an image is worth a thousand words,
a spectrum is worth *n* images, where

$$\underline{n} = \frac{(\lambda_{red} - \lambda_{blue})}{\Delta\lambda}$$



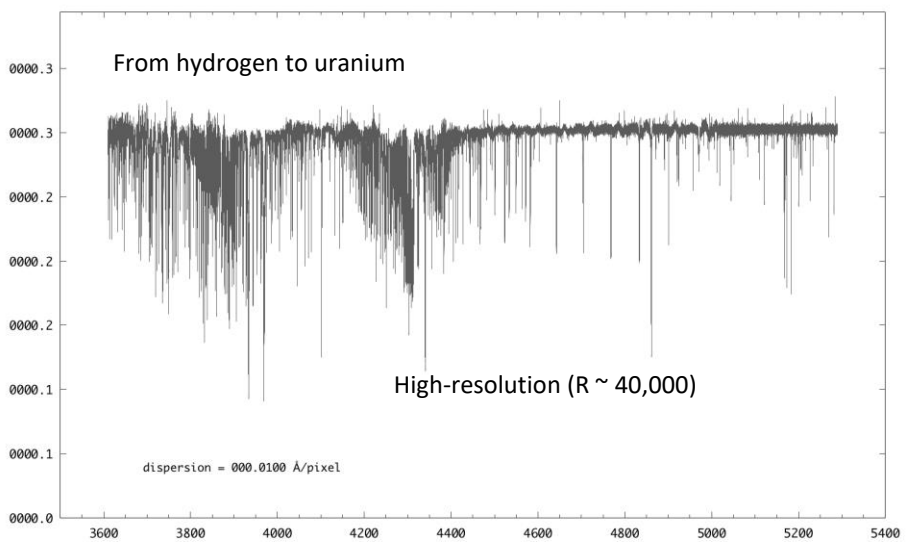


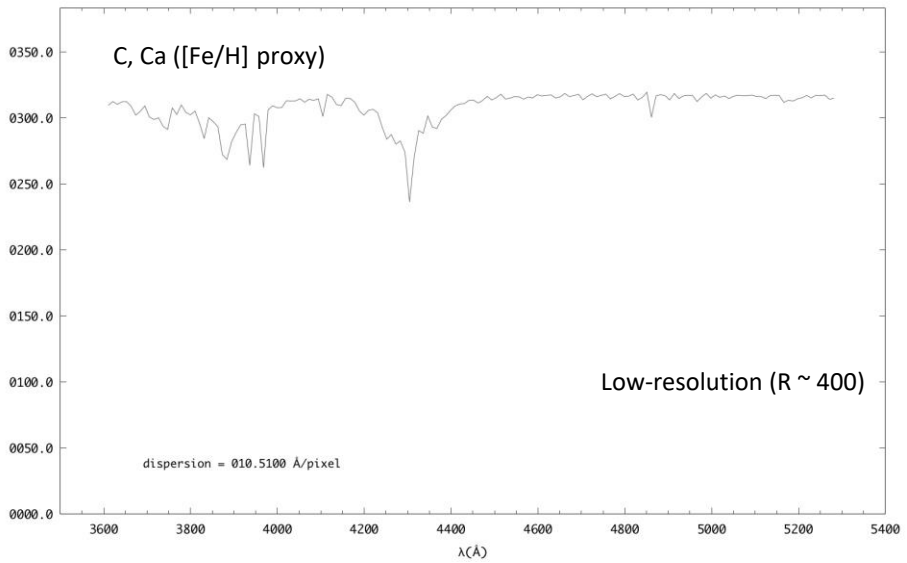
What is the ideal *n*?

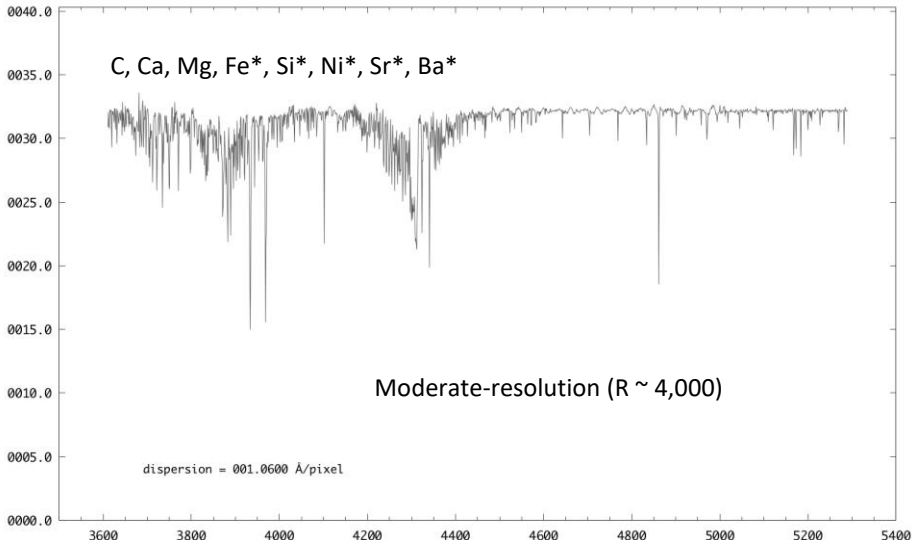


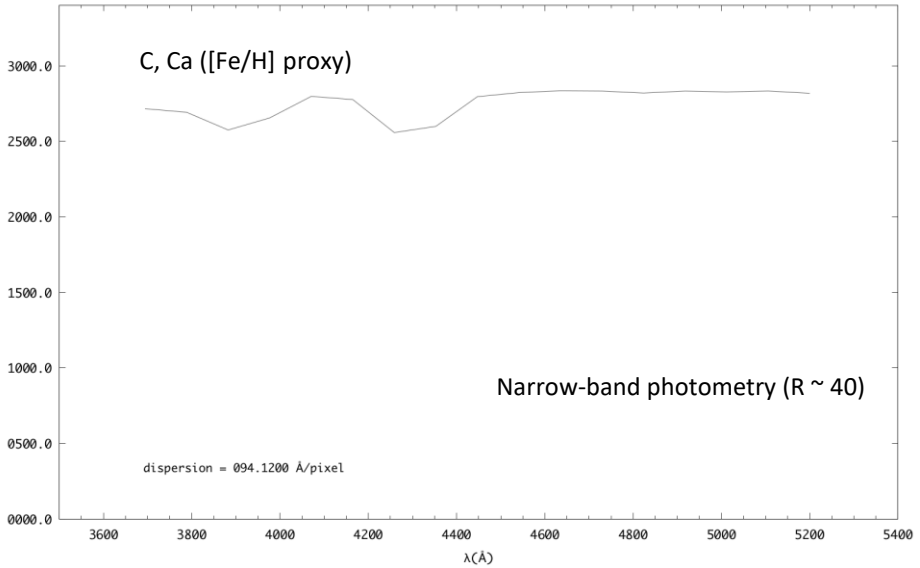
From R~40 to R~40,000

(finding the ideal *n* to determine chemical abundances)

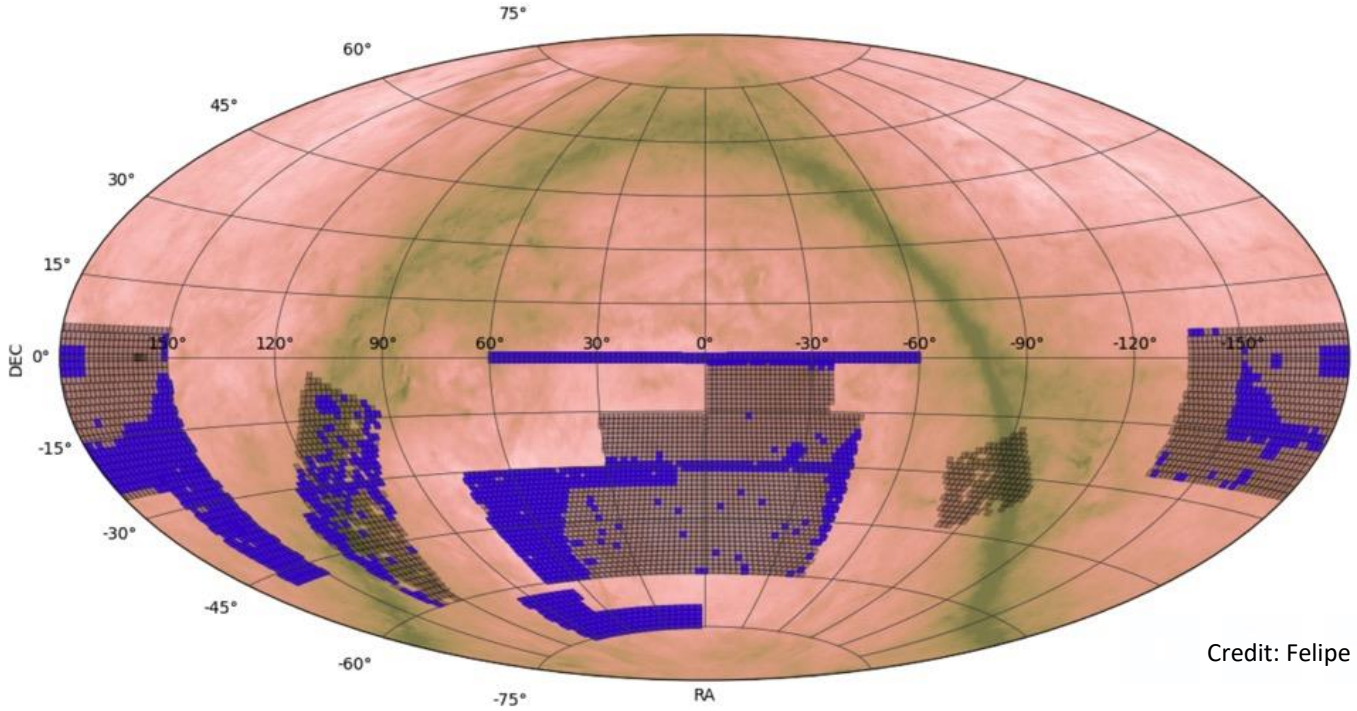








S-PLUS (Southern Photometric Local Universe Survey)

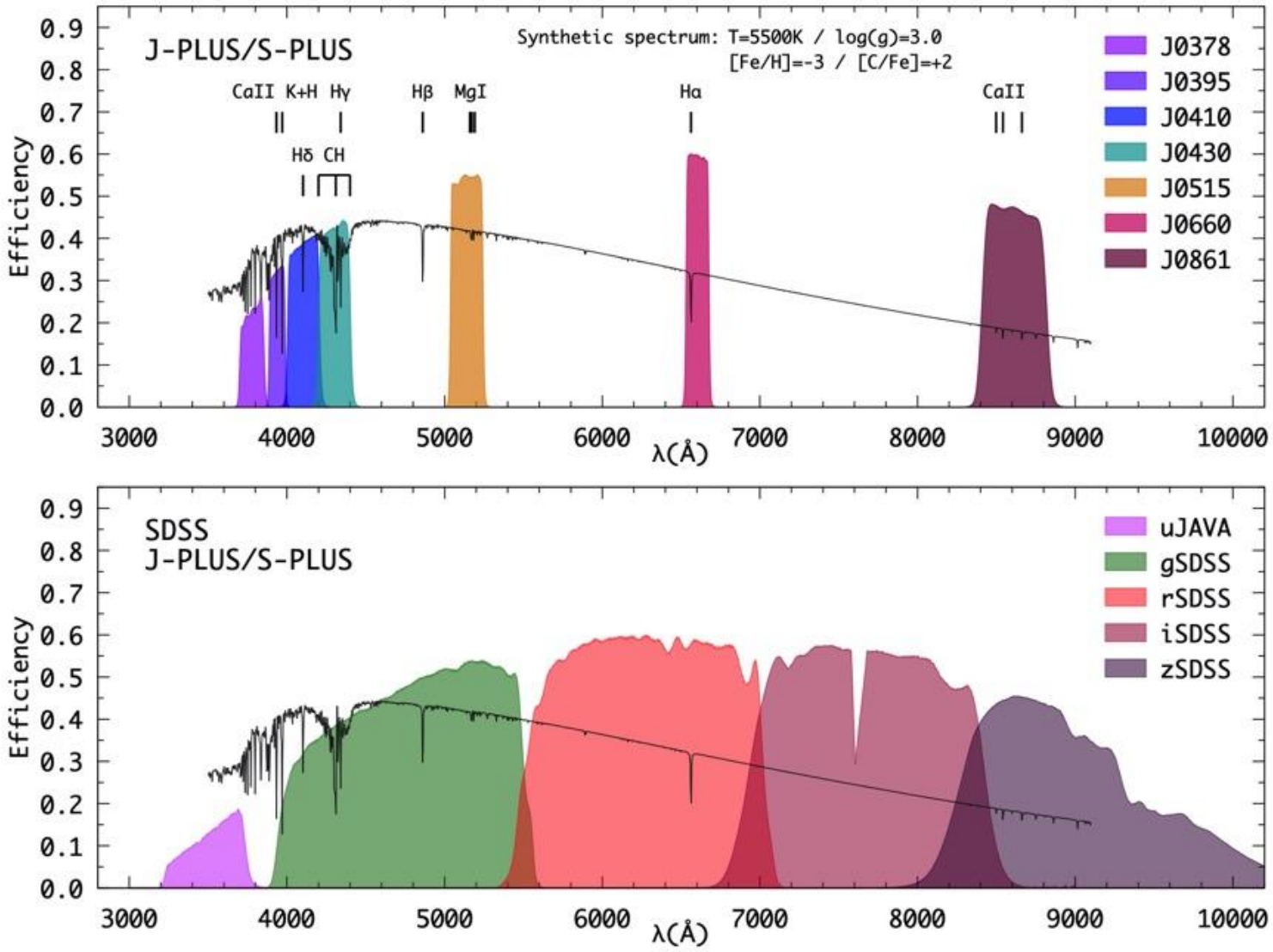


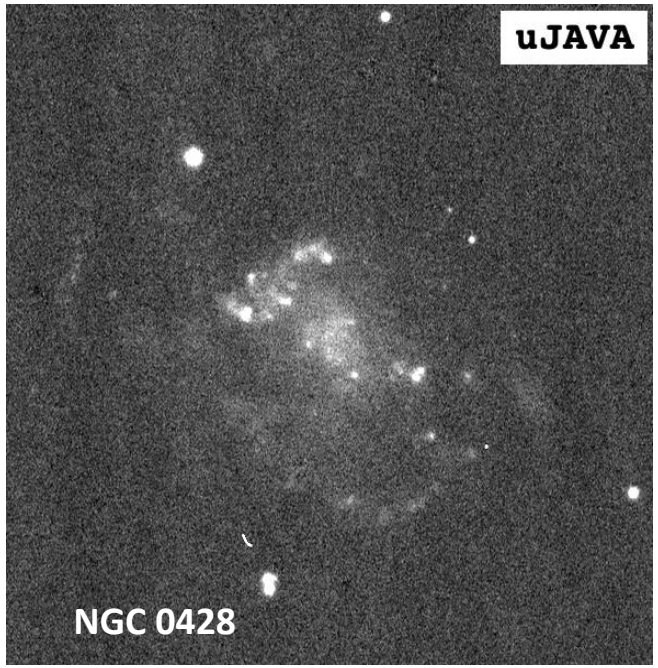
Credit: Felipe Almeida-Fernandes

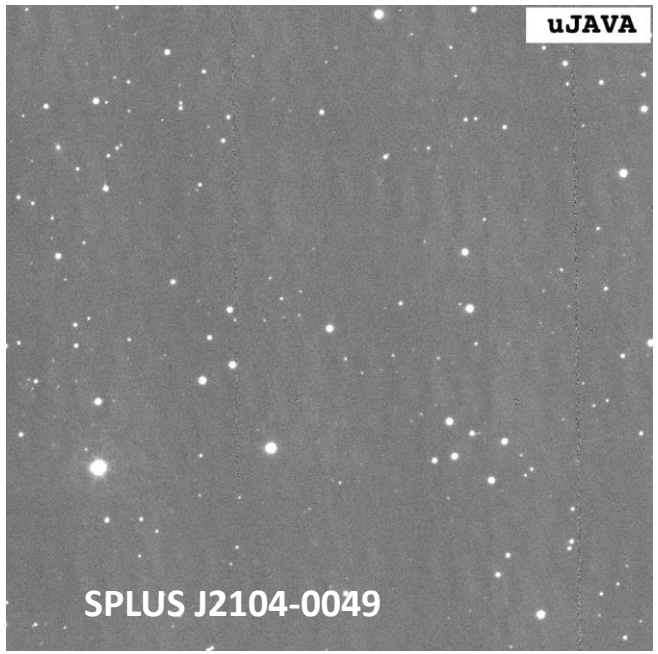
T80 South: 80cm
FOV: 2 deg^2
Footprint: 9,300 deg^2
DR4 (2024): 3,000 deg^2

Mendes de Oliveira+2019
Almeida-Fernandes+2022

S-PLUS (Javalambre filter system)

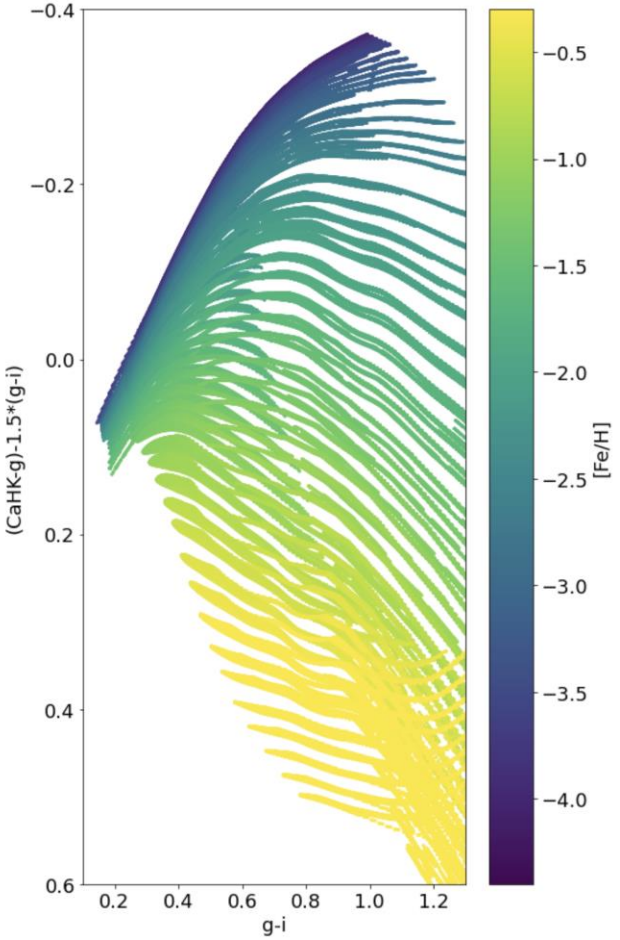


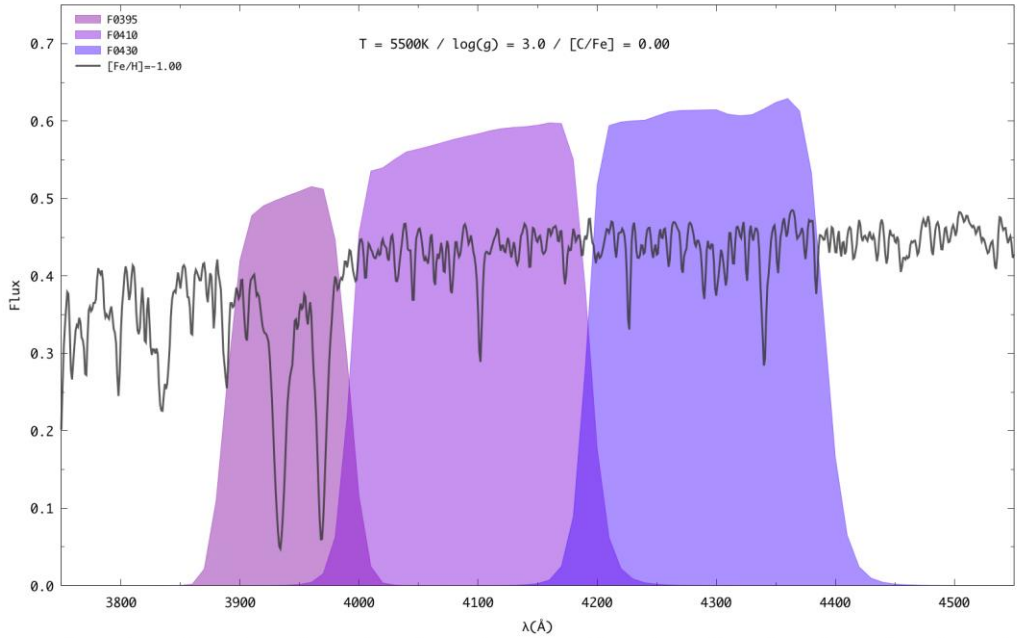


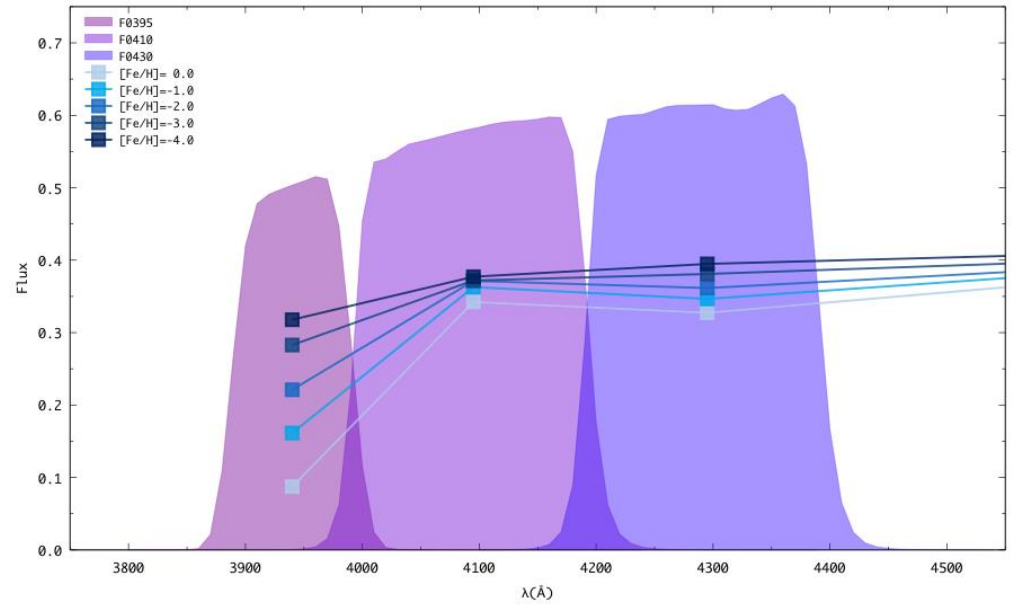


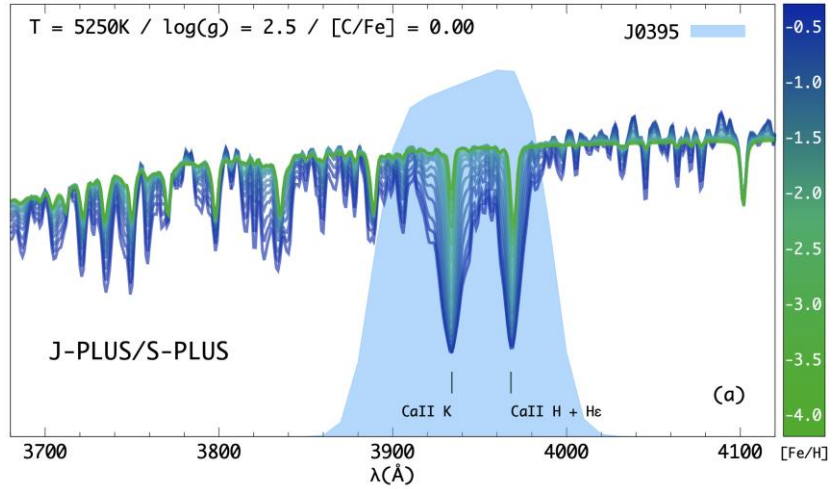
credit: Vinicius Placco

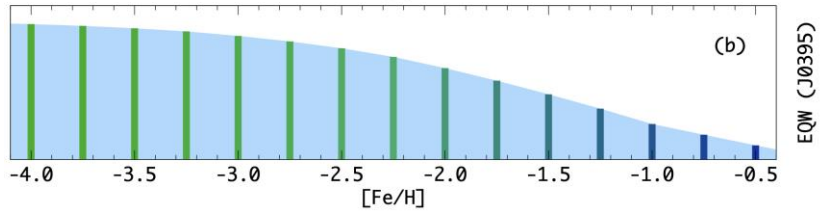
S-PLUS (metallicity indicator)

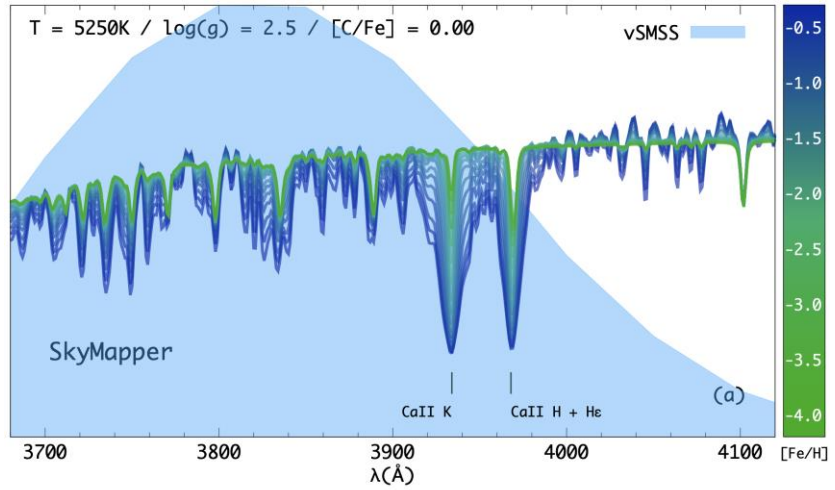


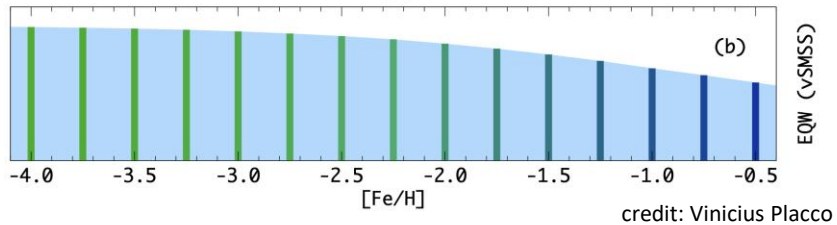






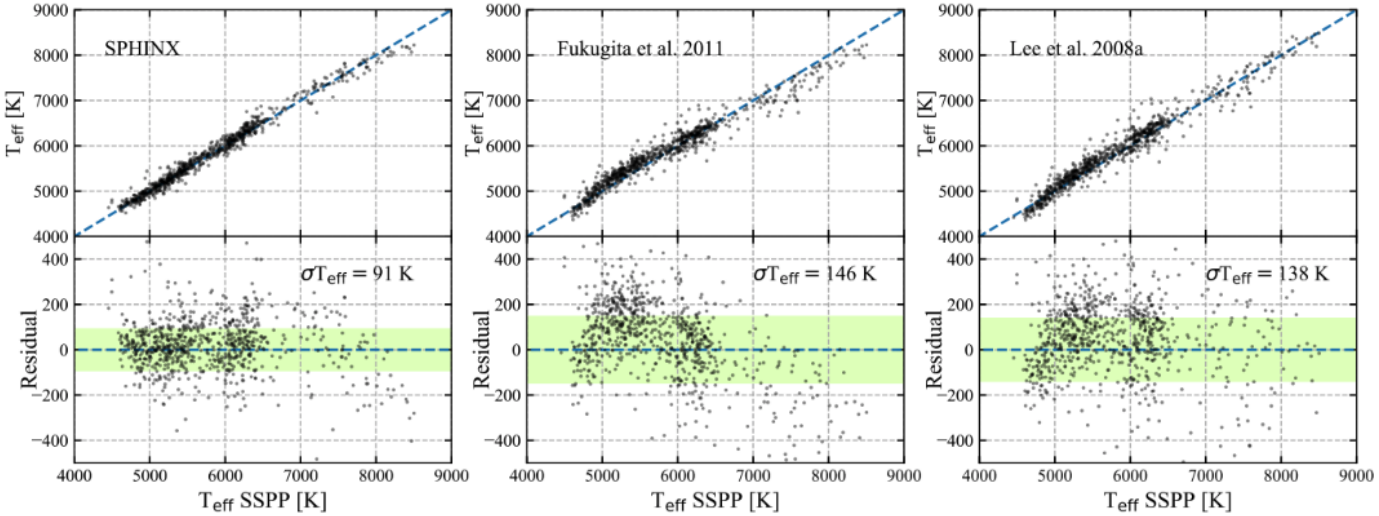


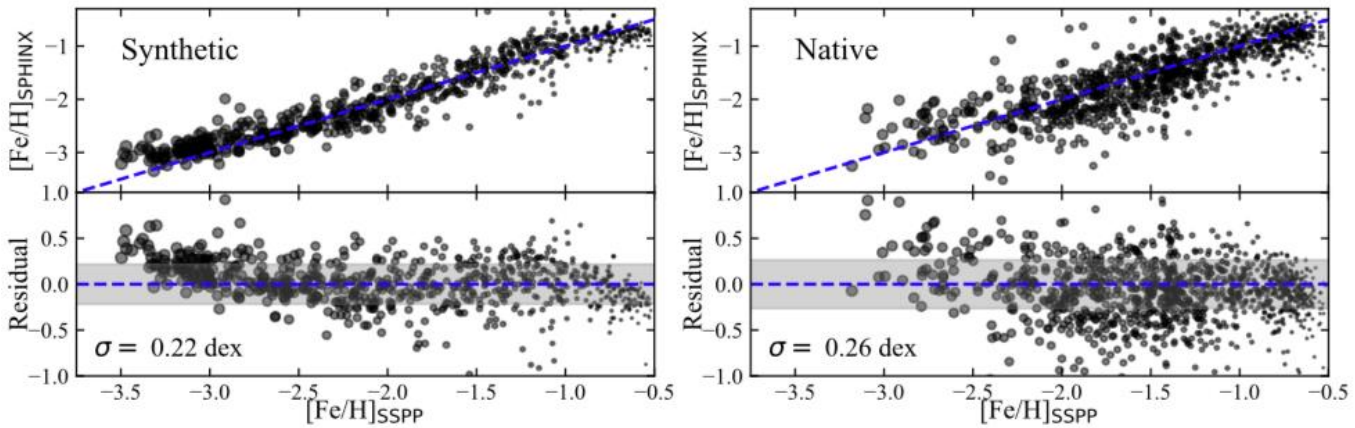


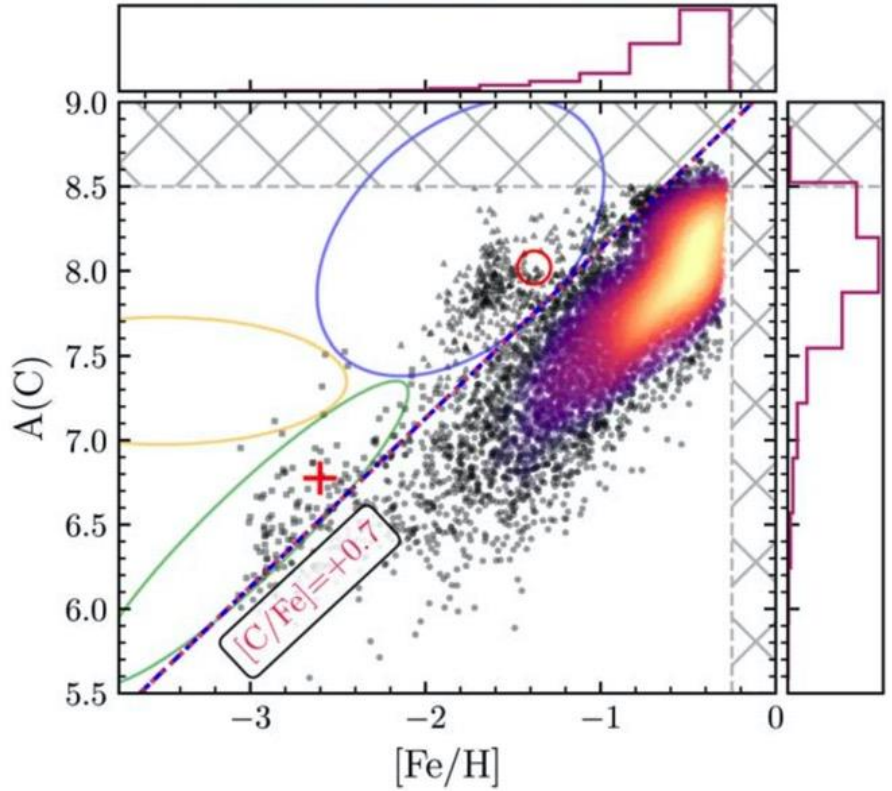


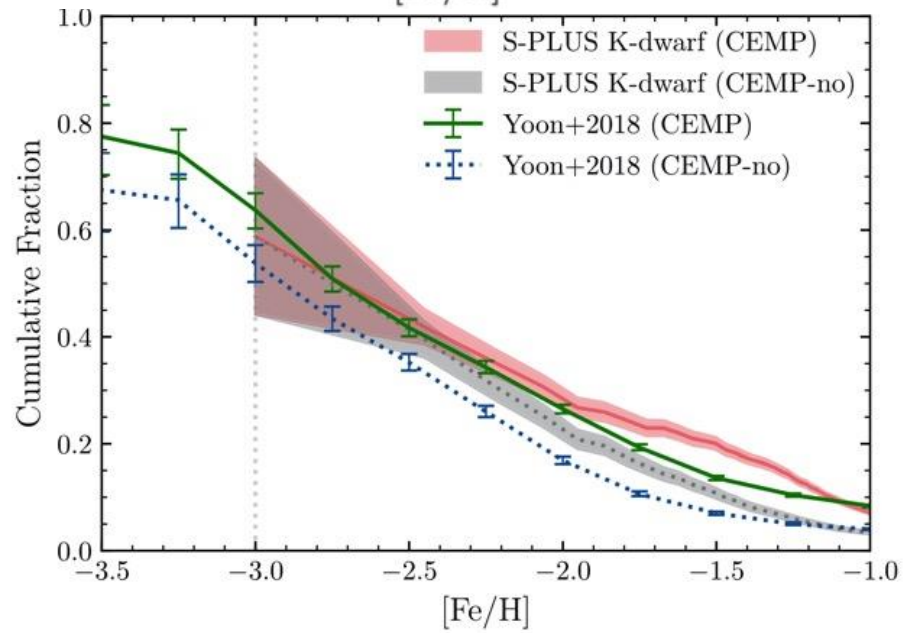
credit: Vinicius Placco

Artificial Neural Networks and Random Forests



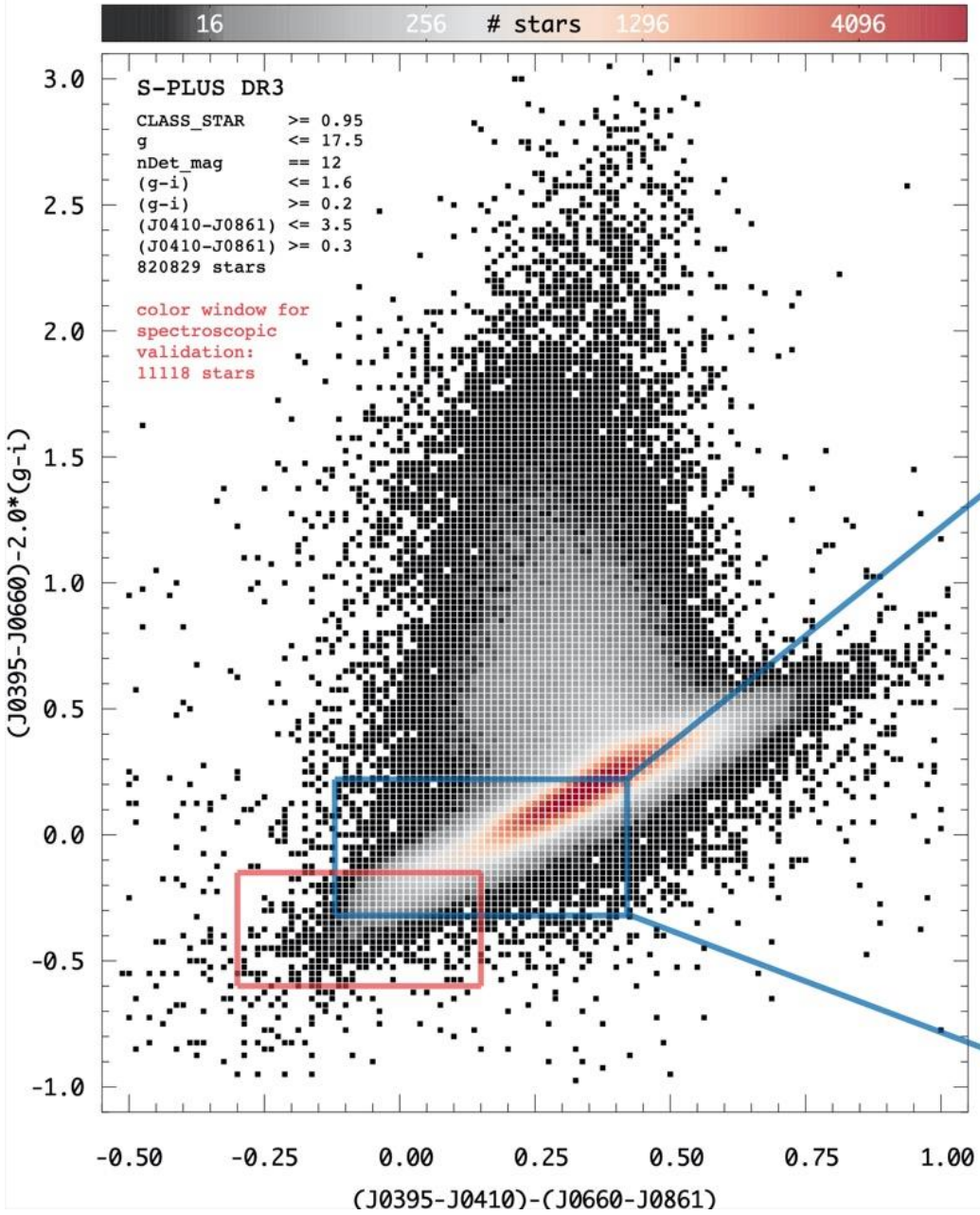


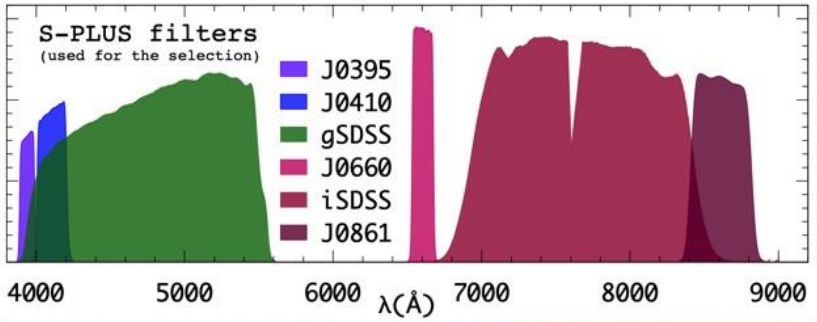


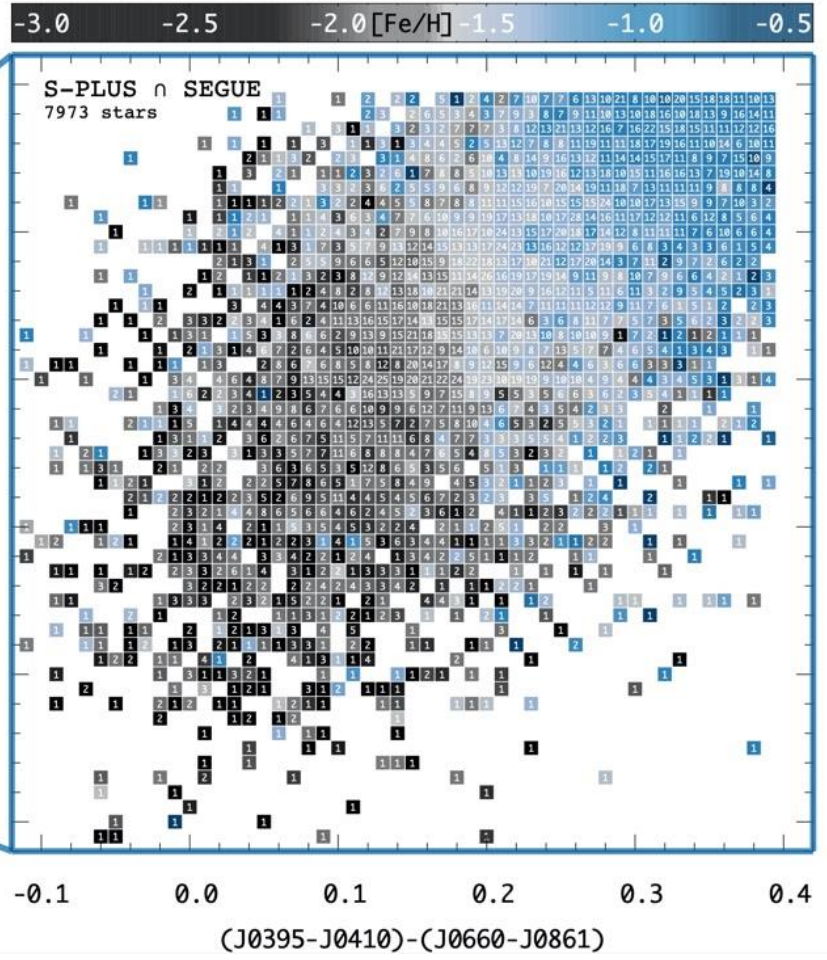


Whitten, Placco+2019/2021, Galarza+2023

Color-color diagrams

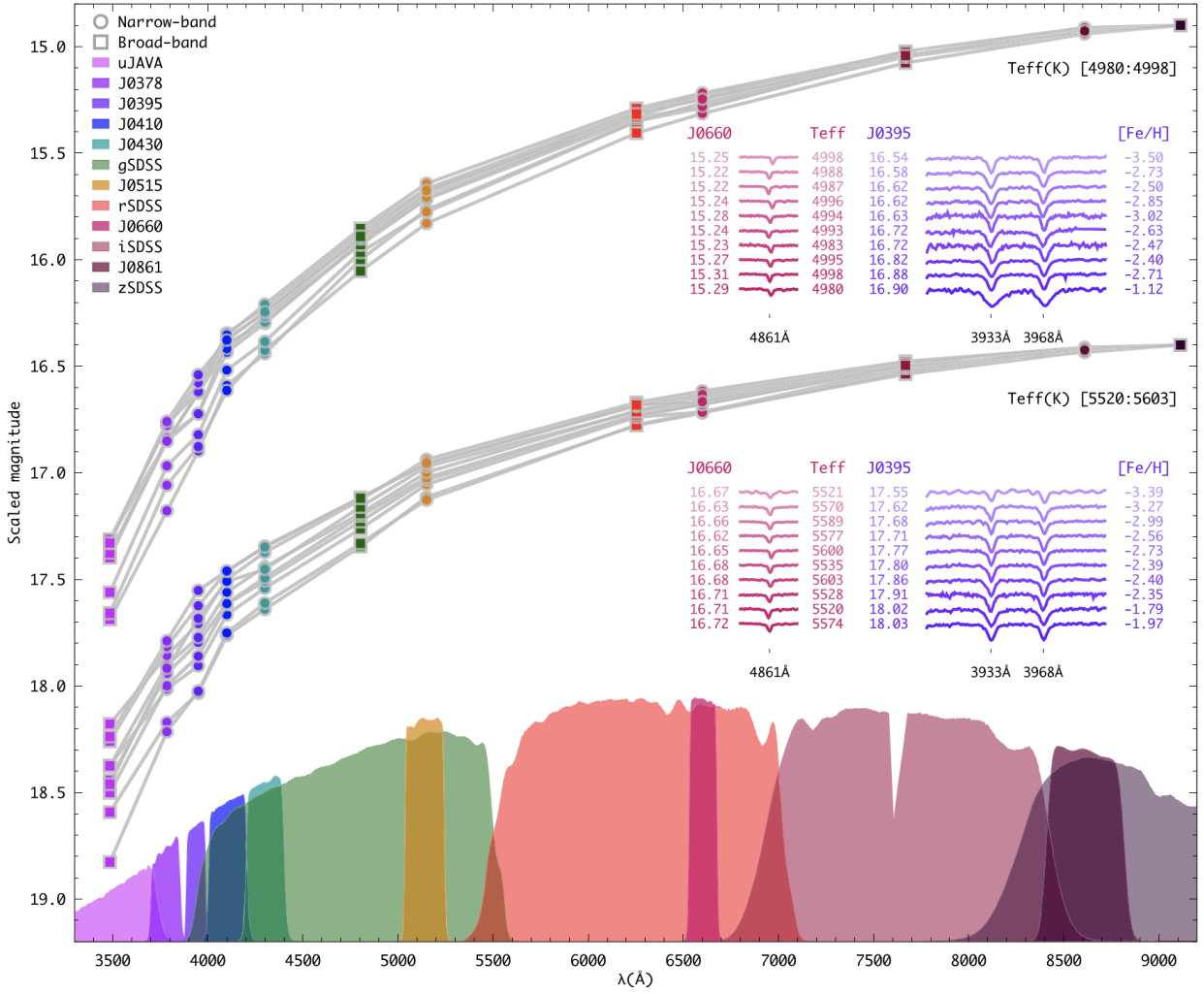


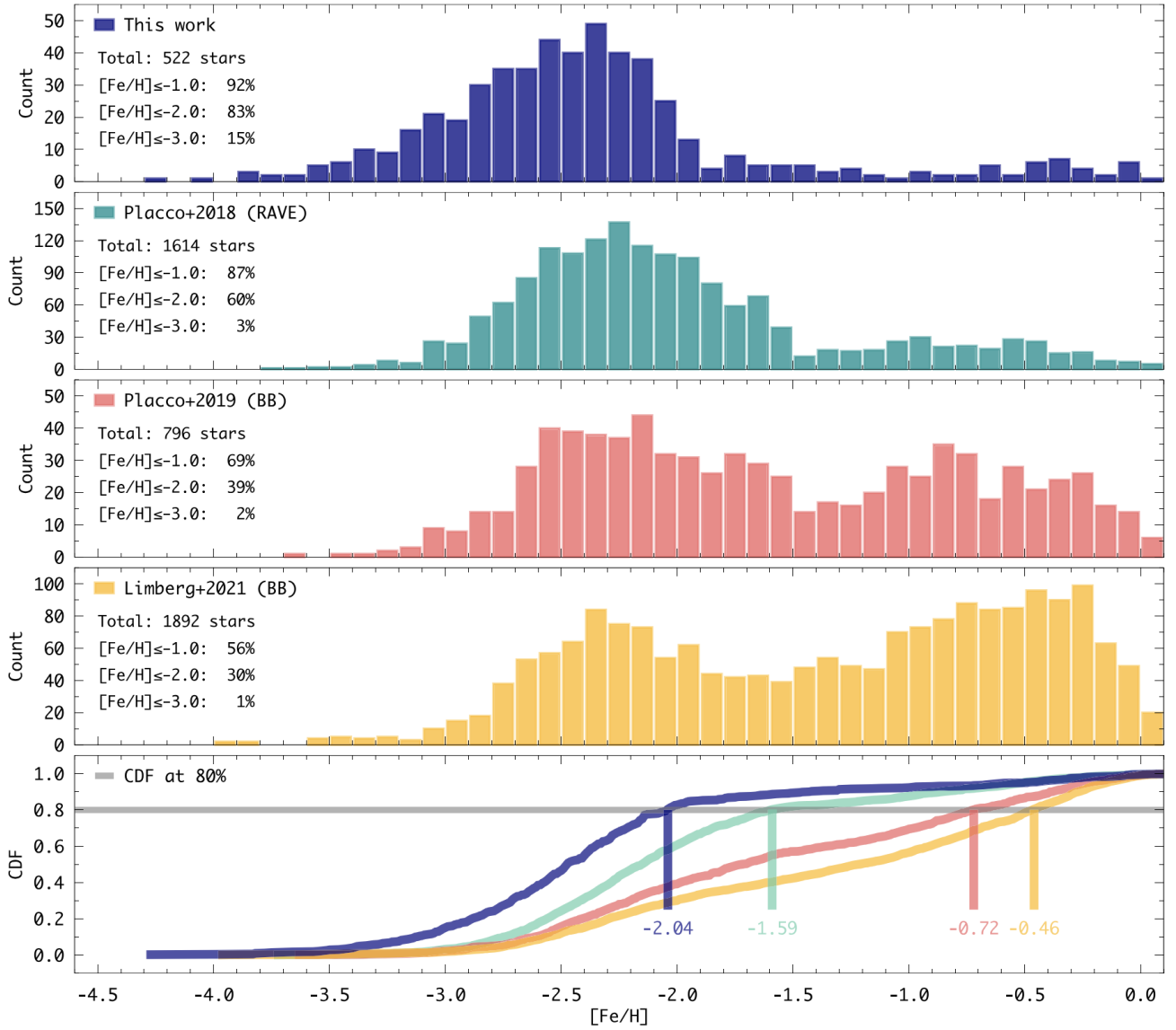




Placco+2022

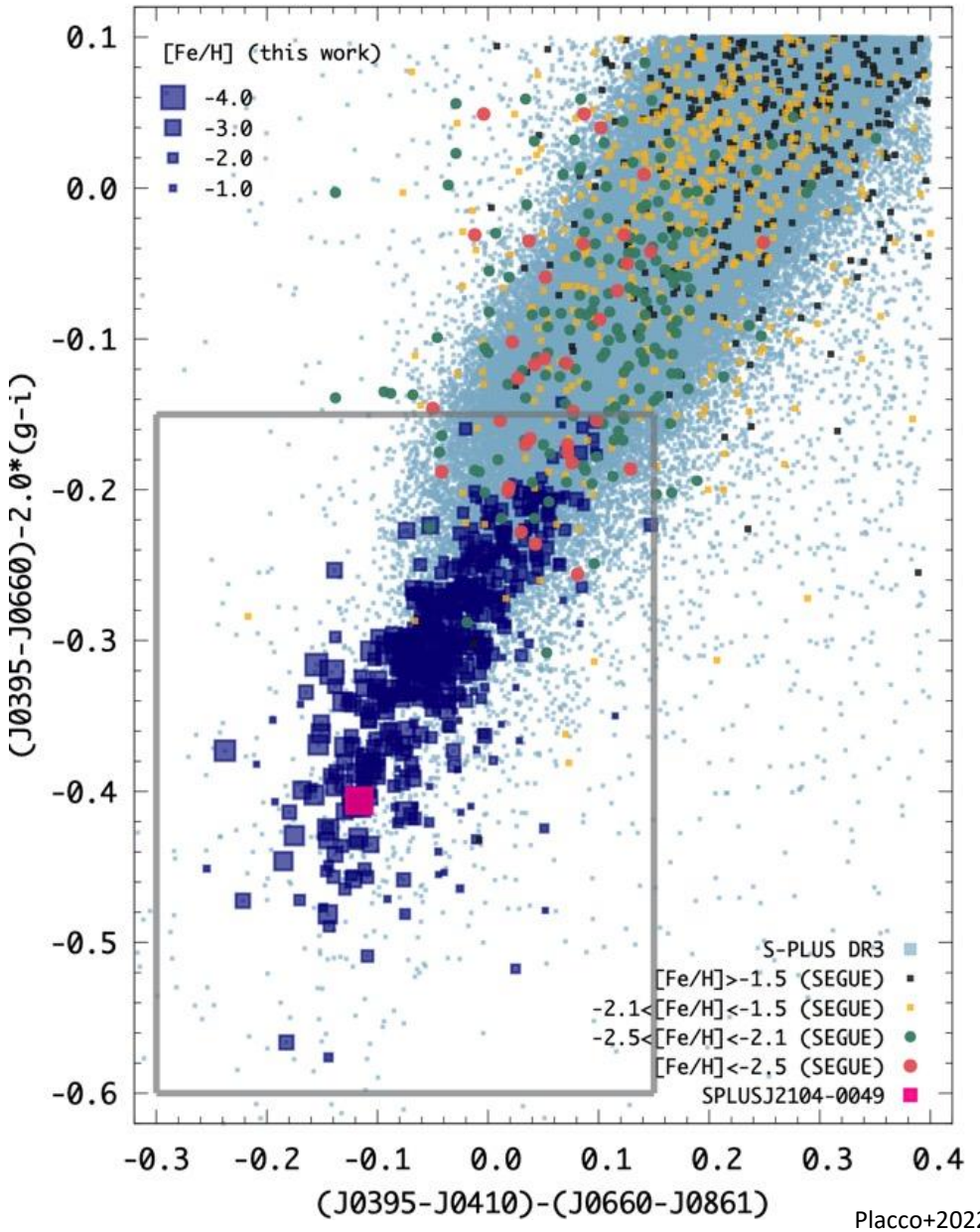
Effectiveness in finding [Fe/H]<-2 stars



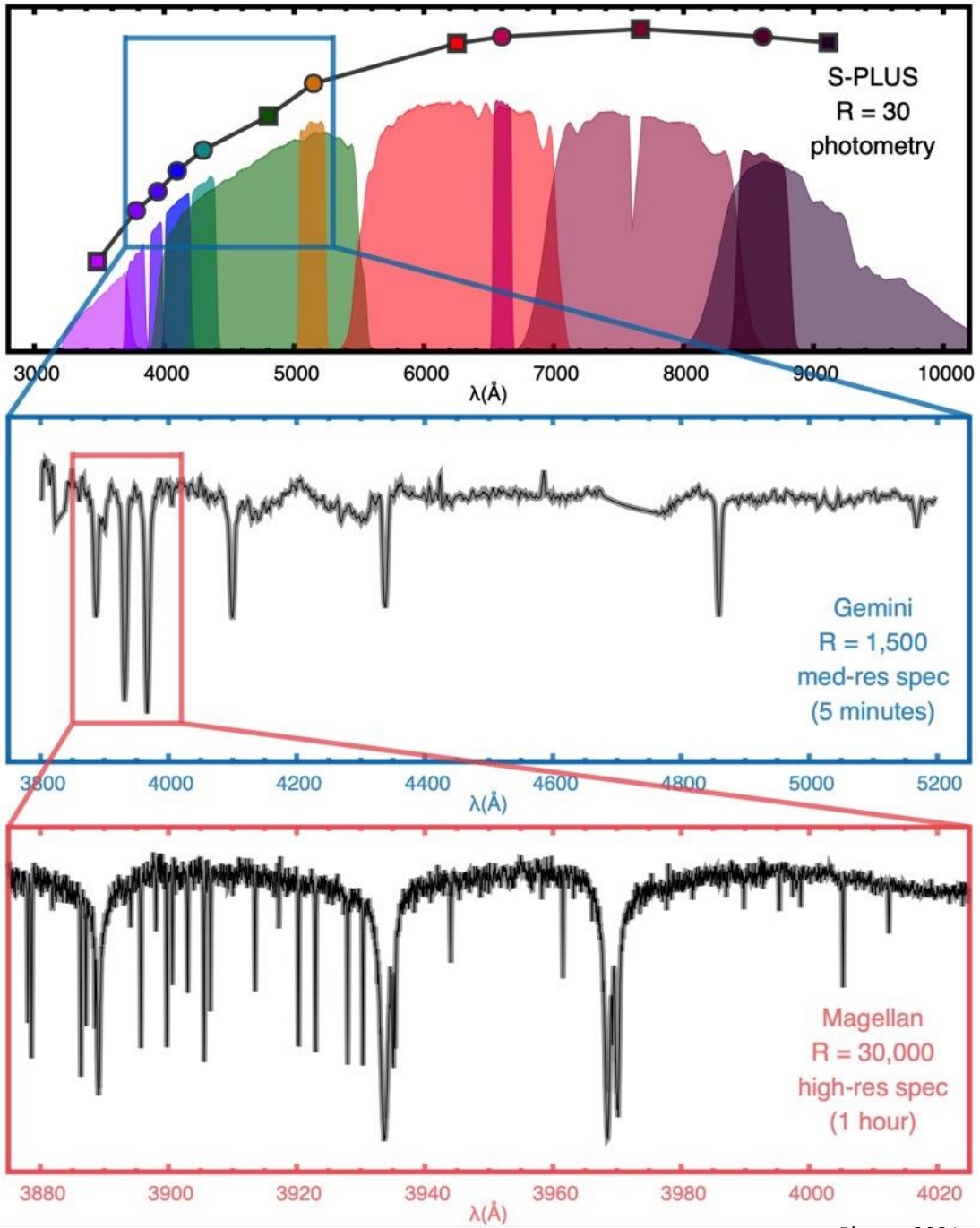


Placco+2022

SPLUS J210428.01-004934.2

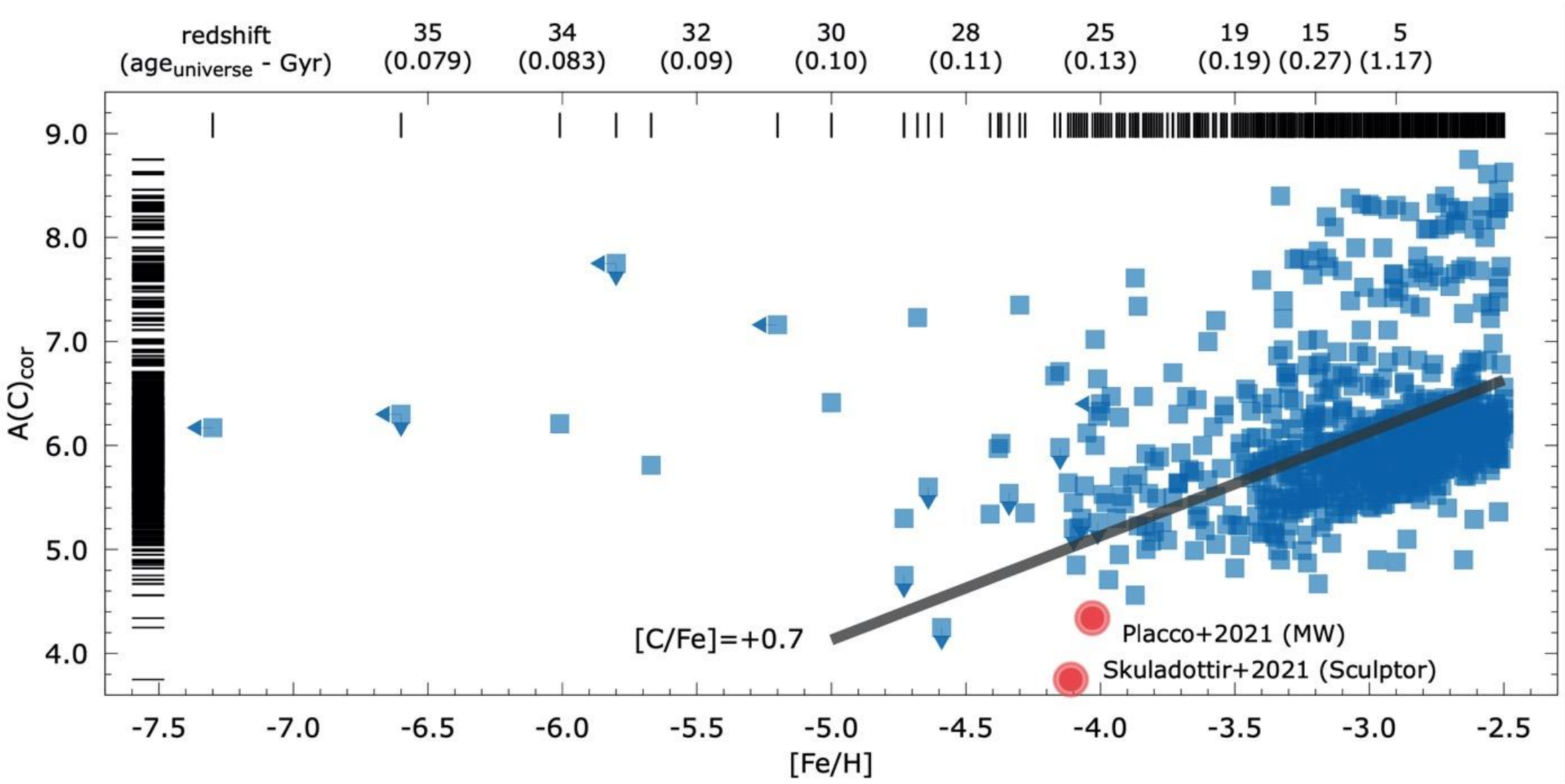


Placco+2022

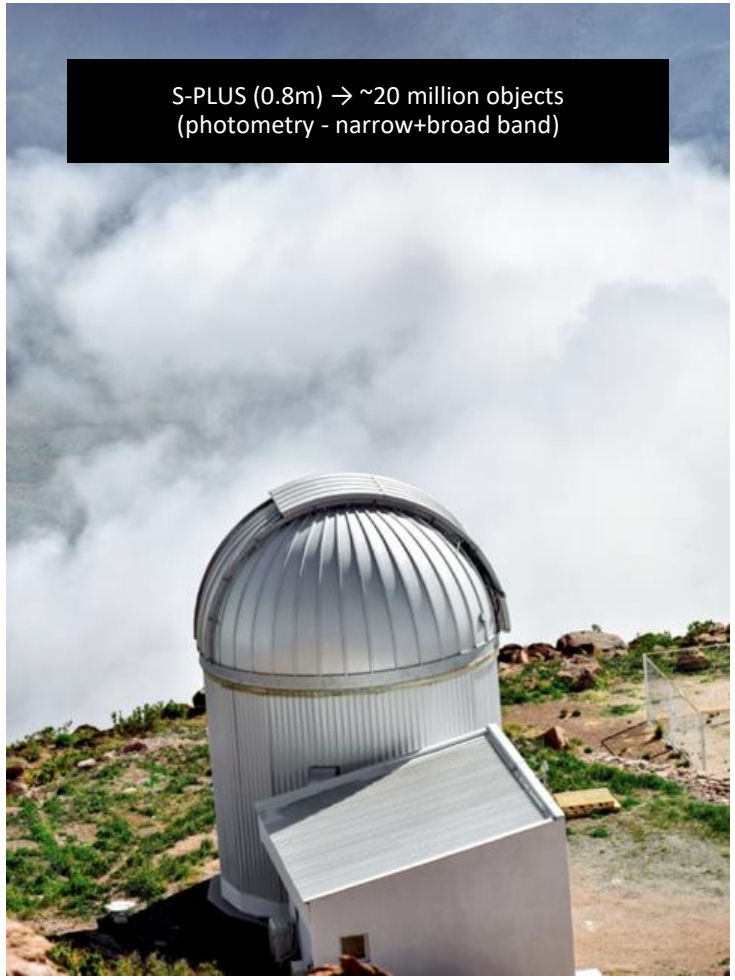


Placco+2021

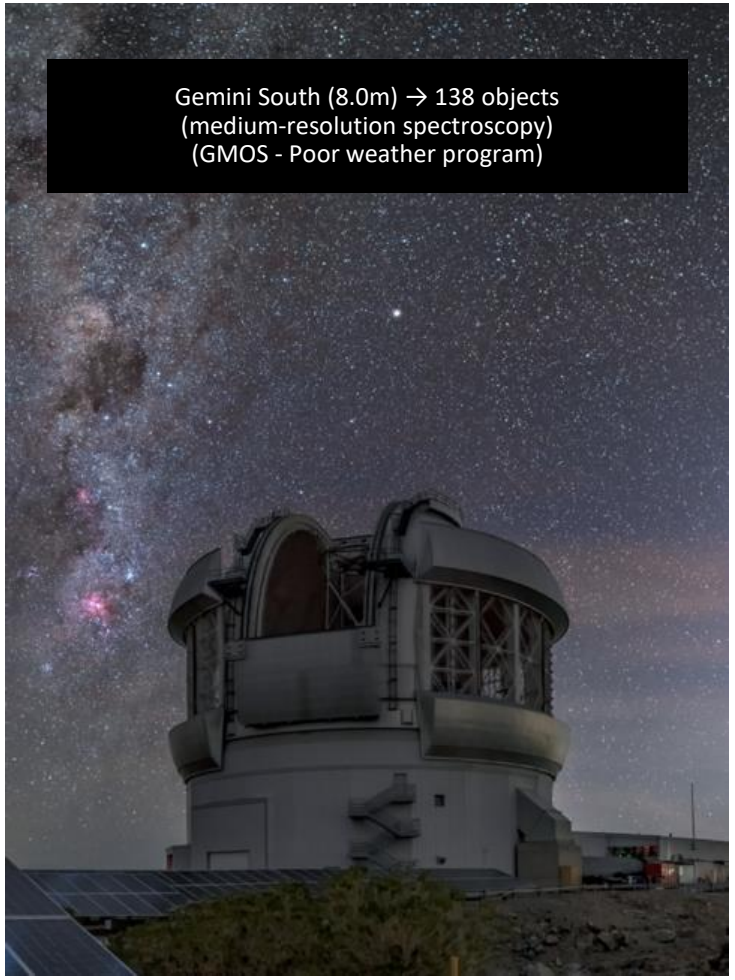
Galactic bright point sources with cosmological significance



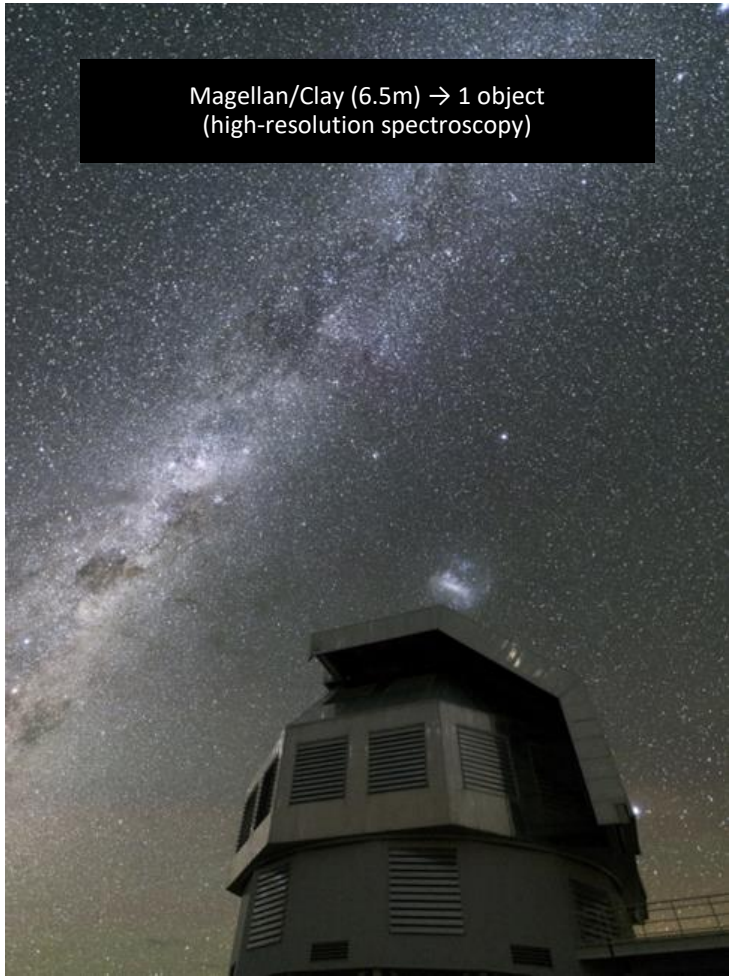
The power in numbers (finding one needle in one haystack)



Almeida-Fernandes+2022



Placco+2022



Placco+2021/2023

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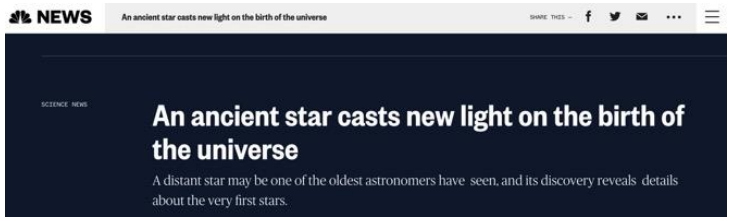
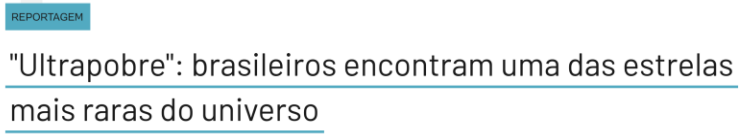

NEWS

An ancient star casts new light on the birth of the universe

SCIENCE NEWS

An ancient star casts new light on the birth of the universe

A distant star may be one of the oldest astronomers have seen, and its discovery reveals details about the very first stars.


REPORTAGEM

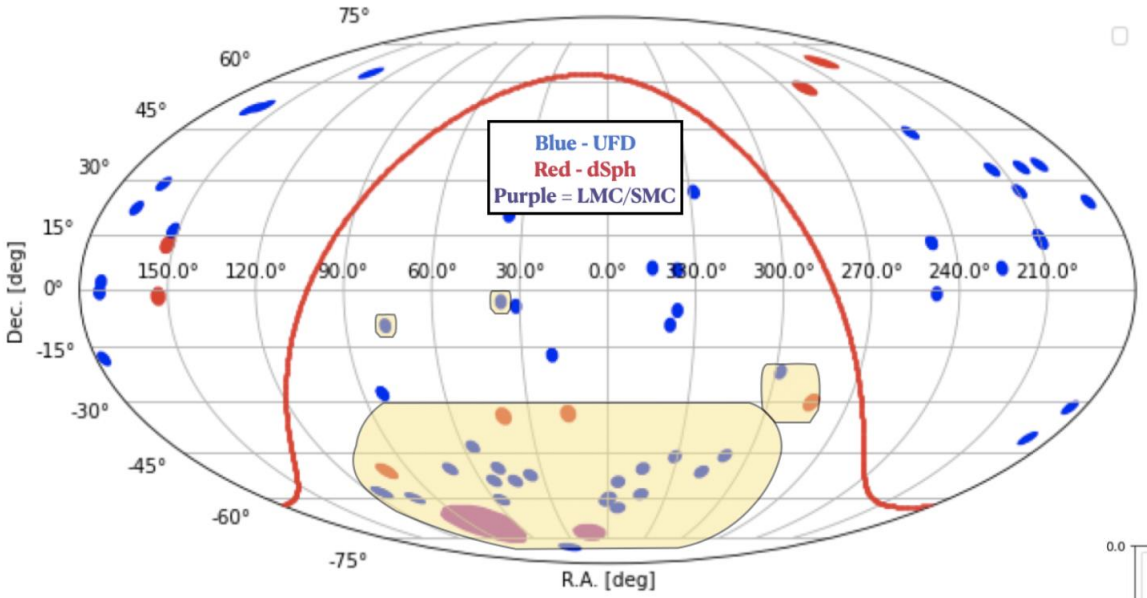
"Ultrapobre": brasileiros encontram uma das estrelas mais raras do universo


CIENCIA

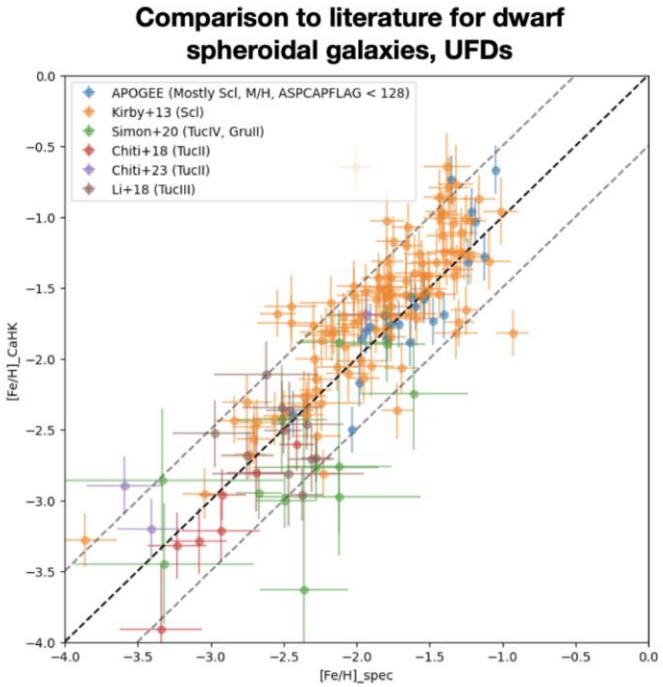
La humanidad podría haber descubierto una de las estrellas más antiguas del universo

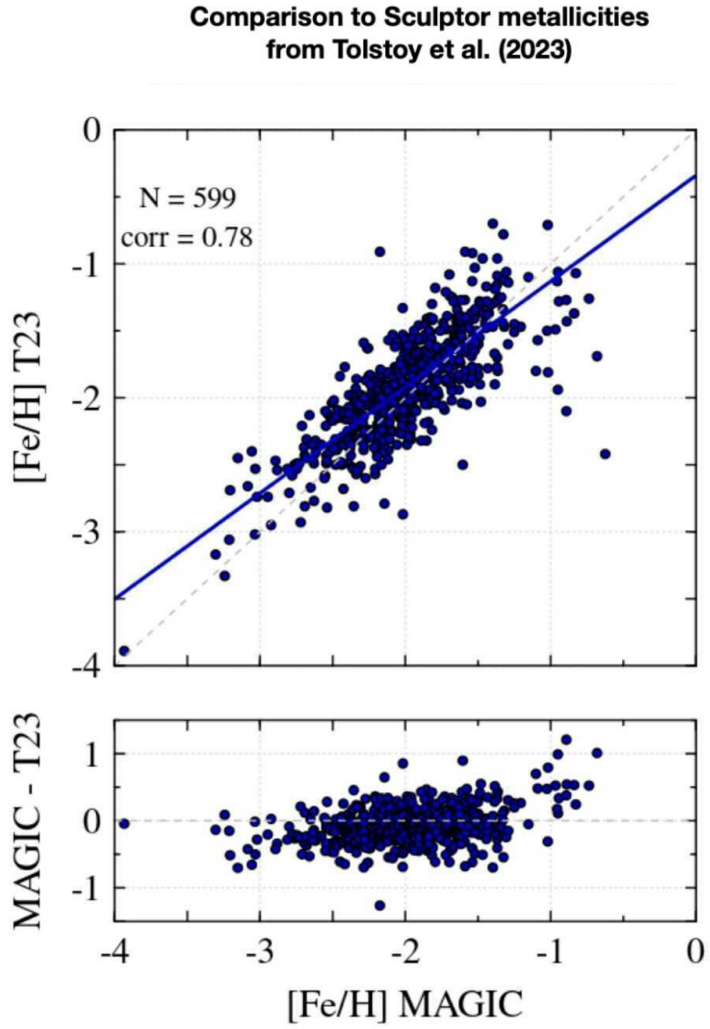
Por **Oriana Linares** - May 14, 2021

The DECam MAGIC Survey: Mapping the Ancient Galaxy in CaHK



- 54 nights on CTIO/Blanco
- UFDs, dSph, SMC, LMC, MW Halo
- Narrow-band CaHK imaging filter on DECam
- Footprint: 5,400 deg^2
- Identify [Fe/H]<-3.3 red giants to g~18
- 0.3 dex precision for [Fe/H]~-2 to g~20.5





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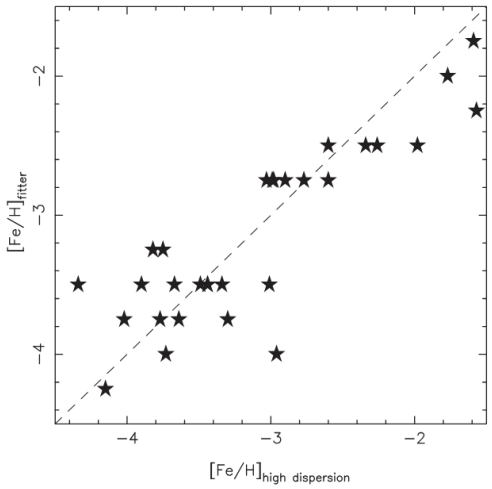
Credit: Ani Chiti and the MAGIC team

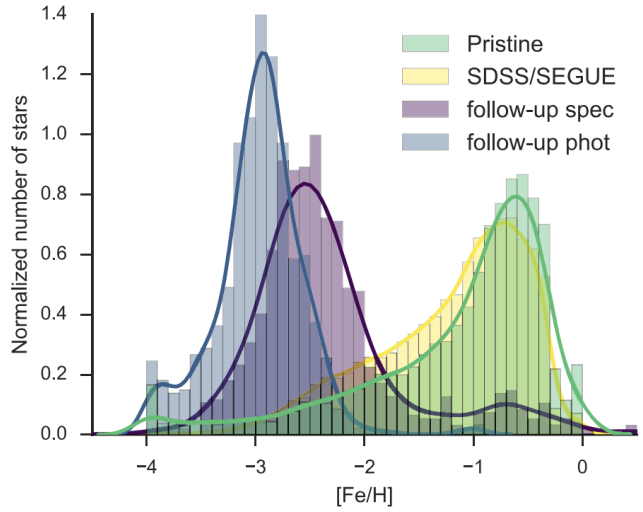
Metal-Poor Stars and Big Data: the future is *now*

SkyMapper



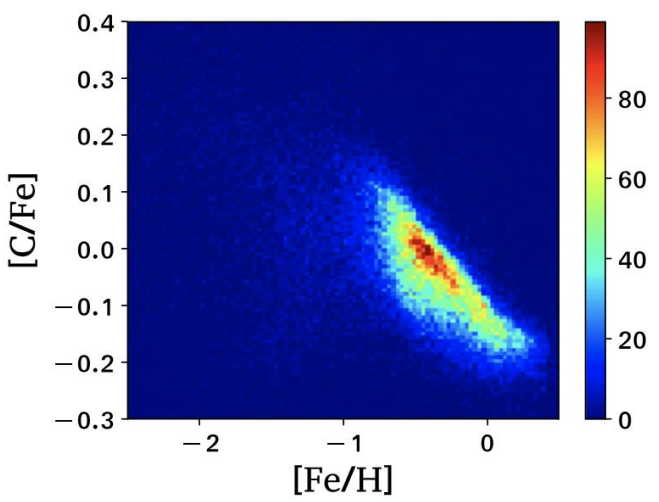
Da Costa+2019

Pristine



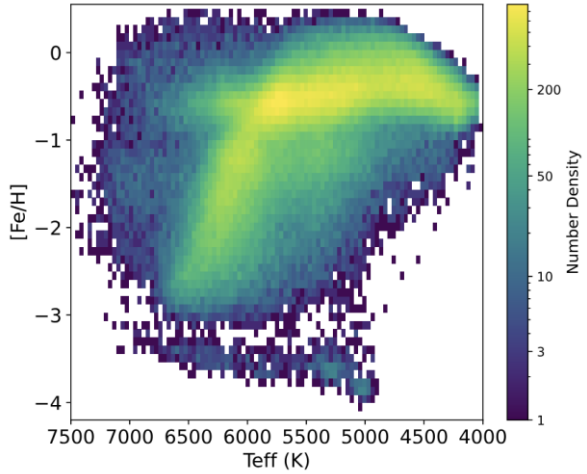
Youakim+2020

J-PLUS



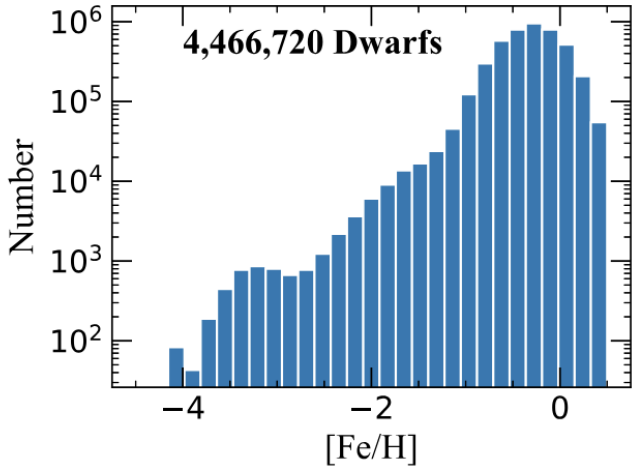
Yang+2022

DESI



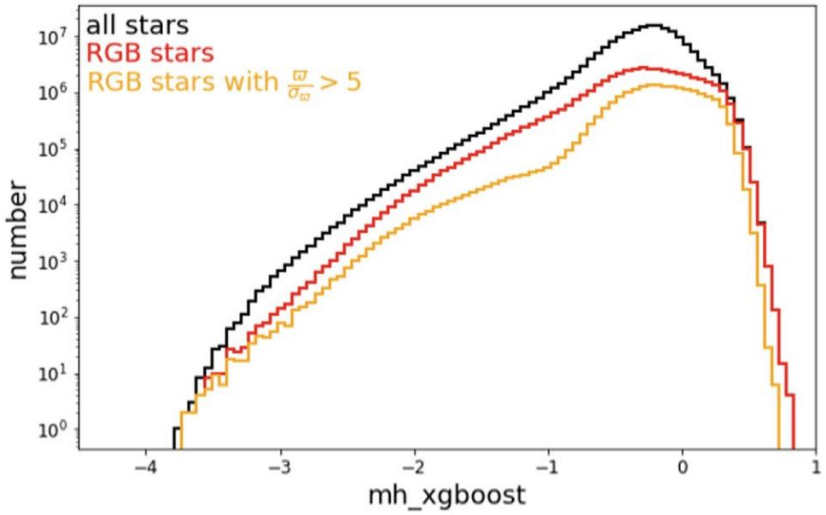
Zhang+2024

GALEX



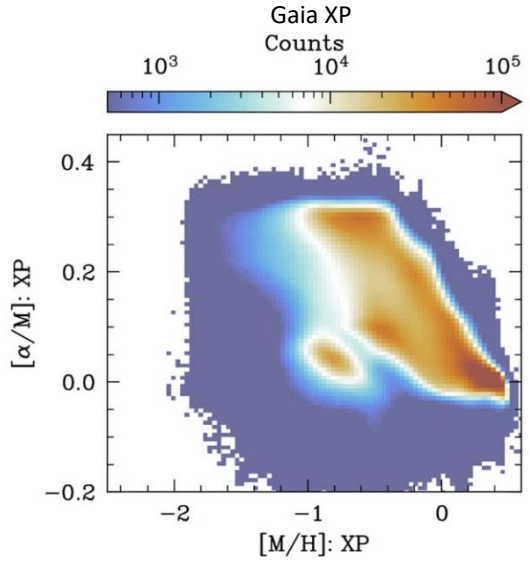
Lu+2024

Gaia XP



Andrae, Rix & Chandra 2023

Gaia XP



Li+2024

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The path forward: a data driven future

What comes next for Near-Field Cosmology:

- What is the real “delta science” of a low-mass Pop III star?
- Constrain transition between Pop III and Pop II
- Potential for discovery and incremental science

Narrow-band photometry:

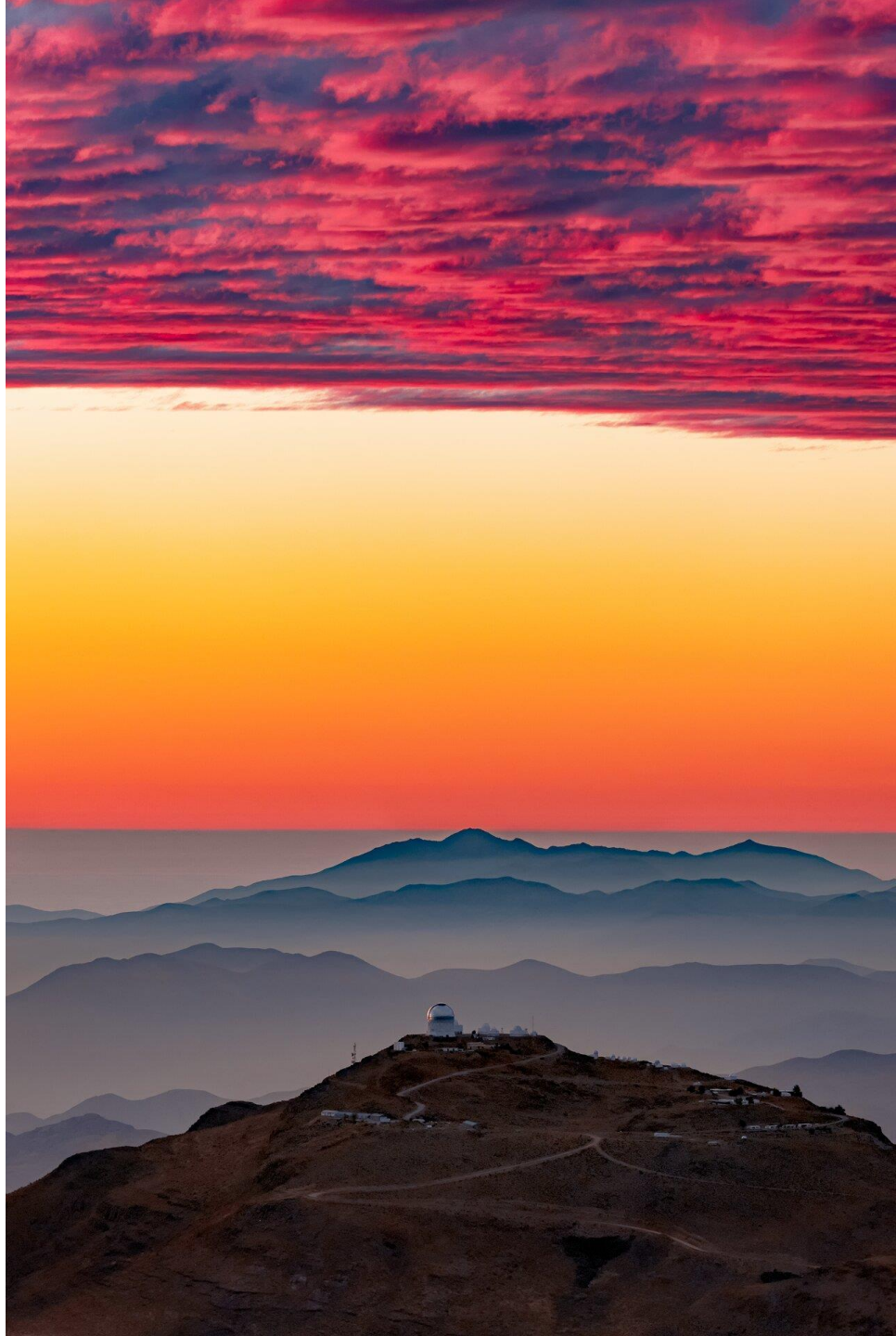
- Accurate Teff, logg, and [Fe/H]
- Selected chemical abundances (C, Mg, Ca, N, Si)

Spectroscopy:

- Statistics on metal-poor stars (10^7 stars)
- Conduct detailed chemical studies

Things to be excited about:

- Gaia, GALAH, DESI, 4MOST, MSE…
- Rubin and US-ELT



credit: Babak Tafreshi /NOIRLab/AURA/NSF