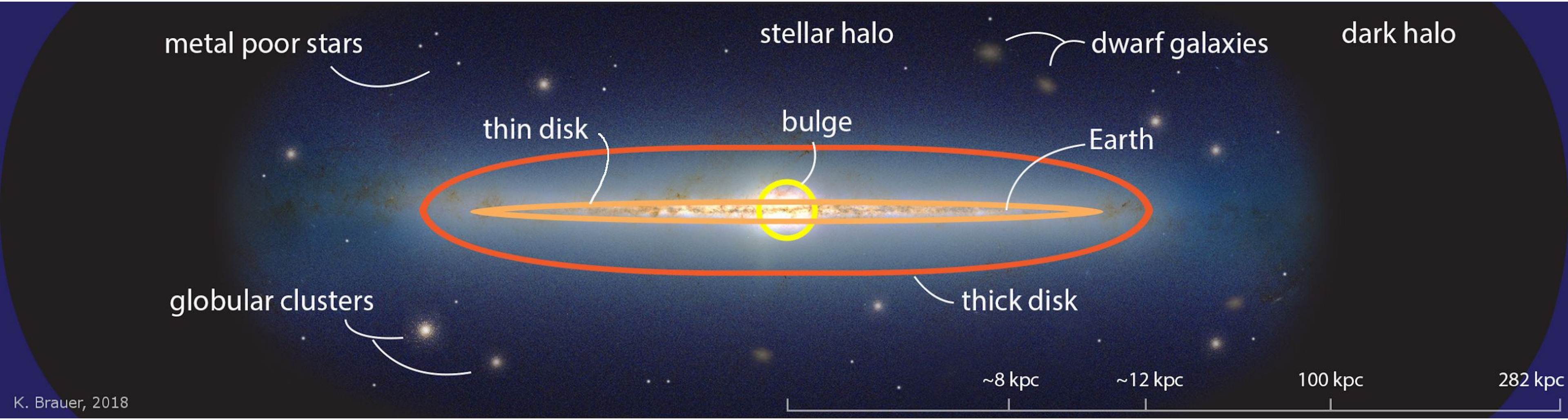
Searching for very metal-poor star candidates in S-PLUS

Andrés Galarza, Simone Daflon, Vinicius Placco,
Carlos Allende Prieto
Phd candidate, Observatório Nacional, December 2020
carlosgalarza@on.br

Why VMPs matter?

Low metallicity stars provide fundamental constraints on the formation and chemical evolution of **the structure of the Galaxy.**



Let’s recall the ELS Model…

EVIDENCE FROM THE MOTIONS OF OLD STARS THAT THE GALAXY COLLAPSED

O. J. Eggen, D. Lynden-Bell,* and A. R. Sandage
Mount Wilson and Palomar Observatories
Carnegie Institution of Washington, California Institute of Technology
Received May 17, 1962

ABSTRACT

The (U, V, W)-velocity vectors for 221 well-observed dwarf stars have been used to compute the eccentricities and angular momenta of the galactic orbits in a model galaxy. It is shown that the eccentricity and the observed ultraviolet excess are strongly correlated. The stars with the largest excess (i.e., lowest metal abundance) are invariably moving in highly elliptical orbits, whereas stars with little or no excess move in nearly circular orbits. Correlations also exist between the ultraviolet excess and the W-velocity. Finally, the excess and the angular momentum are correlated; stars with large ultraviolet excesses have small angular momenta.

These correlations are discussed in terms of the dynamics of a collapsing galaxy. The data require that the oldest stars were formed out of gas falling toward the galactic center in the radial direction and collapsing from the halo onto the plane. The collapse was very rapid and only a few times 10^8 years were required for the gas to attain circular orbits in equilibrium (i e., gravitational attraction balanced by centrifugal acceleration). The scale of the collapse is tentatively estimated to be at least 10 in the radial direction and 25 in the Z-direction. The initial contraction must have begun near the time of formation of the first stars, some 10^{10} years ago.

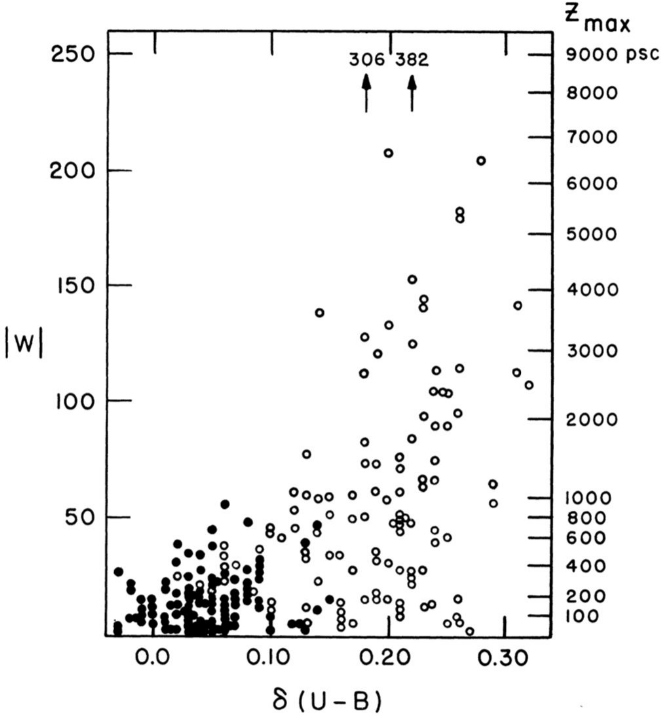


Fig 5 —The correlation between the W-velocity, perpendicular to the galactic plane, and the ultraviolet excess for the 221 stars in our sample. The filled and open circles represent the stars in our first and second catalogues, respectively.

A little reminder...

$$[Fe/H] = \mathrm{Log}(N_{Fe}/N_H)_{Star} - \mathrm{Log}(N_{Fe}/N_H)_{Sun}$$

TABLE 1 Nomenclature for stars of different metallicity

[Fe/H]	Term	Acronym
> +0.5	Super metal-rich	SMR
~0.0	Solar	—
< −1.0	Metal-poor	MP
< −2.0	Very metal-poor	VMP
< −3.0	Extremely metal-poor	EMP
< −4.0	Ultra metal-poor	UMP
< −5.0	Hyper metal-poor	HMP
< −6.0	Mega metal-poor	MMP

TABLE 2 Definition of subclasses of metal-poor stars

Neutron-capture-rich stars	
r-I	0.3 ≤ [Eu/Fe] ≤ +1.0 and [Ba/Eu] < 0
r-II	[Eu/Fe] > +1.0 and [Ba/Eu] < 0
s	[Ba/Fe] > +1.0 and [Ba/Eu] > +0.5
r/s	0.0 < [Ba/Eu] < +0.5
Carbon-enhanced metal-poor stars	
CEMP	[C/Fe] > +1.0
CEMP-r	[C/Fe] > +1.0 and [Eu/Fe] > +1.0
CEMP-s	[C/Fe] > +1.0, [Ba/Fe] > +1.0, and [Ba/Eu] > +0.5
CEMP-r/s	[C/Fe] > +1.0 and 0.0 < [Ba/Eu] < +0.5
CEMP-no	[C/Fe] > +1.0 and [Ba/Fe] < 0

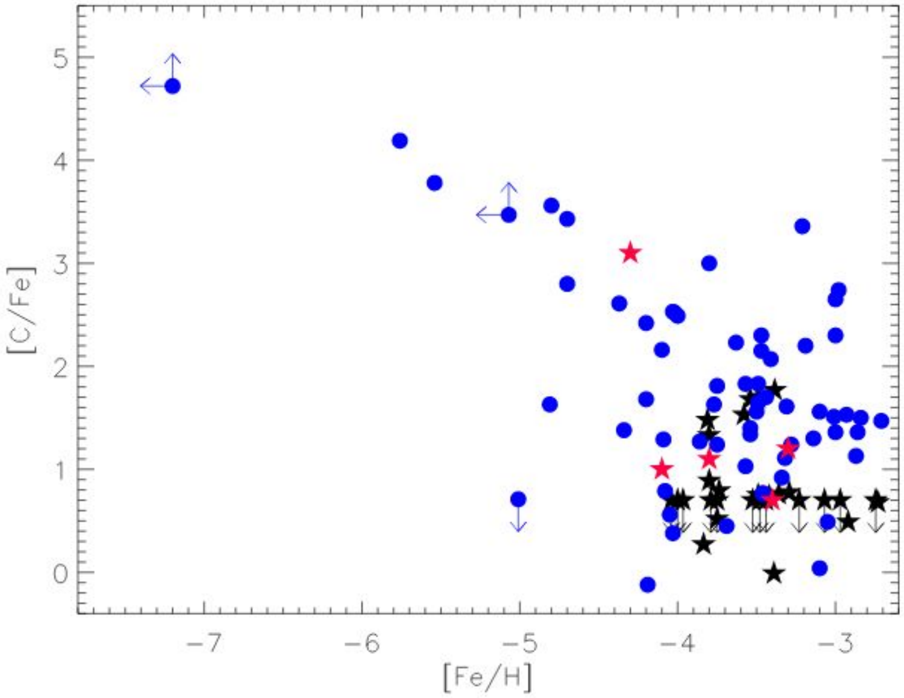
Beers & Christlieb 2005, Annu. Rev. Astron. Astrophys.

What will be the [Fe/H] limit for detecting metal poor stars?

How hard is to find extremely low metallicity stars?

1 in 800 Stars
[Fe/H] < -3.0

1 in 80000!!
[Fe/H] < -4.0



Aguado, Allende Prieto, et. al. (2018)

Interesting Surveys:

SEGUE (Sloan)
Pristine

LAMOST

4MOST (Futuro)

How to select good candidates?

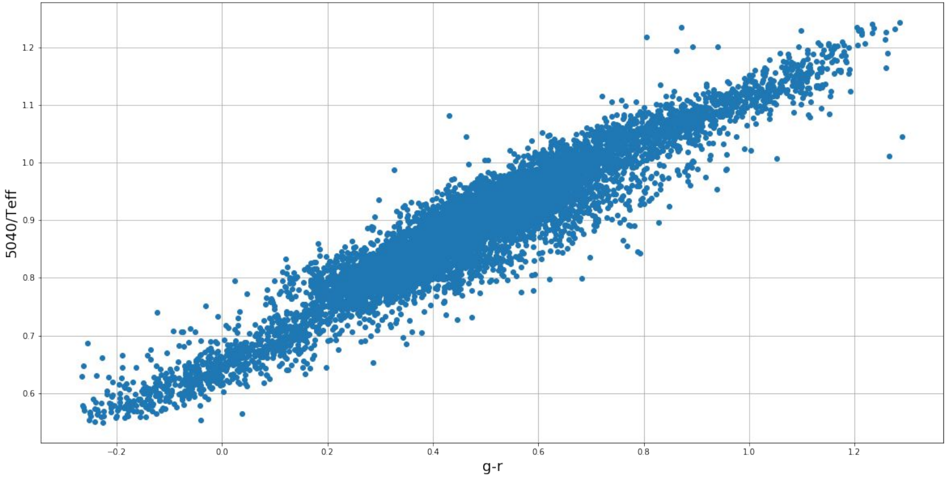
a. Wide-angle survey (J-PLUS).
b. Moderate-resolution spectroscopic follow up.
c. High-resolution spectroscopy / Chemical Abundances.

How to select good candidates?

a. Wide-angle survey (J-PLUS). ★
b. Moderate-resolution spectroscopic follow up.
c. High-resolution spectroscopy / Chemical Abundances.

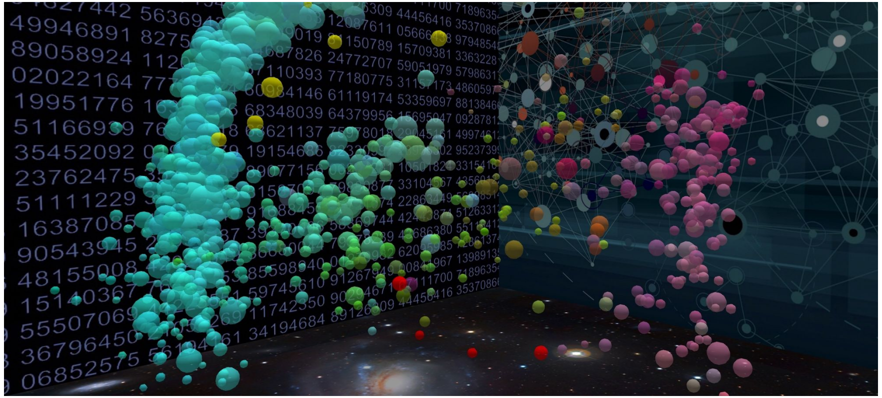
Photometric Calibrations vs Machine Learning

Semi-empirical formulas usually based on a single or few photometric colors.



Allows extrapolation / More restrictions to obtain better predictions.

Can deal with a big set of variables as input parameters.



“Learns” from the ingested data - predictions restricted to its range of values.

AI for Astronomy

Machine Learning models for Teff, [Fe/H] and Logg

J-PLUS SPEEM Pipeline

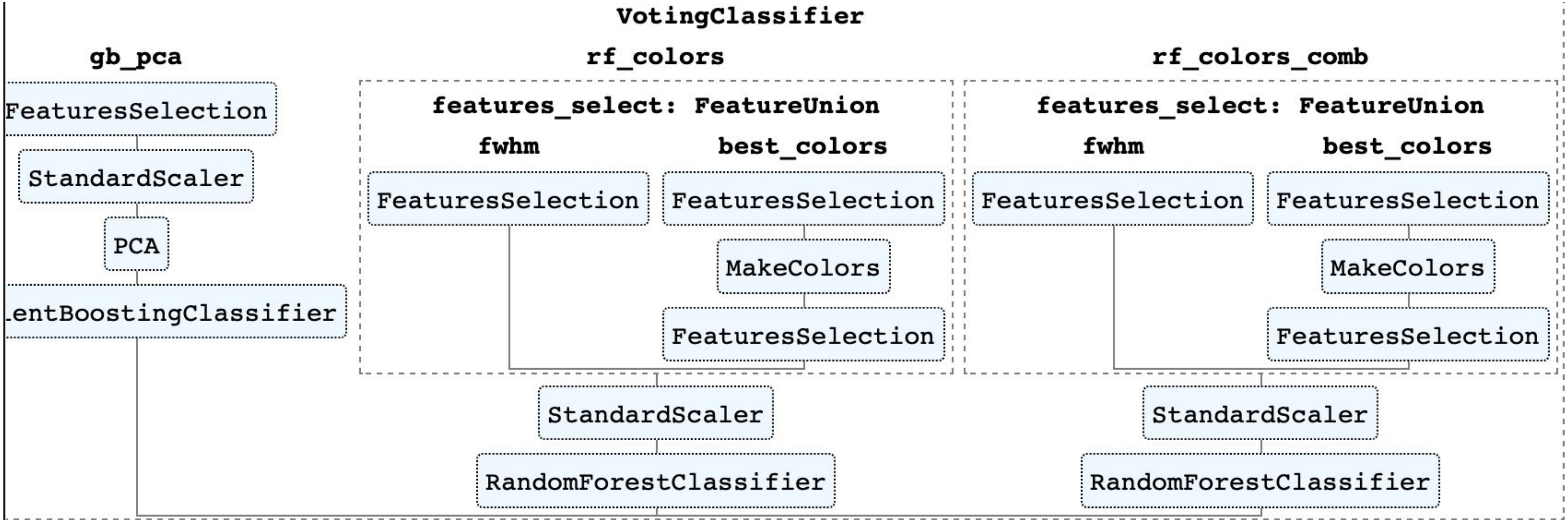
Stellar Parameters Estimations based on Ensemble Methods

Random subsets of data ingested into random sets of decision trees.

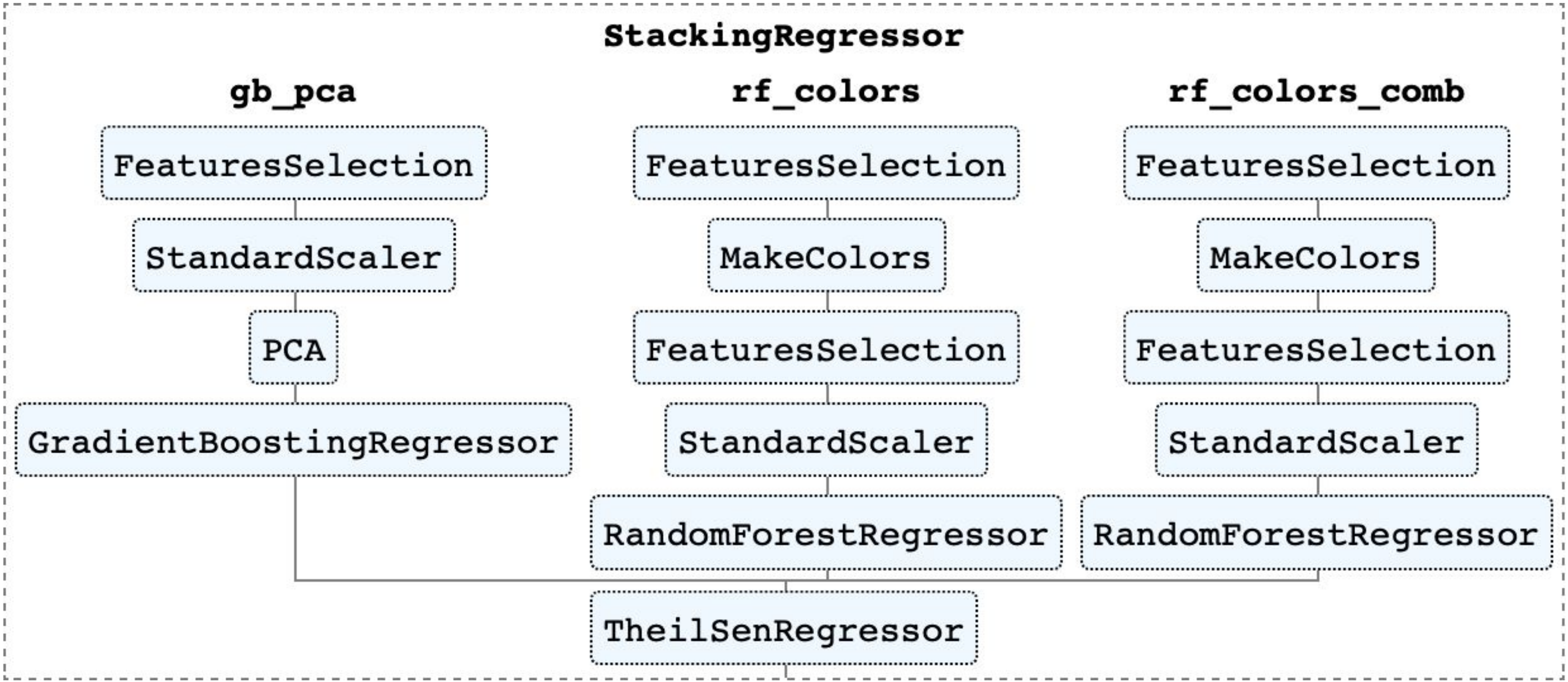
Tasks performed by the pipeline.

- Identification of QSOs & WDs candidates.
- Training / Test sample of 13602 stars from SEGUE & Apogee for Teff, [Fe/H] & Logg.
- Extra validation dataset of 106769 stars from LAMOST DR4.

J-PLUS SPEEM Architecture Classifier



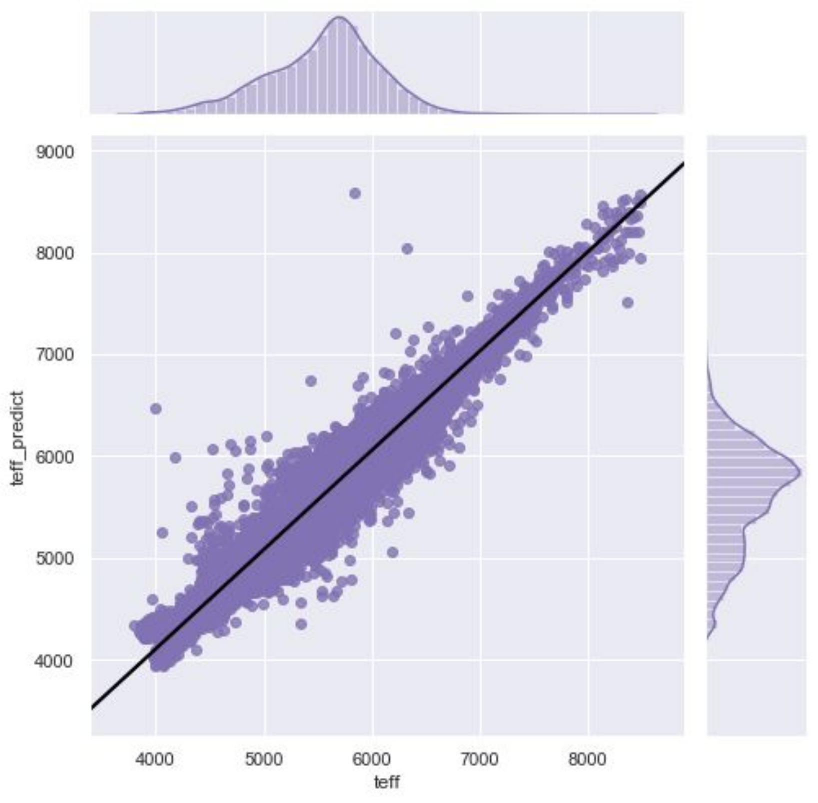
J-PLUS SPEEM Architecture Regressor



Effective Temperature

Mean error = 101 K
Median error = 85 K
RMS error = 130 K
r^2 = 0.94

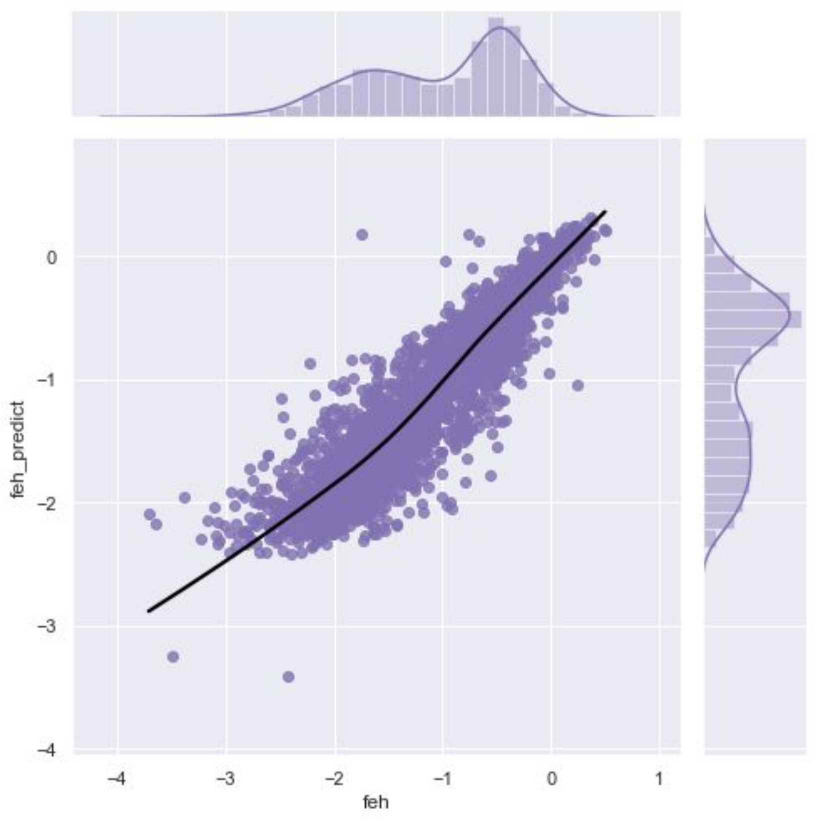
Values compared to LAMOST DR4 for a sample of 106769 stars



Metallicity [Fe/H]

Mean error = 0.19 dex
Median error = 0.13 dex
RMS error = 0.27
$r^2 = 0.87$

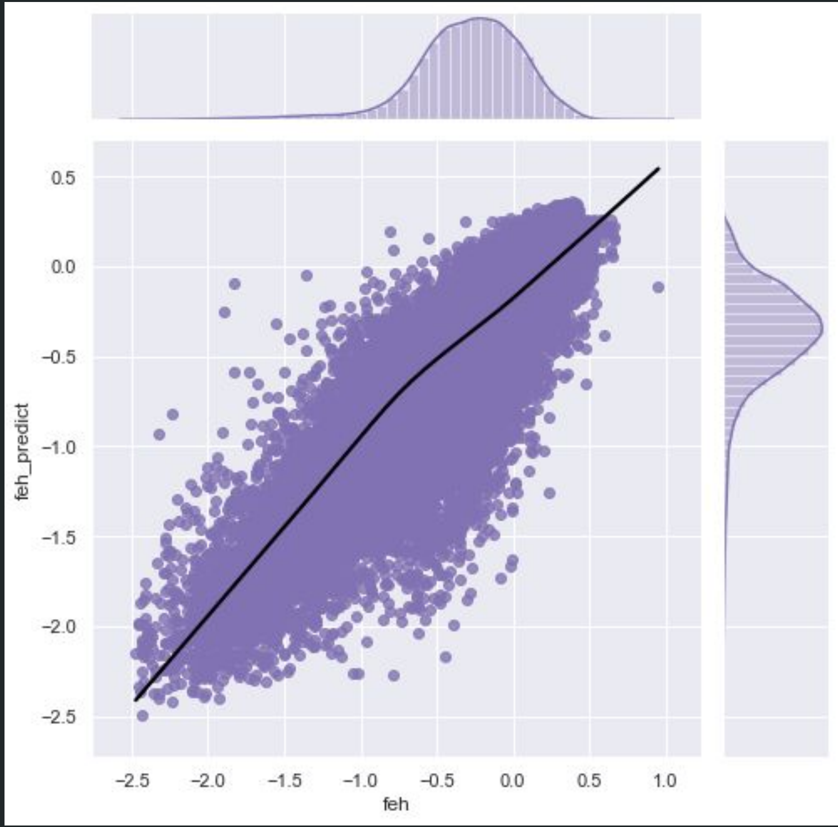
Values compared to SEGUE



Metallicity [Fe/H]

Mean error = 0.16 dex
Median error = 0.14 dex
RMS error = 0.21
r^2 = 0.66

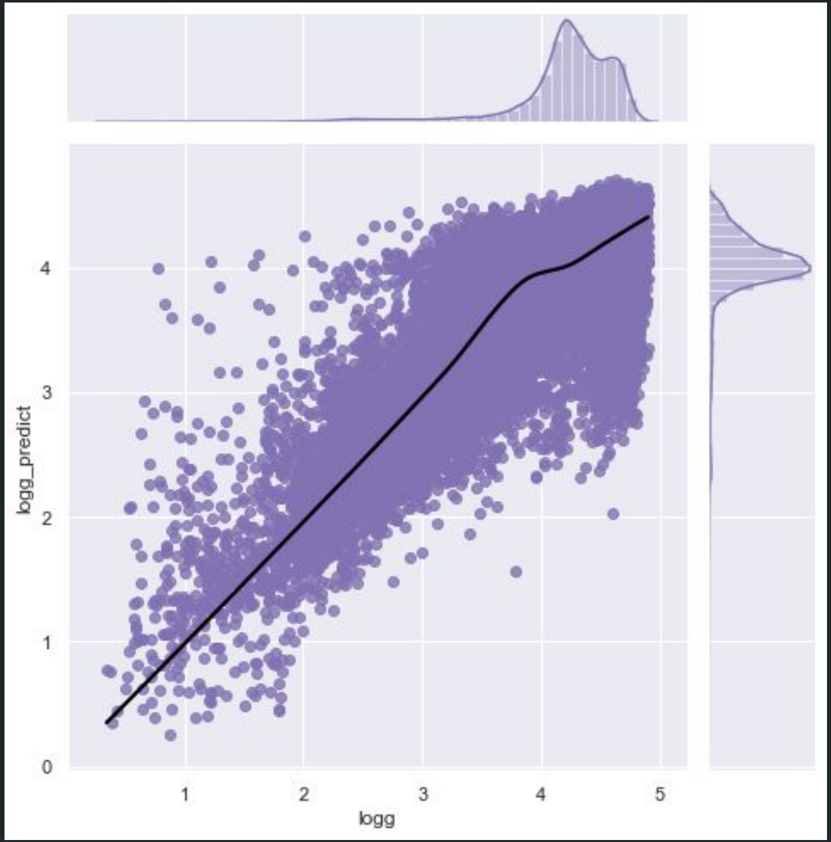
Values compared to LAMOST DR4 for a sample of 106769 stars



Surface Gravity Logg

Mean error = 0.29 dex
Median error = 0.25 dex
RMS error = 0.37
r^2 = 0.42

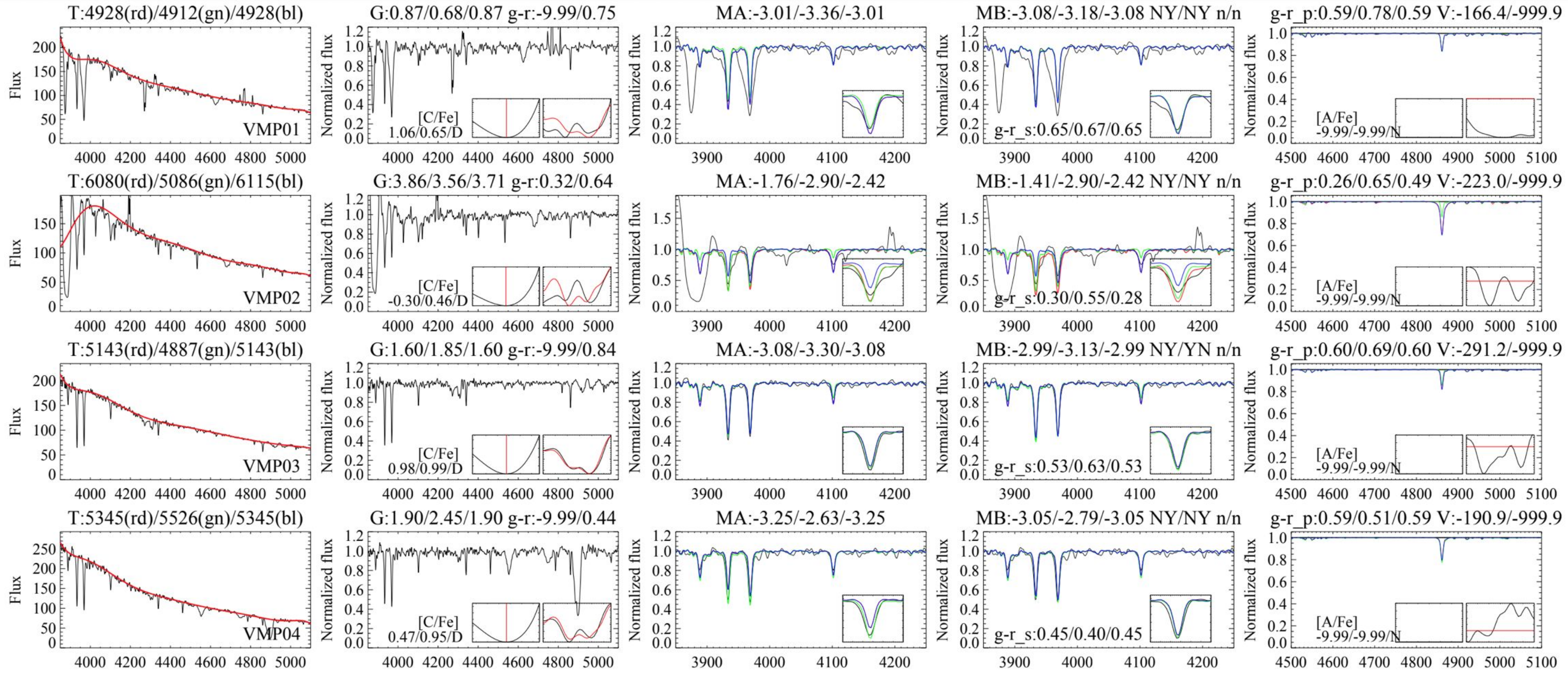
Values compared to LAMOST DR4 for a sample of 106769 stars



Spectroscopic Validation

- 11 candidates were selected with g mag [14.98, 16.75] and old J-PLUS calibration.
- Observations made by Carlos Allende with WHT and ISIS instrument.
- Standard reduction process with IRAF.

Confirmation of VMPs Candidates

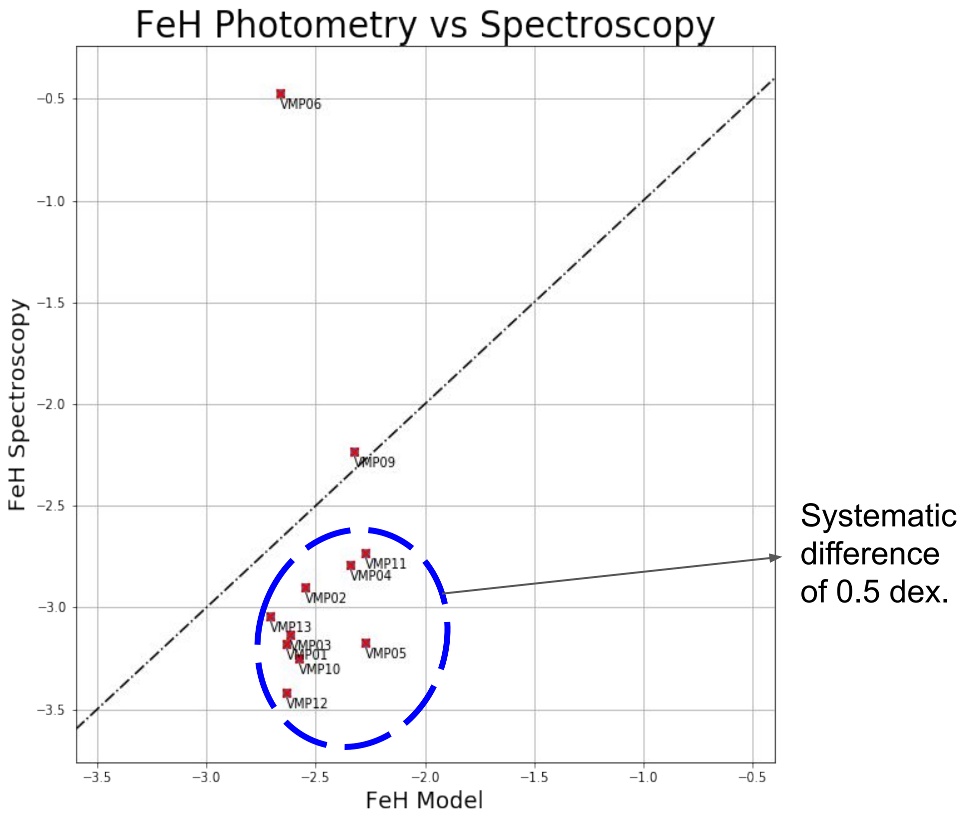


Vinicius Placco ➔ Pipeline ref. n-SSPP (Beers et al. 2014)

Confirmation of VMPs candidates!

1. First VMPs detected and confirmed by J-PLUS. g mag [14.8, 16.75]

2. Average differences of 178K, 0.76 dex and 0.5 dex for Teff, Logg & [Fe/H].
3. [Fe/H]_Spec < [Fe/H]_Model by ~ 0.5 dex
4. Stars are too faint to validate with High-res. spectroscopy.

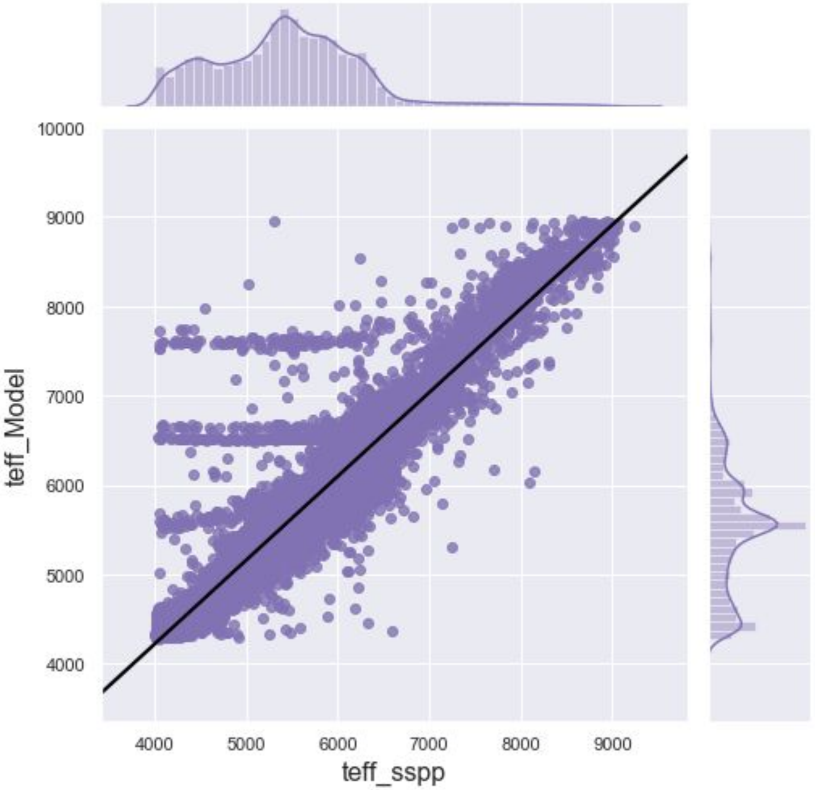


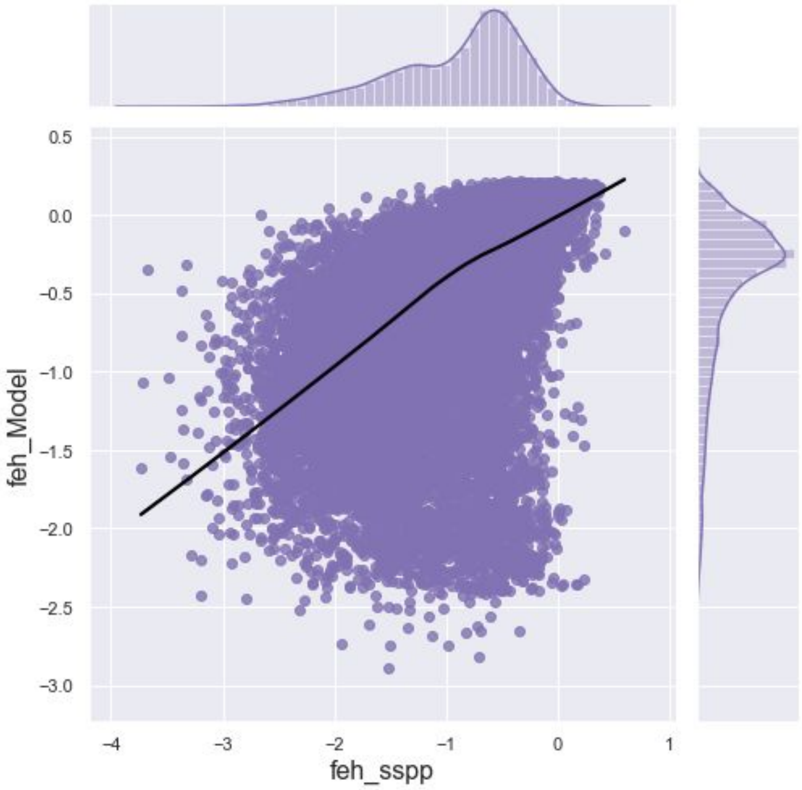
J-PLUS SPEEM can properly identify new VMPs along with the identification of potential QSOs & WDs.

Conclusions

- In order to properly select extremely metal poor candidates ([Fe/H] < -3.0) is essential to identify potential QSOs and WDs.
- J-PLUS SPEEM operates in the range of (4000K, 9000K) for Teff, (-3.5, 0.5) dex for [Fe/H] and (0.2, 5.0) dex for Logg.
- Not always huge amounts of data are required to train good machine learning models.

SPEEM Pipeline applied to S-PLUS Stripe 82





Highest Correlations between Colors and [Fe/H]

F378-F861	0.028926
F395-F861	0.026273
F378-I	0.026155
F378-F660	0.024768
F378-R	0.024289
F395-I	0.023555
F395-F660	0.022103

J0395-J0410	0.702976
J0378-J0410	0.694970
J0395-J0430	0.666869
J0378-J0430	0.655345
J0378-gSDSS	0.647072
J0395-gSDSS	0.639314
J0378-J0515	0.637066

Thank you!

Any question, comment or suggestion will be appreciated!

carlosgalarza@on.br