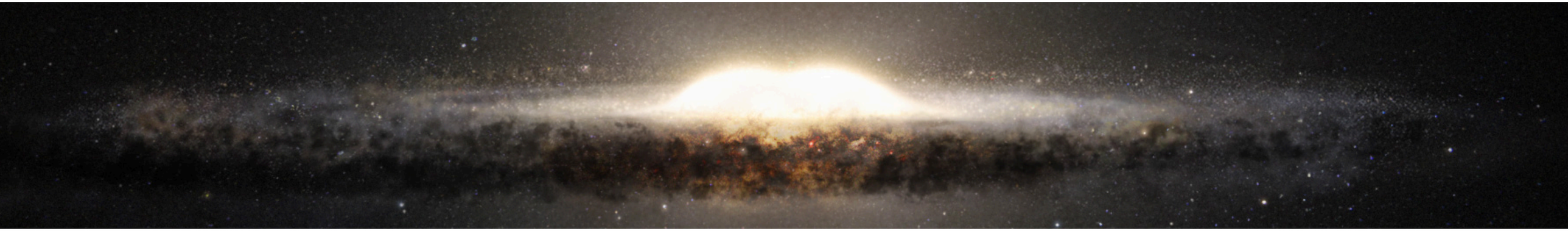
# Exploring the metal-poor inner Galaxy with the PRISTINE survey




**Anke Arentsen**

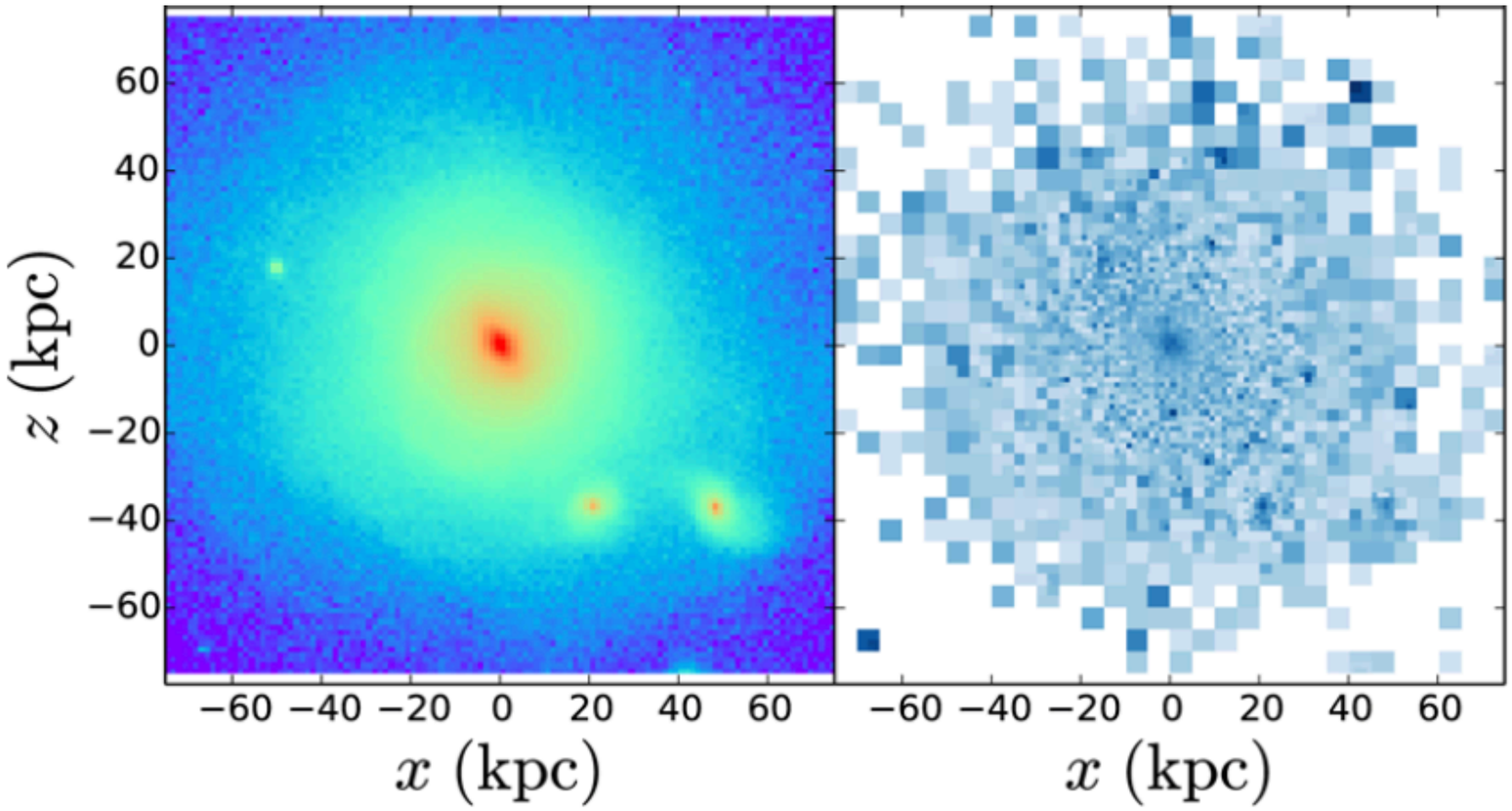
(AIP, Potsdam, Germany)

With: Else Starkenburg (AIP), Nicolas Martin (Observatoire de Strasbourg), Kim Venn (University of Victoria), Dan Zucker (Macquarie University), Andrea Kunder (Saint Martin's University), Vanessa Hill (OCA), Mathias Schultheis (OCA) and the *Pristine* team

# Where are the oldest stars?

Colour-coded by density

Colour-coded by fraction of **old** stars




*Starkenburg+17b*

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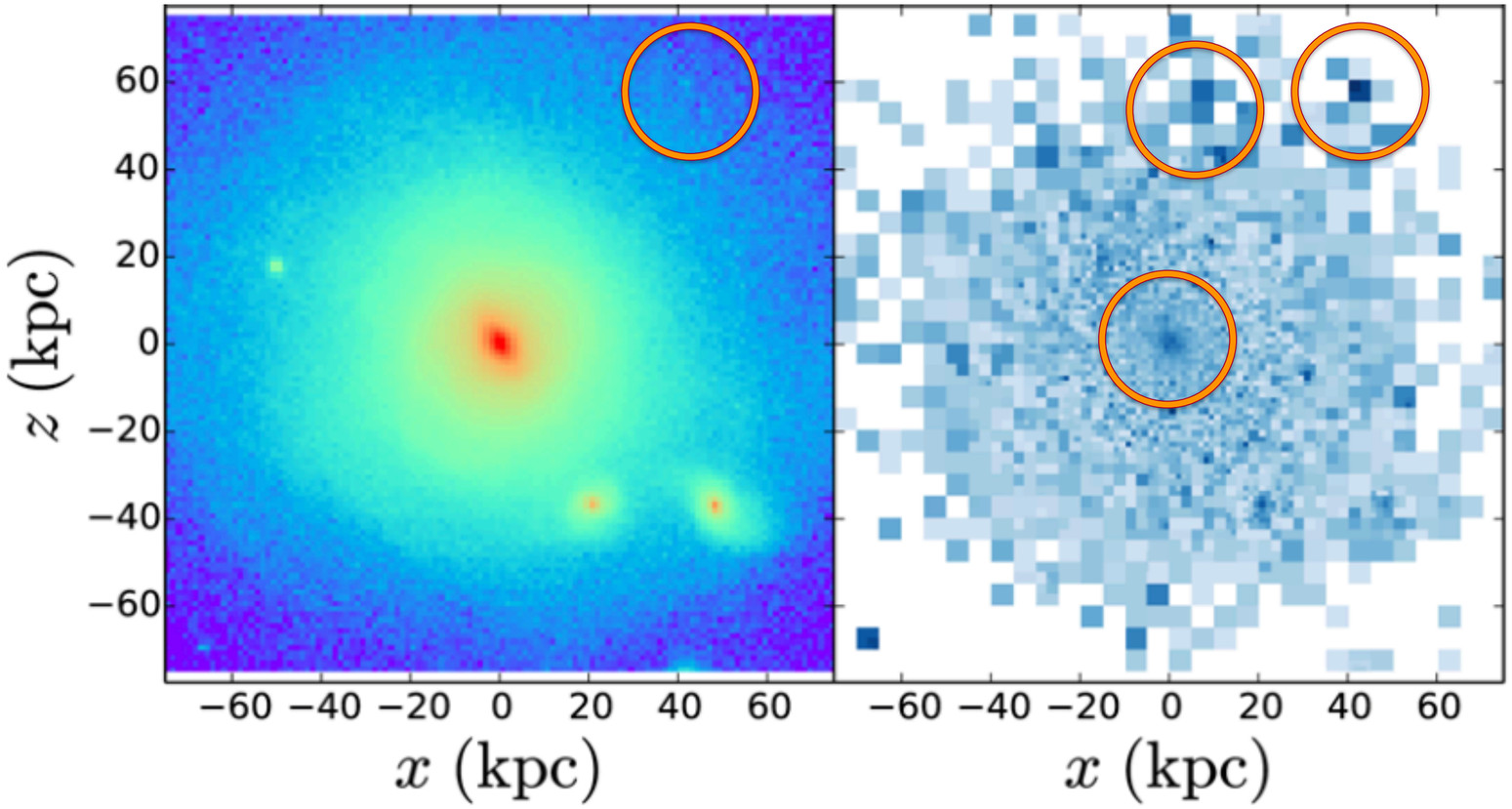
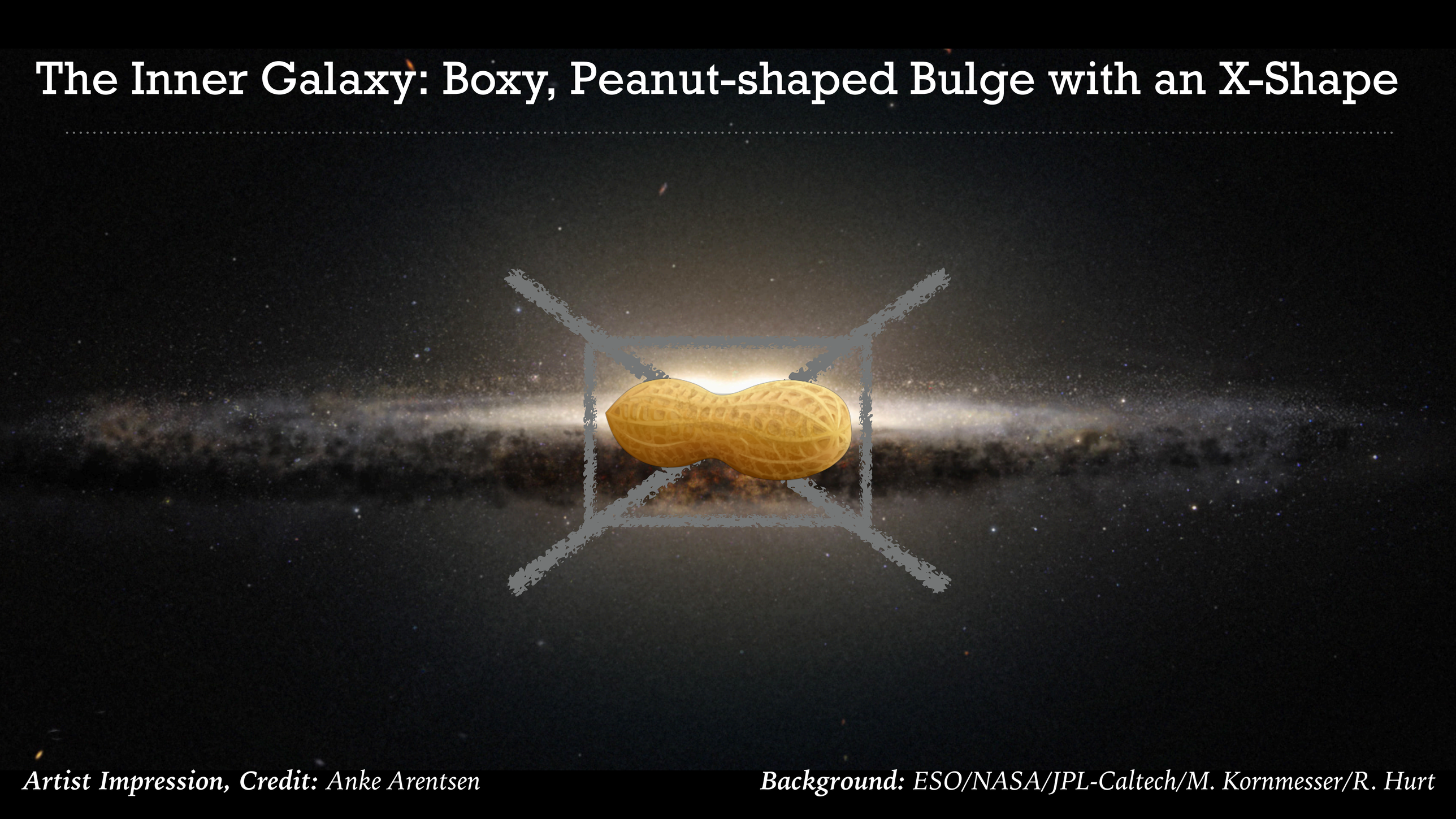



*Starkenburg+17b*

# The Inner Galaxy

***Artist Impression, Credit:*** *ESO/NASA/JPL-Caltech/M. Kornmesser/R. Hurt*

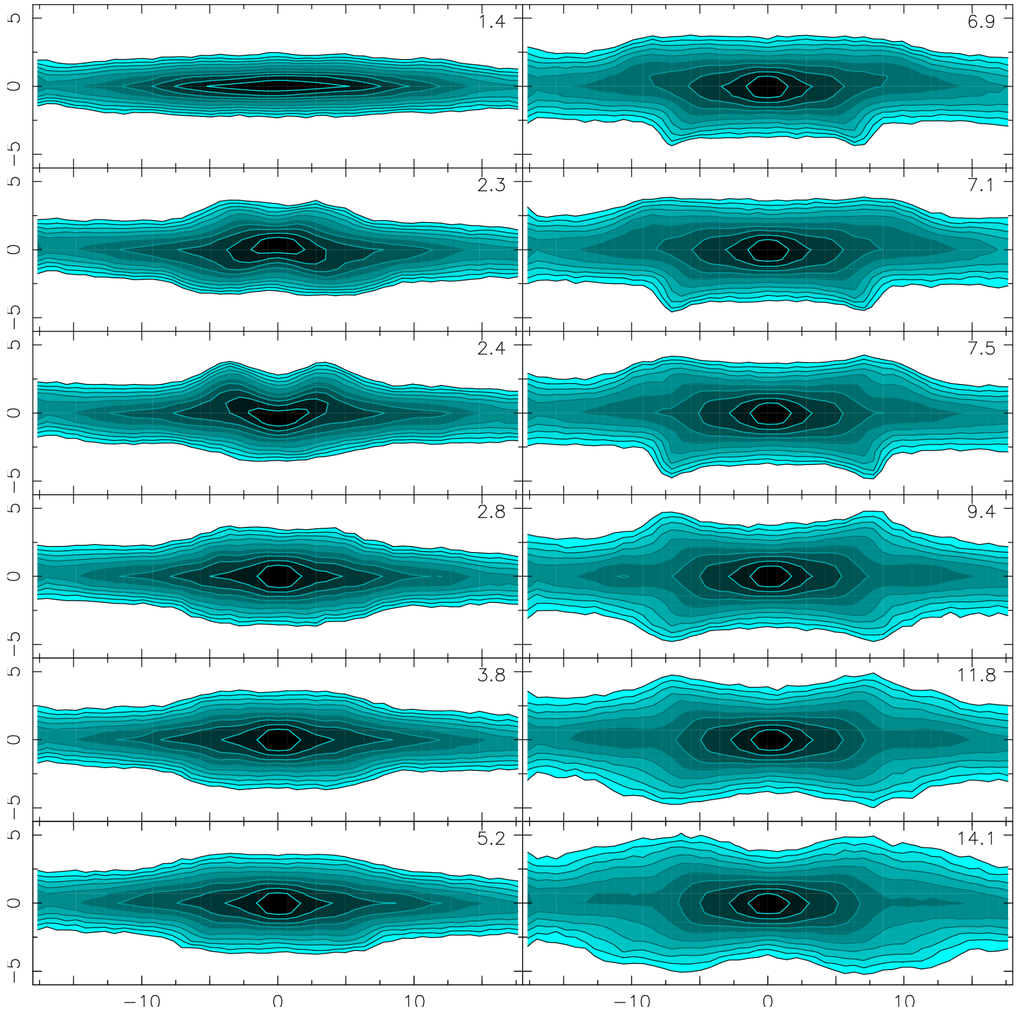
# The Inner Galaxy: Boxy, Peanut-shaped Bulge with an X-Shape



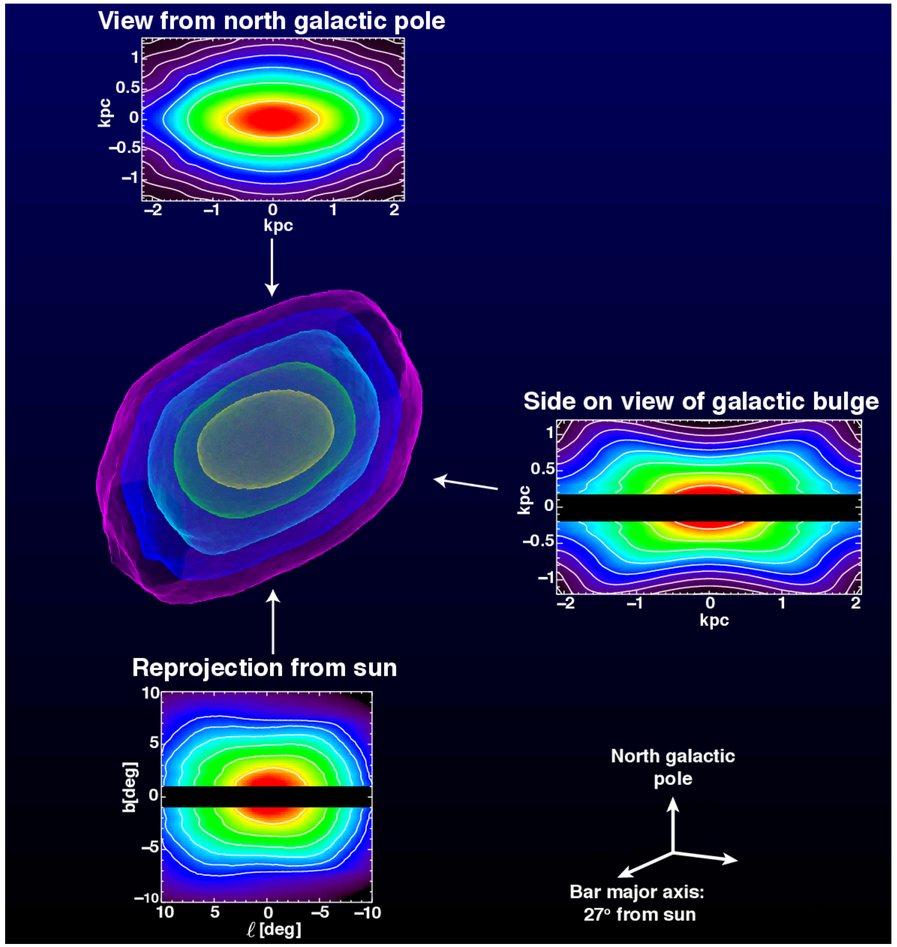
***Artist Impression, Credit:*** *Anke Arentsen*

***Background:*** *ESO/NASA/JPL-Caltech/M. Kornmesser/R. Hurt*

# B/P Bulges: deformed bars




*Martinez-Valpuesta+06*



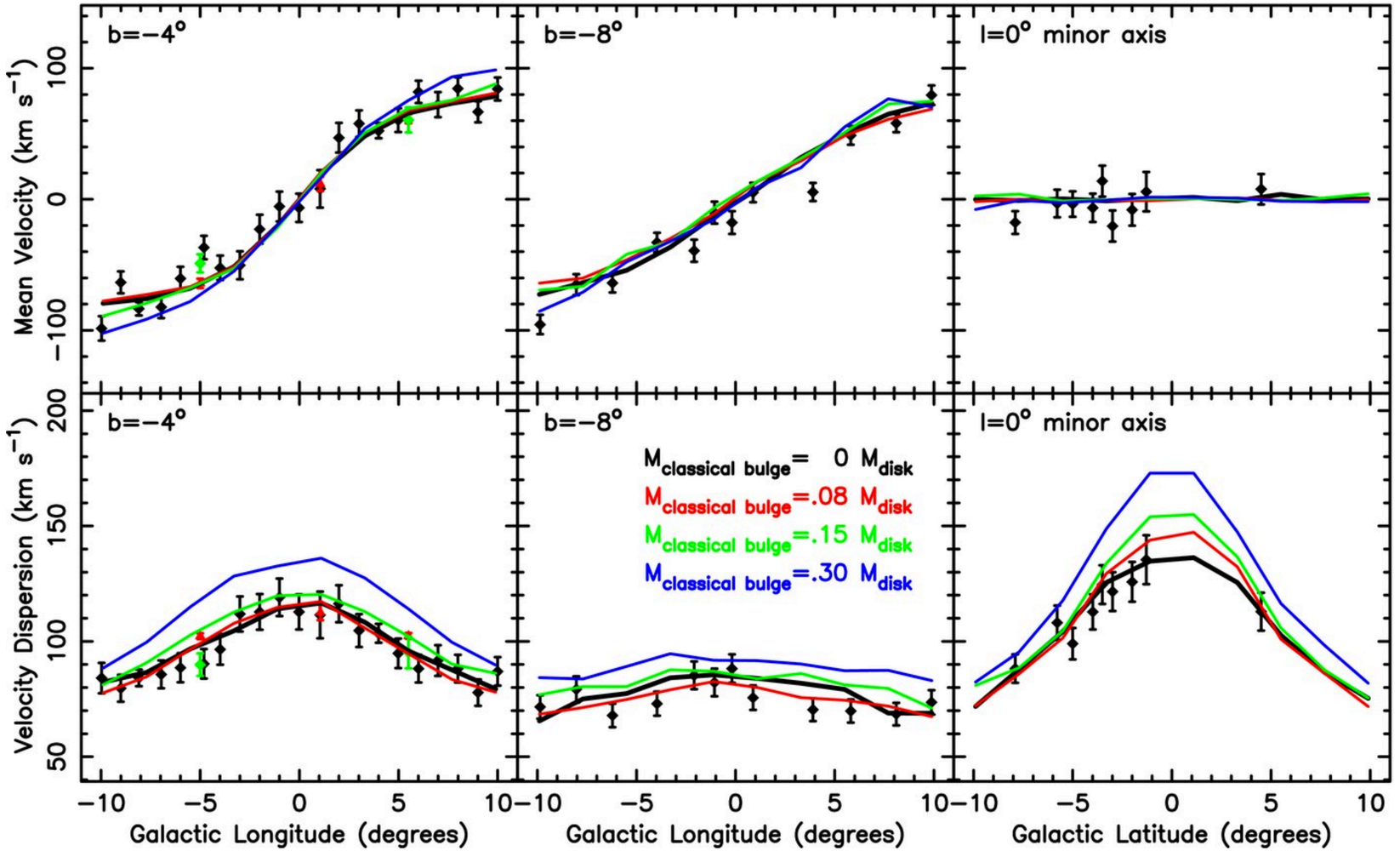

*Wegg & Gerhard (2013)*

# Kinematics: room for a classical bulge?

## Cylindrical rotation

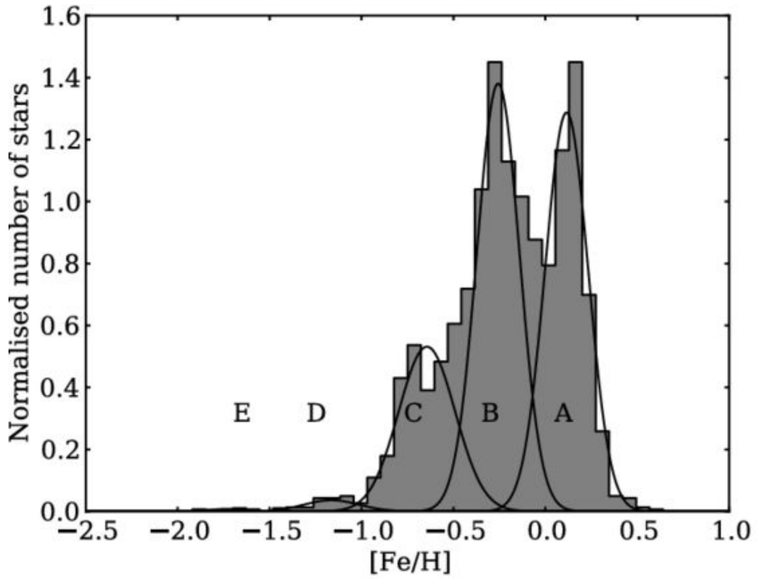
Data:
BRAVA survey
*(Howard+08,09)*

Model:
*Shen+10*

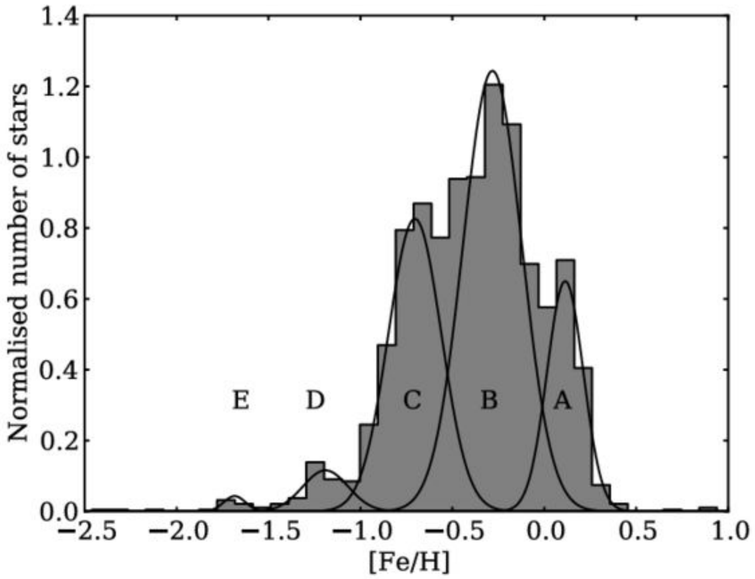


# Metallicity distribution

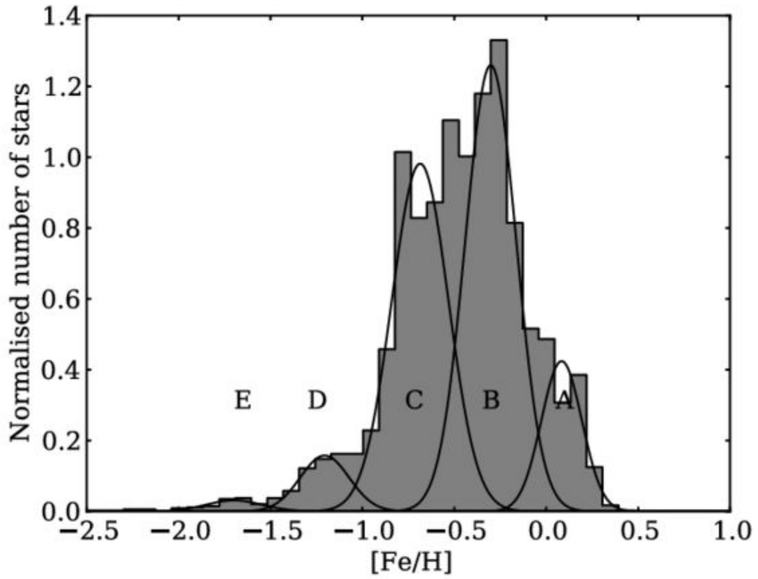
Metallicity Distribution Function (MDF) in the ARGOS red clump survey *(Ness+2013)*




(a) $l \pm 15°, b = -5°$



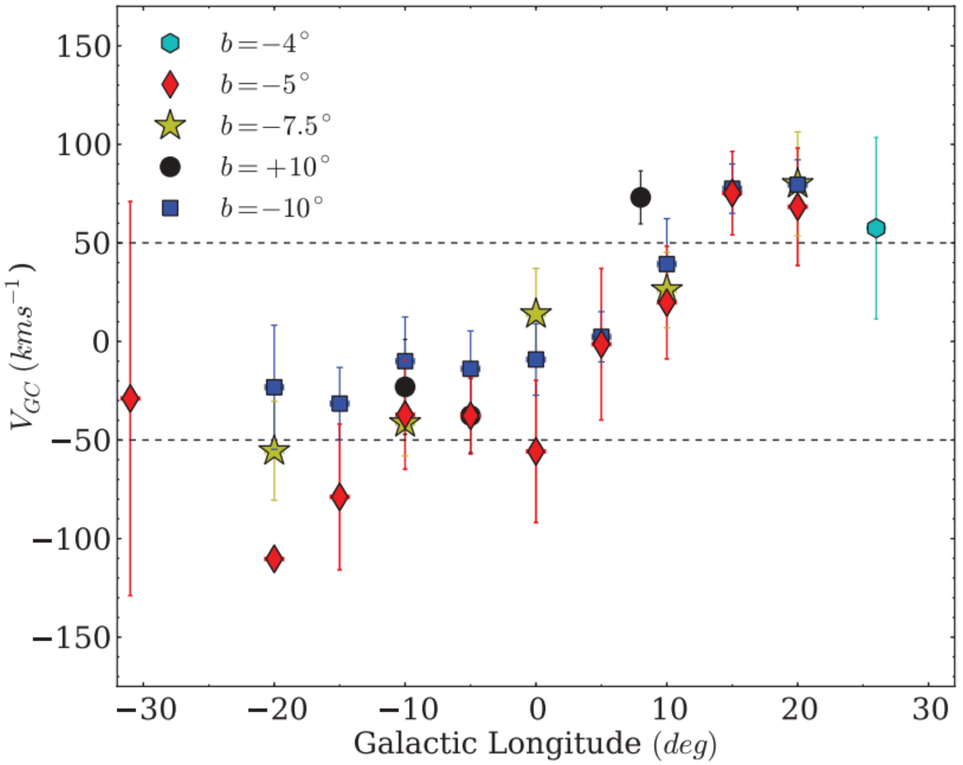

(b) $l \pm 15°, b = -7.5°$




(c) $l \pm 15°, b = -10°$

# What about the metal-poor component?

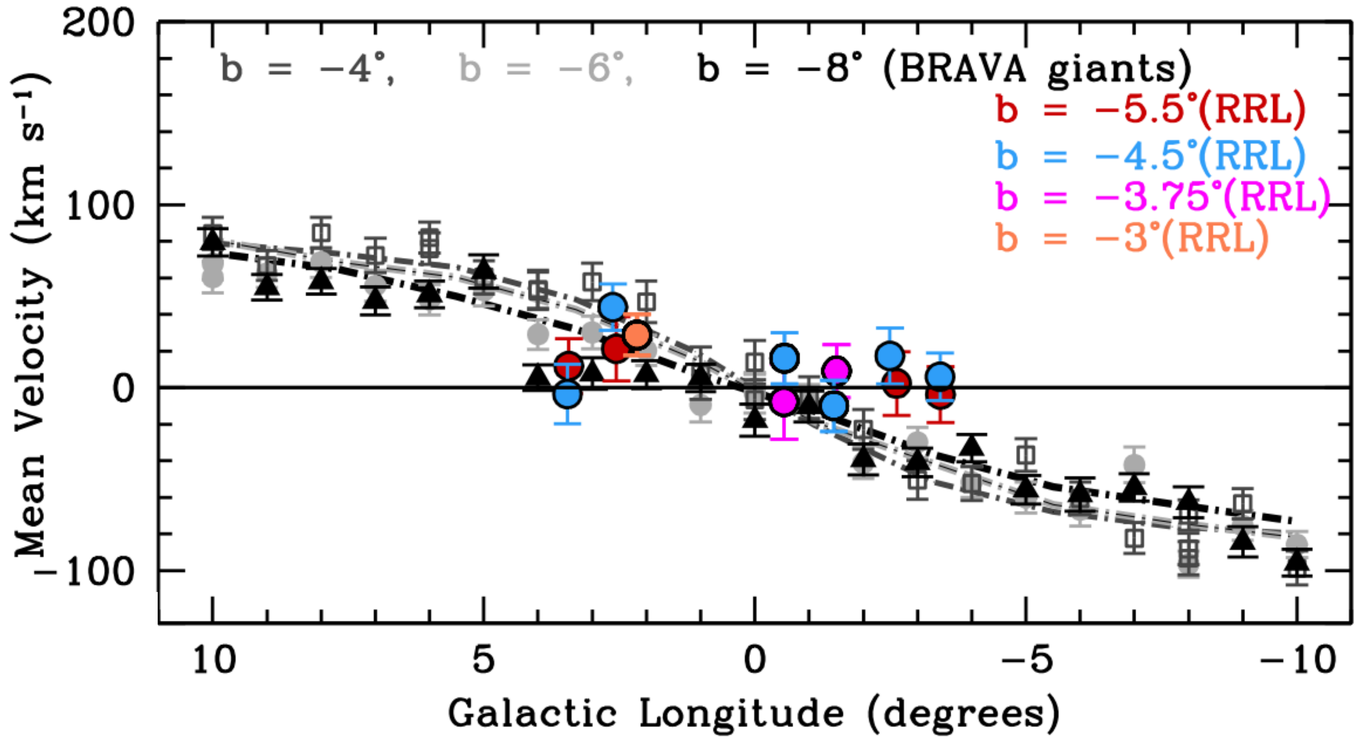
ARGOS [Fe/H] < −1.0 (MP)




**Slight rotation in MP stars (?)**

ARGOS data *(Ness+13)*

# What about the metal-poor component?

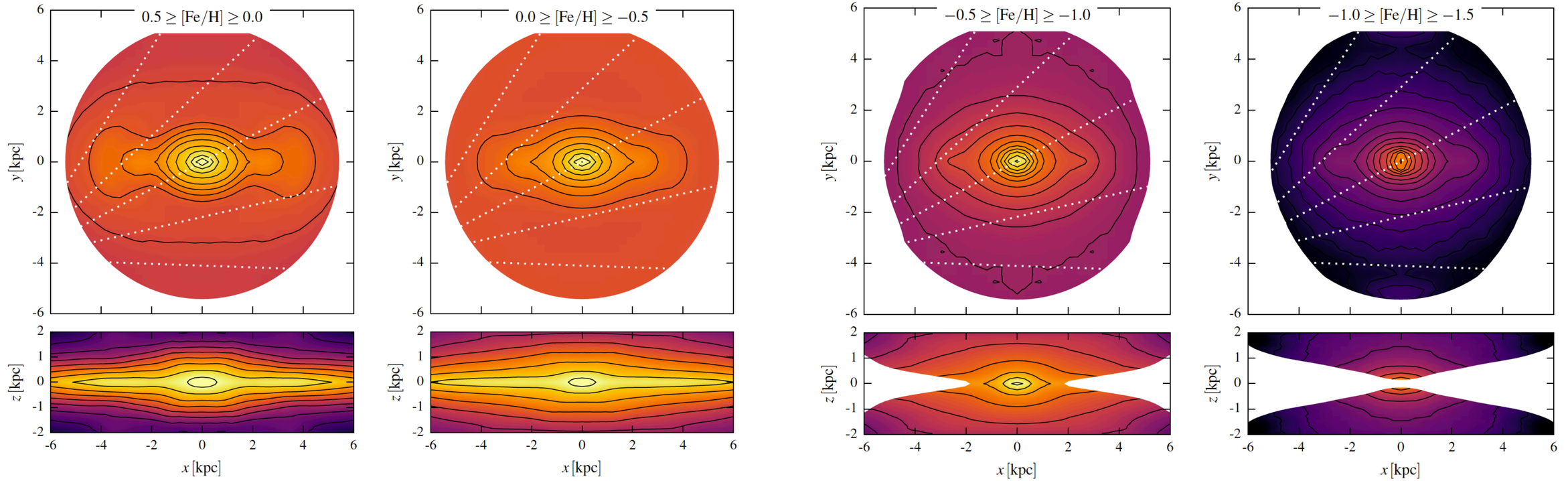


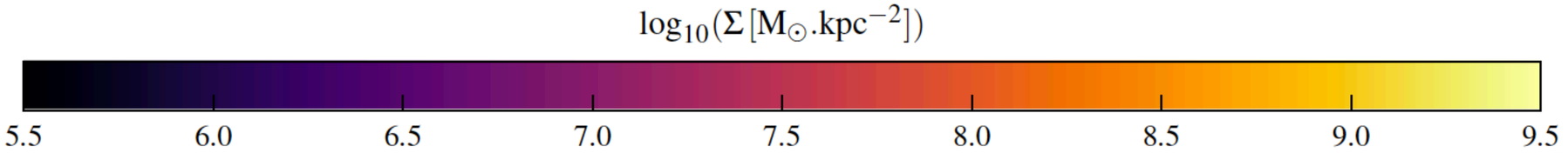

No signature of rotation in metal-poor BRAVA RR Lyrae stars

*(Kunder+16)*

# Model with ARGOS/APOGEE data

Chemodynamical modelling of the Galactic Bulge and Bar *(Portail+2017)*



**Why look for metal-poor stars in the bulge?**

- Find the oldest (metal-poor) stars in the Galaxy
- Need of a larger sample of metal-poor stars to study that component of the bulge

# Metal-poor stars

*Beers & Christlieb 2005*

| [Fe/H] | Term | Acronym |
|---|---|---|
| $> +0.5$ | Super metal-rich | SMR |
| $\sim 0.0$ | 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 |

$$[\mathrm{Fe/H}] = \log(\mathrm{Fe/H})_* - \log(\mathrm{Fe/H})_\odot$$

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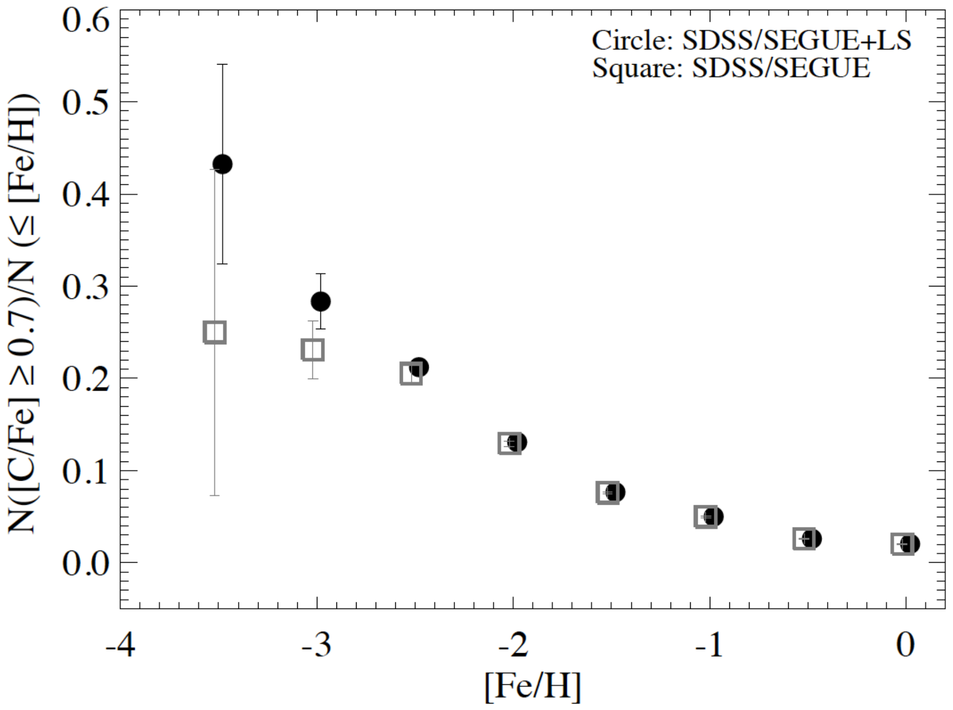
Fraction of CEMP ([C/Fe] > +0.7) stars
(*Lee+13*)



# Metal-poor stars with Pristine

*Beers & Christlieb 2005*

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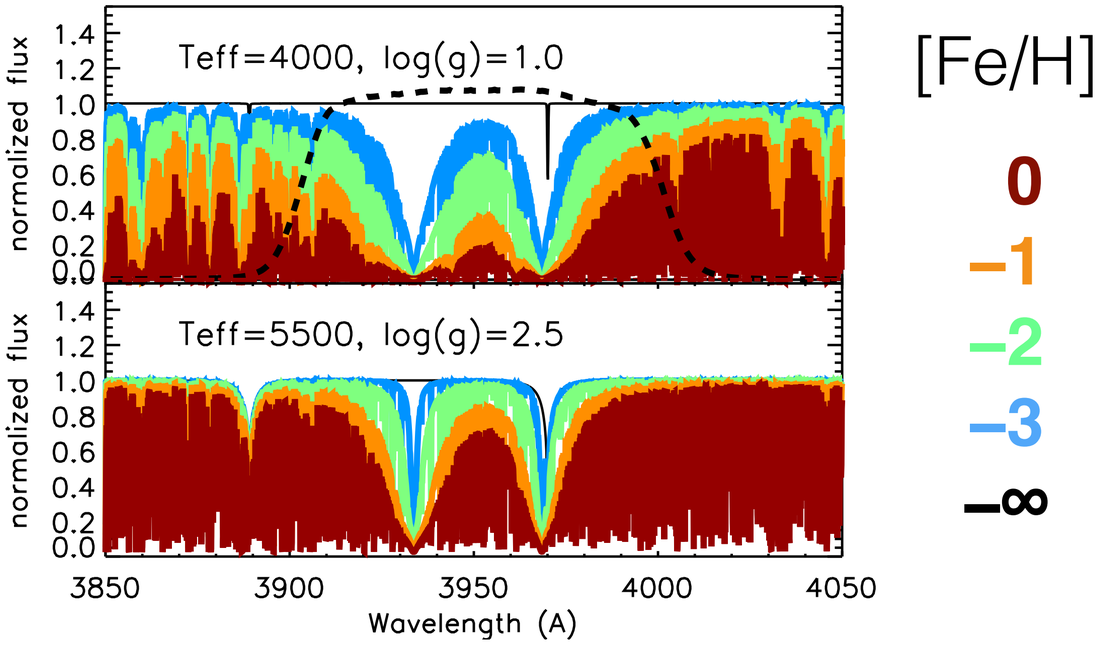
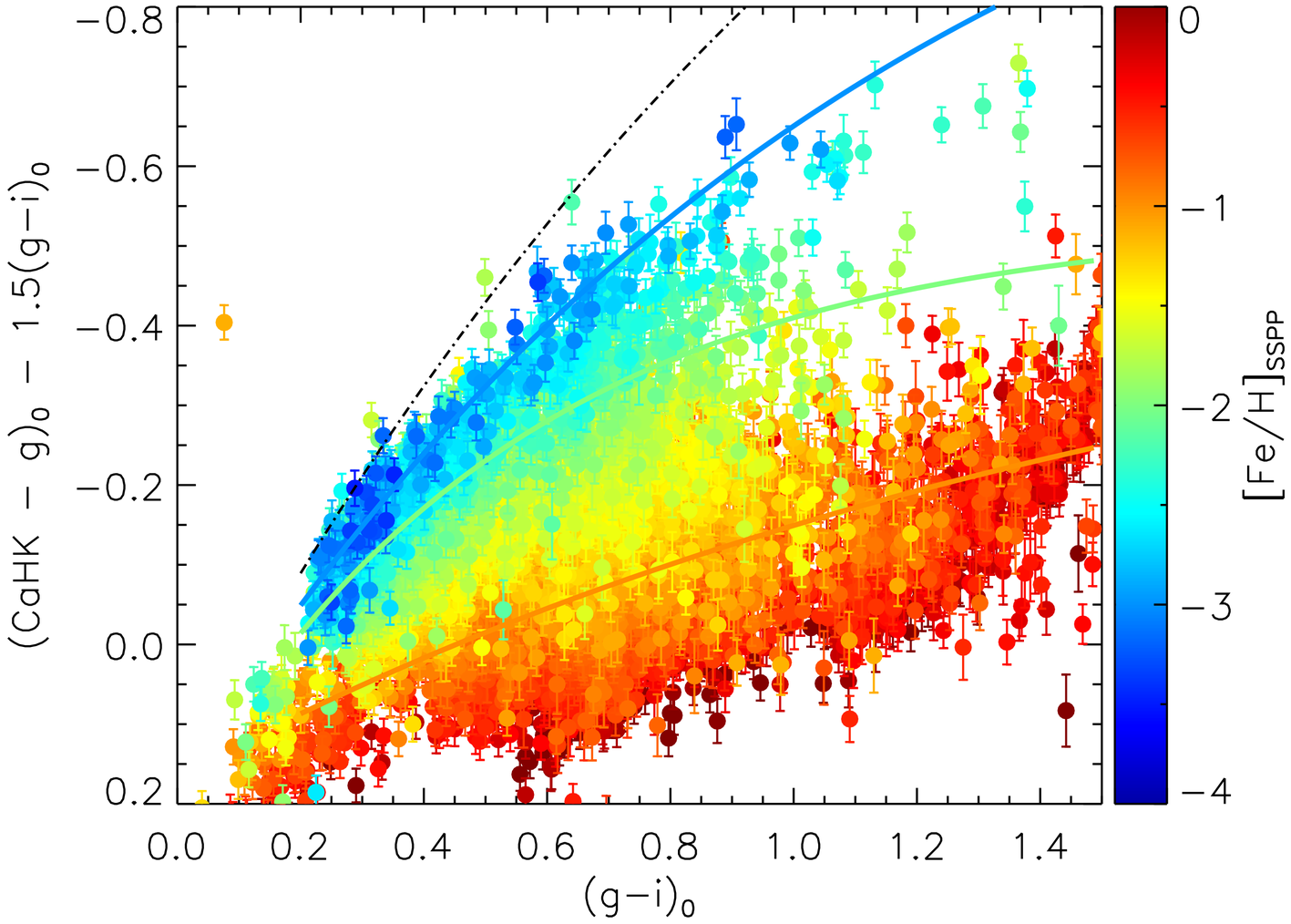
*Starkenburg+17a*




CaHK filter @ CFHT

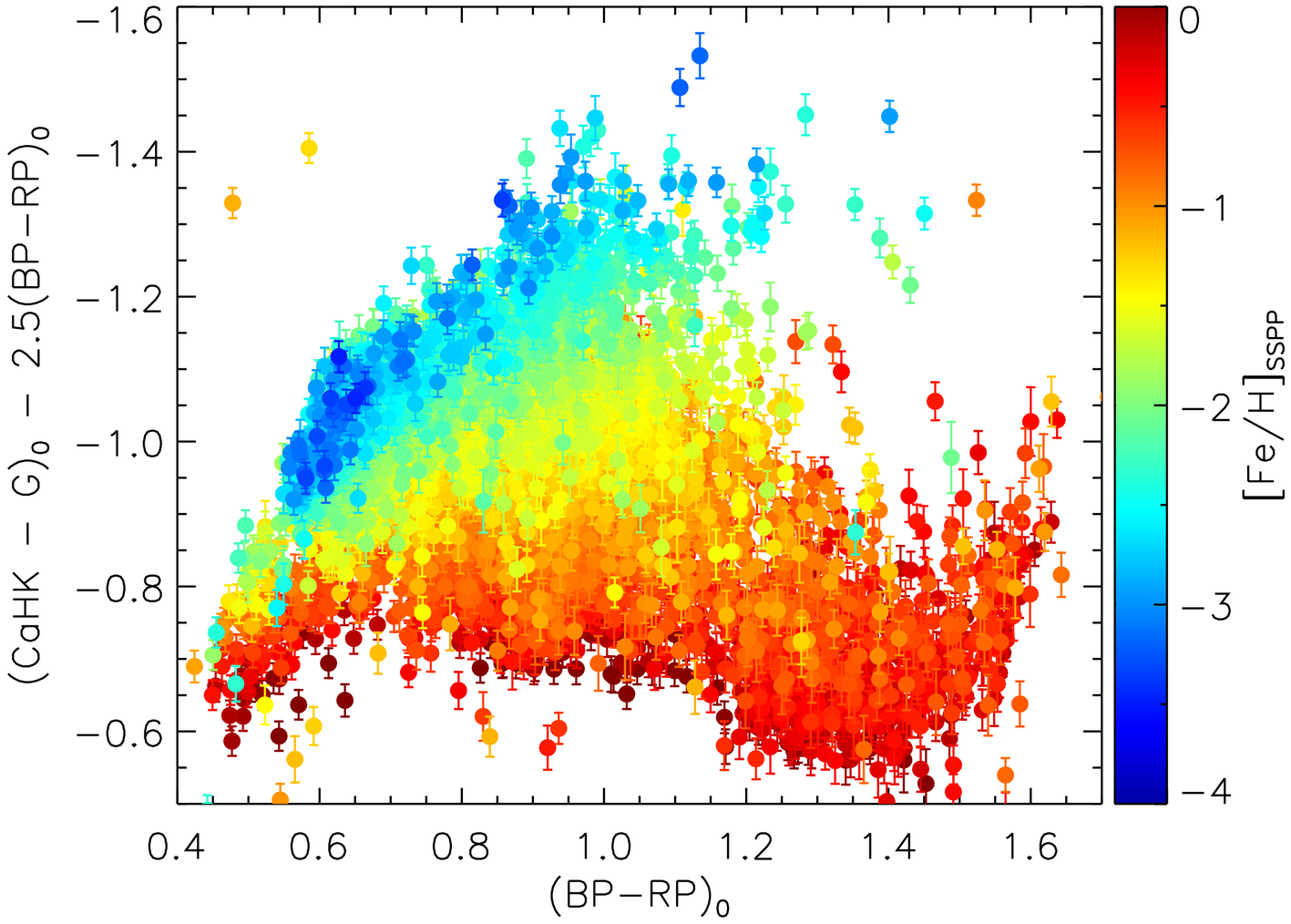
# Metal-poor stars with Pristine




*Starkenburg+17a*

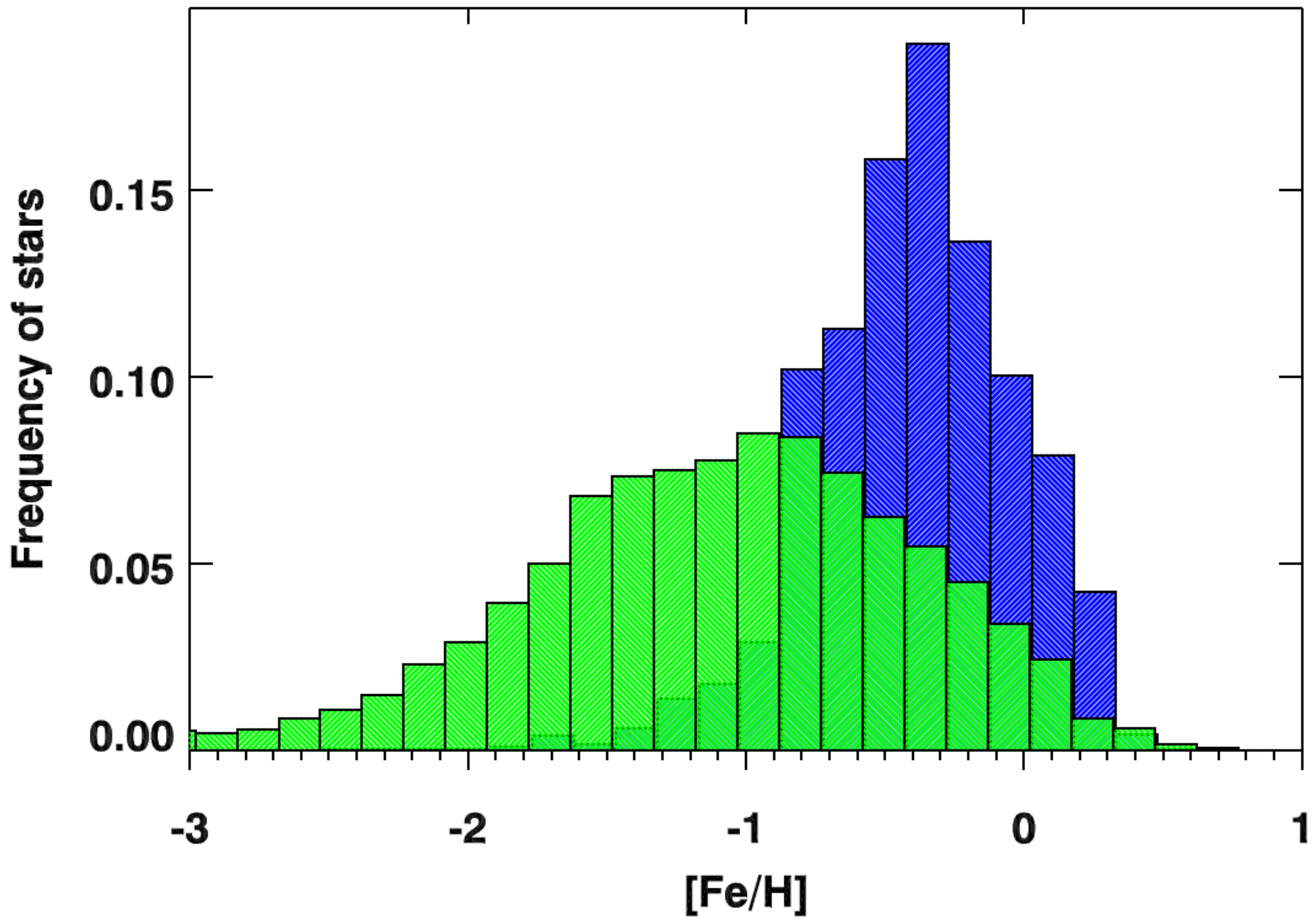
With **SDSS**
photometry & CaHK

# Metal-poor stars with Pristine




With **Gaia DR2**
photometry & CaHK

# The metal-poor stars in the bulge




MDF in the **SkyMapper/EMBLA** survey (Howes+14,15,16) compared to the **ARGOS** survey (Ness+13)

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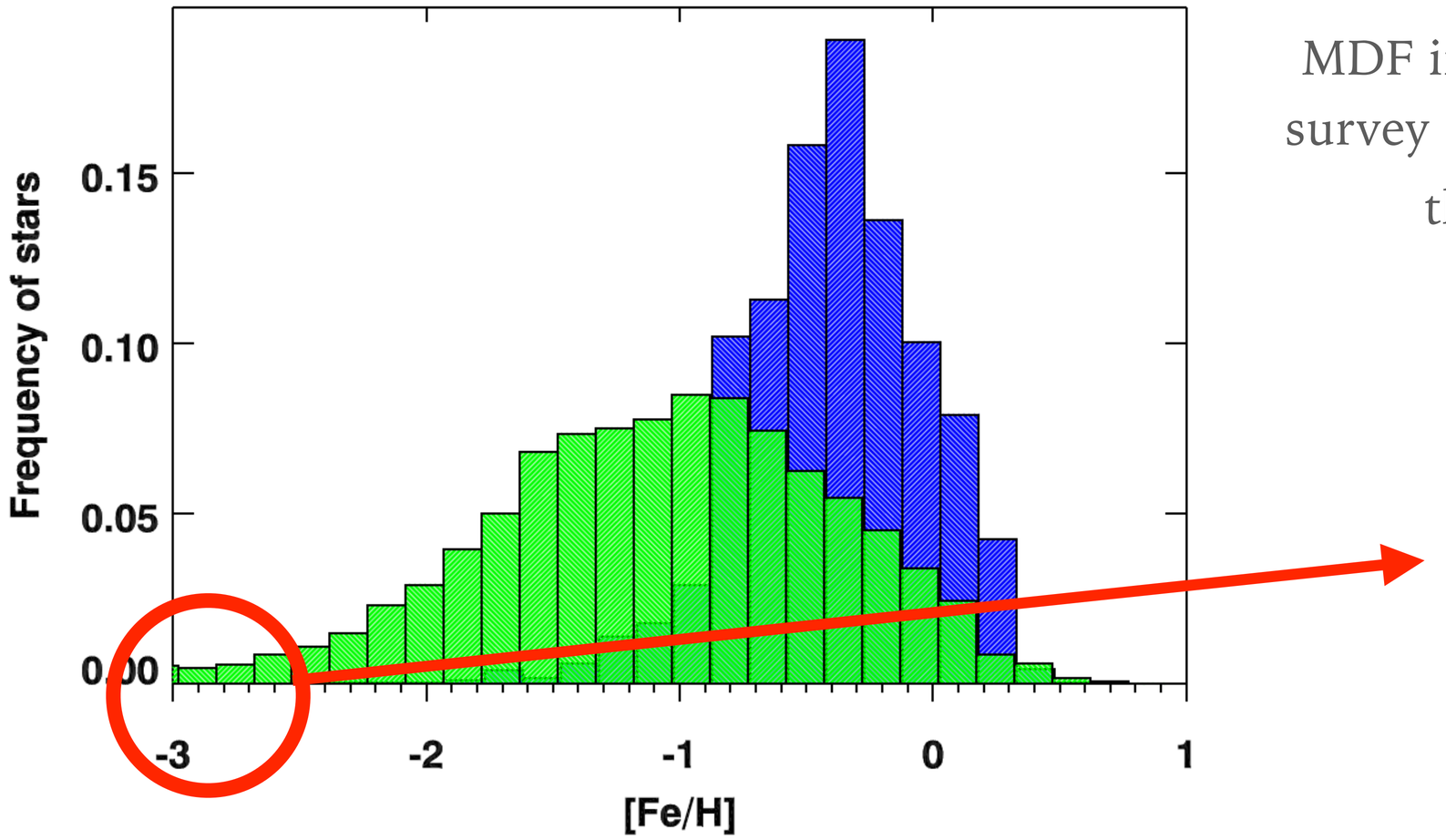


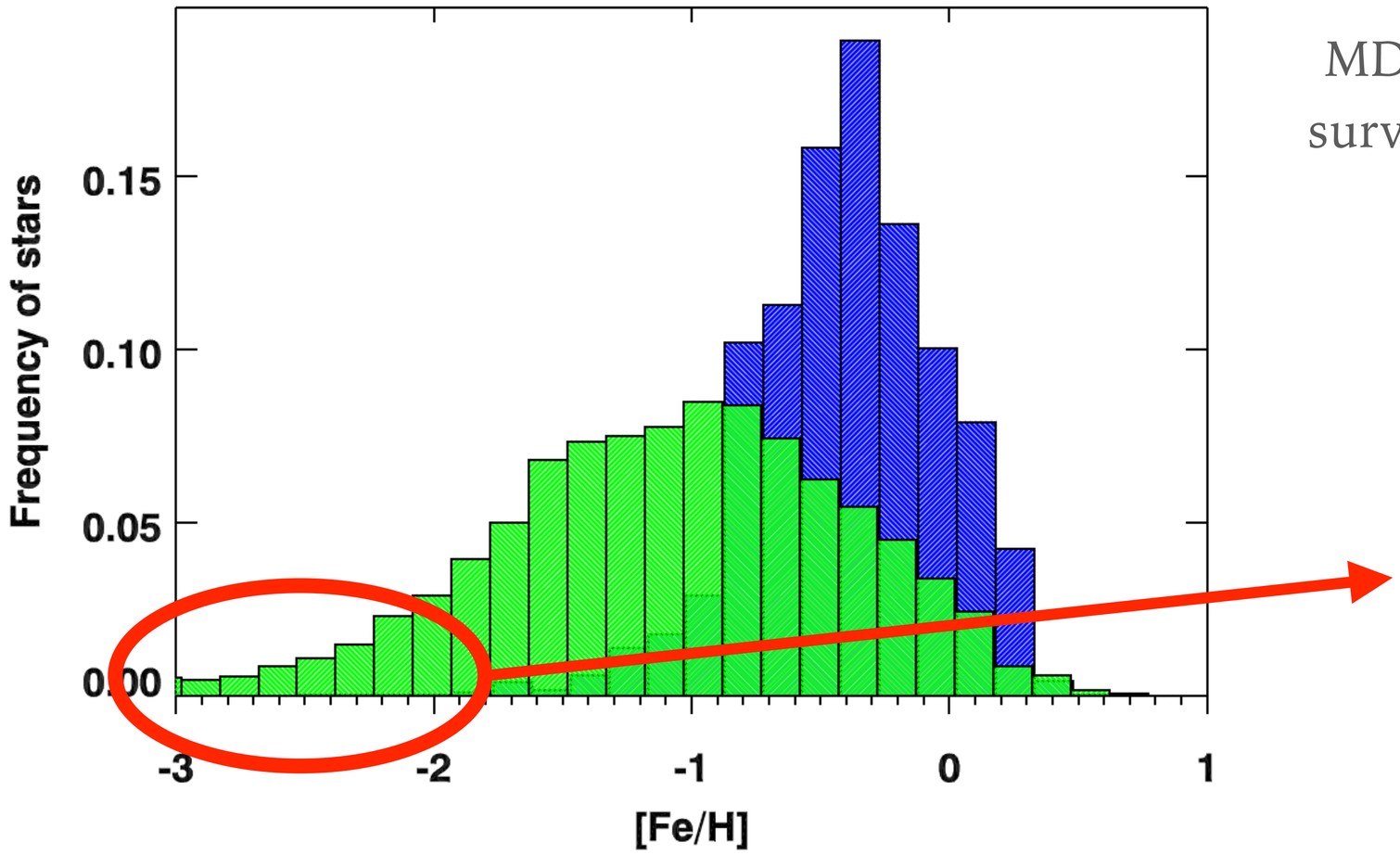

MDF in the **SkyMapper/EMBLA** survey (Howes+14,15,16) compared to the **ARGOS** survey (Ness+13)

Very few stars!

~150 stars [Fe/H] < -2.5

9 stars [Fe/H] < −3.0

# The metal-poor stars in the bulge

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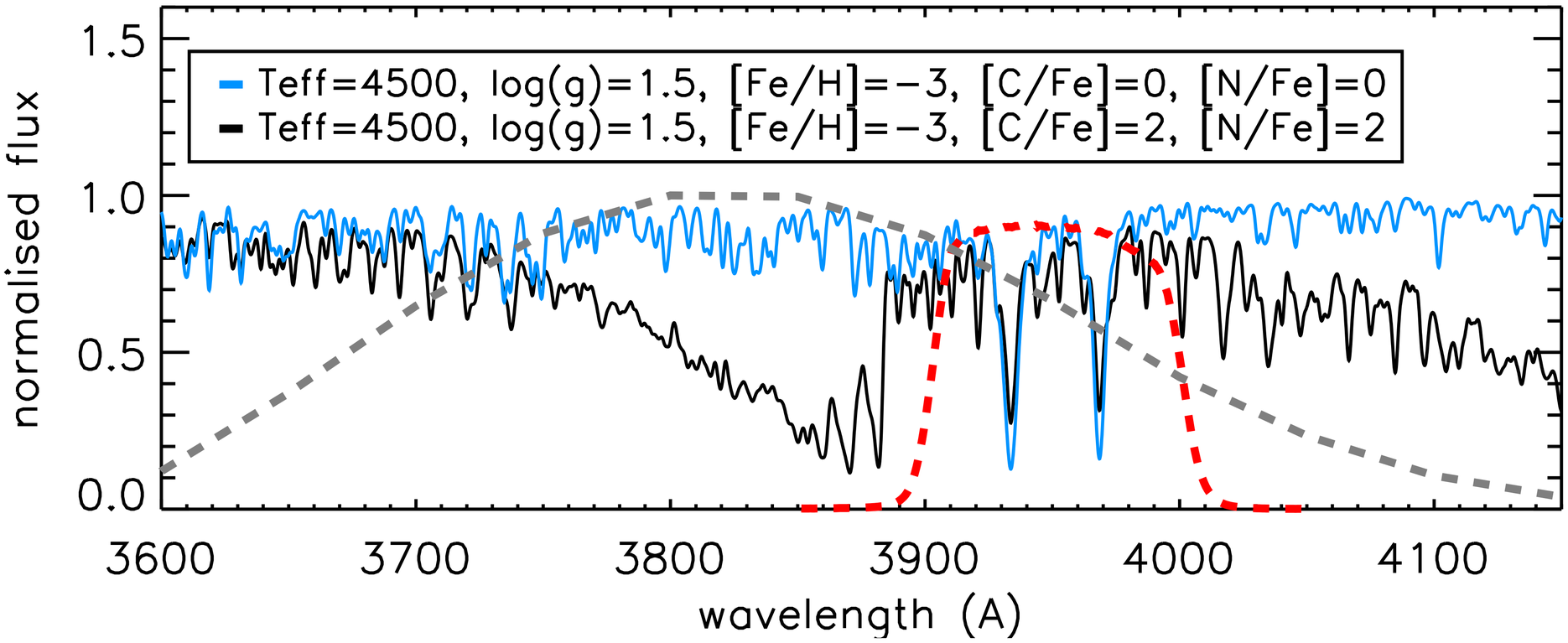
Almost no CEMP stars (3%)!
In the halo it is ~27% for stars with [Fe/H] < −2.0

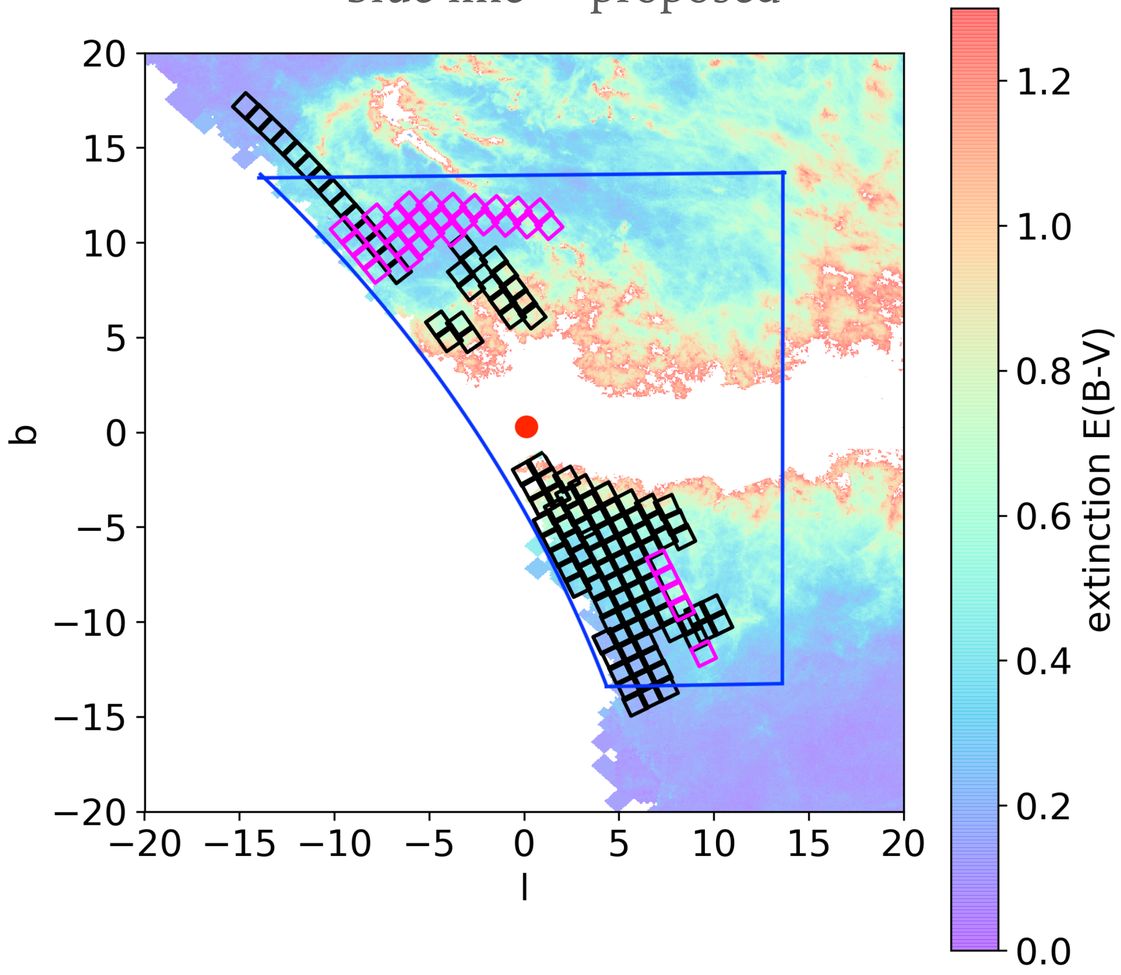
# Comparison of the Pristine and SkyMapper filters




**SkyMapper**
**Pristine**

# Pristine in the Bulge

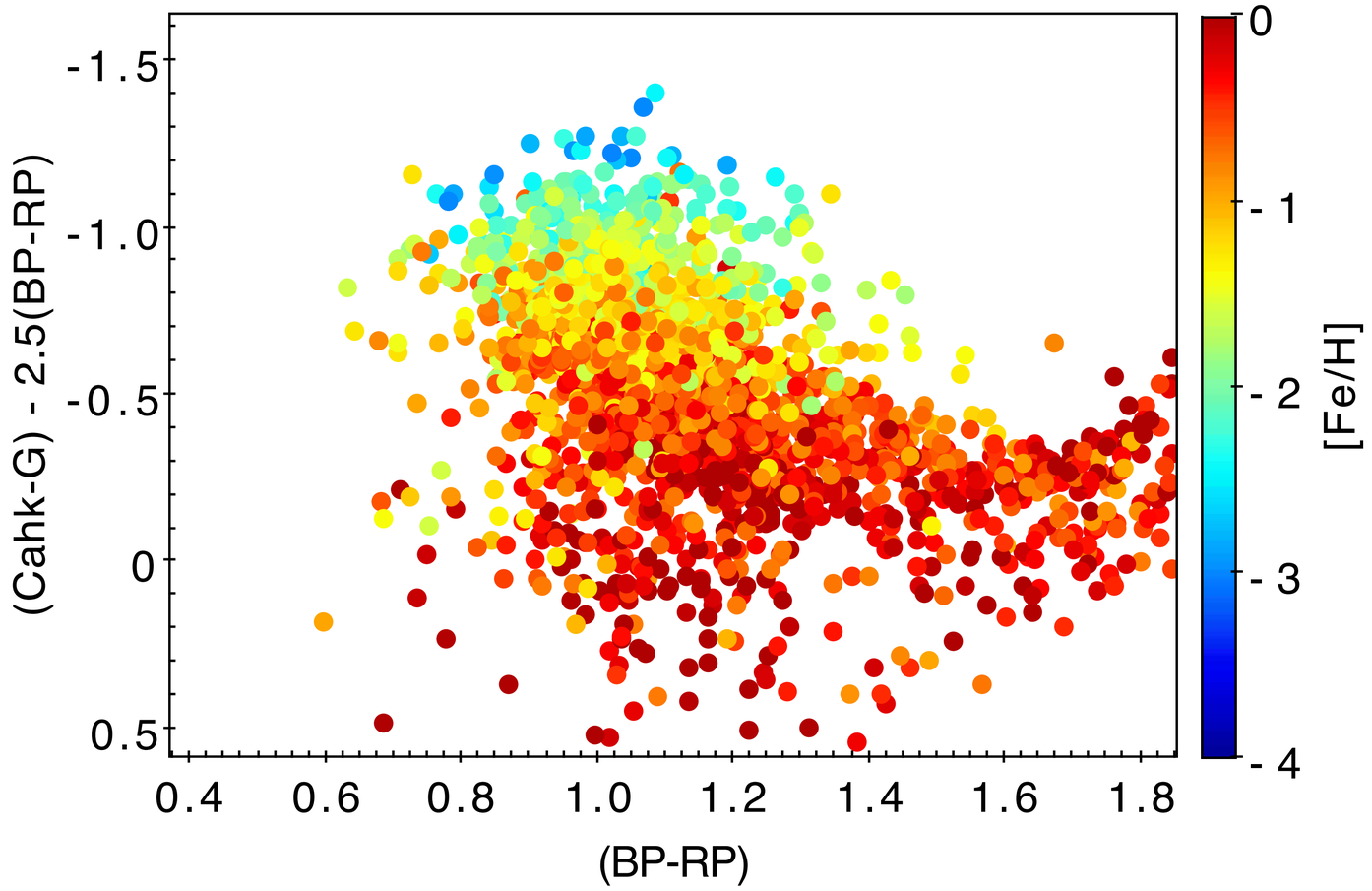
black+magenta squares = observed
blue line = proposed




Using the PanSTARRS1 Bayestar extinction map (Green+15,18)

We are limited by observing from the North (CFHT)

# Pristine in the bulge

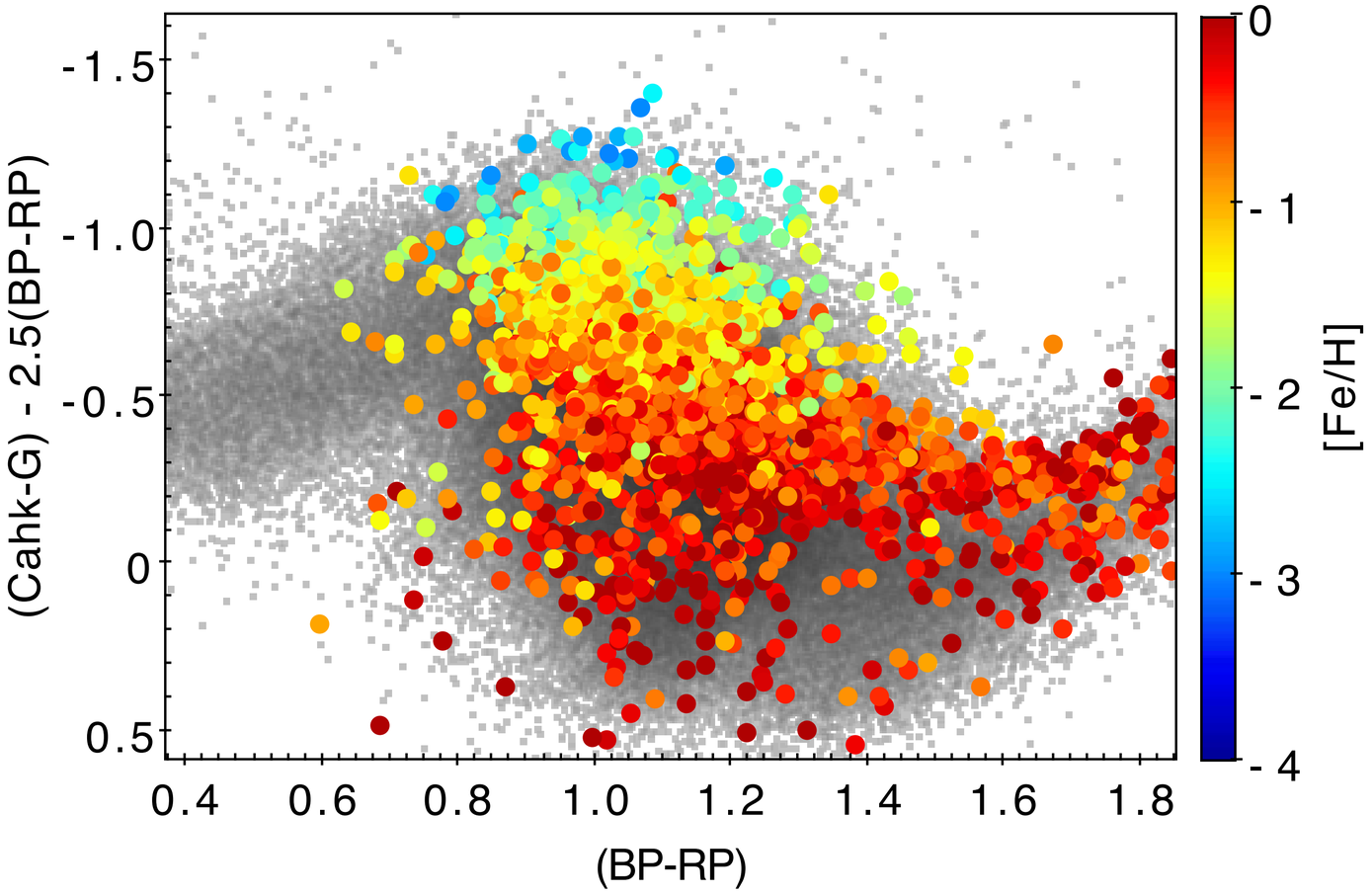



Pilot photometry Pristine colour-colour plot with spectroscopic metallicities from EMBLA, ARGOS, APOGEE

broadband photometry from **Gaia** (with quality cuts)

*We thank Louise Howes and Melissa Ness for sharing (part) of the EMBLA and ARGOS metallicities*

# Pristine in the bulge

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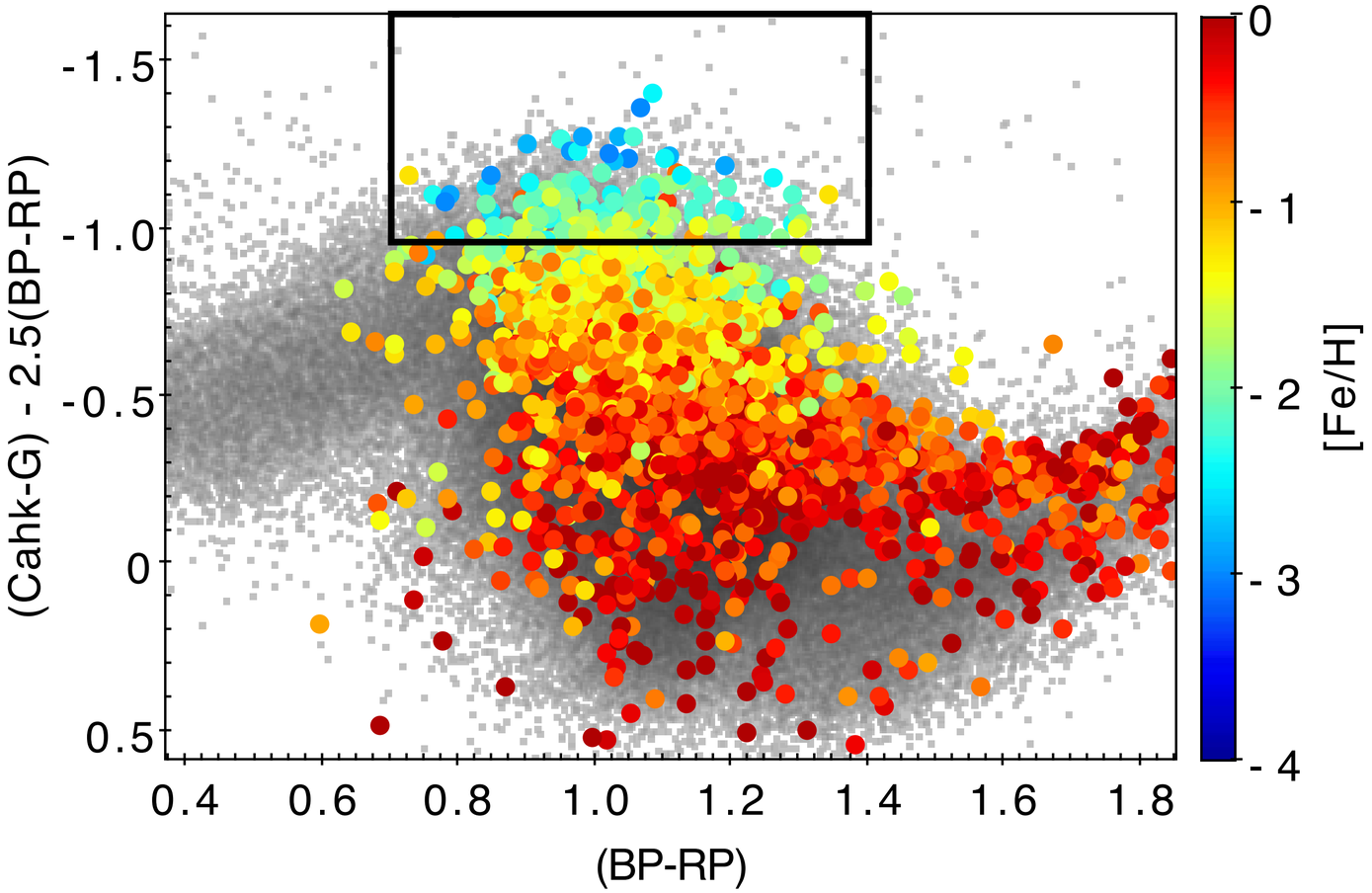


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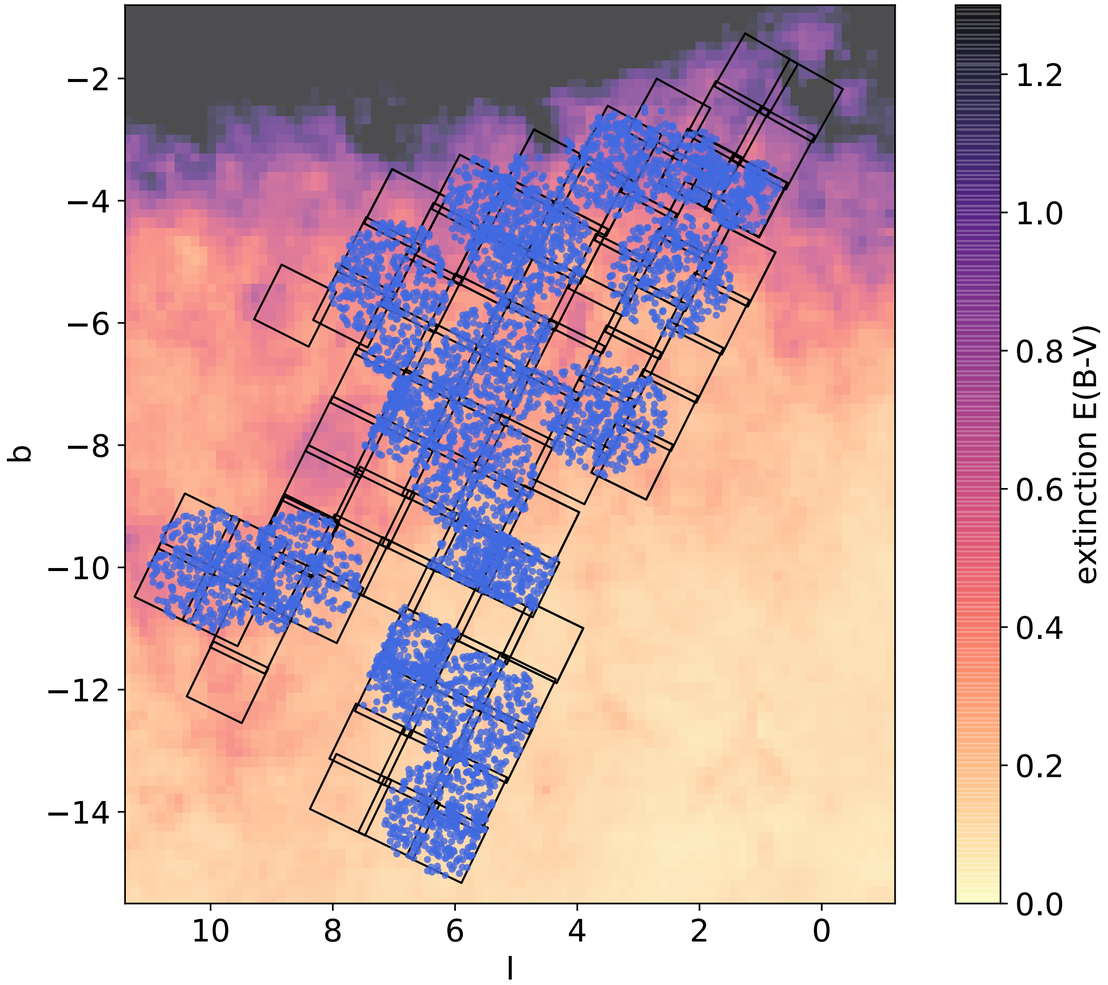
# Low-/intermediate resolution follow-up



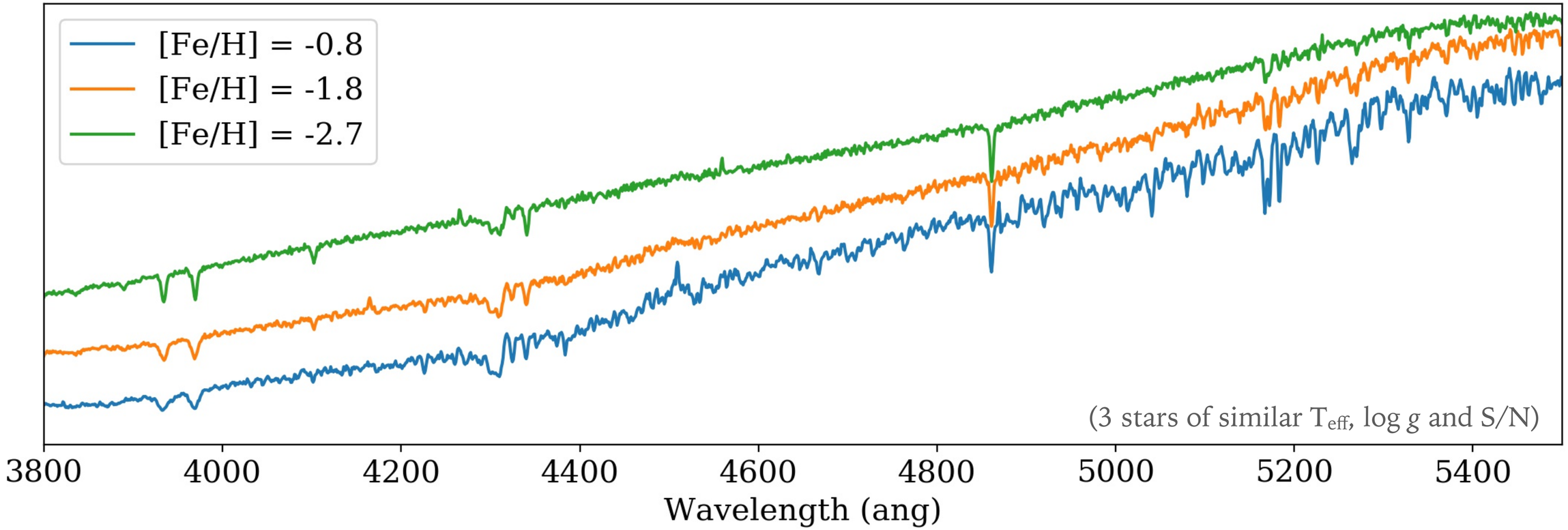

~6000 stars

AAT/AAOmega+2dF
(400 fibres in 2 degree field)

R~1300 in blue arm
R~10000 in red (CaT)

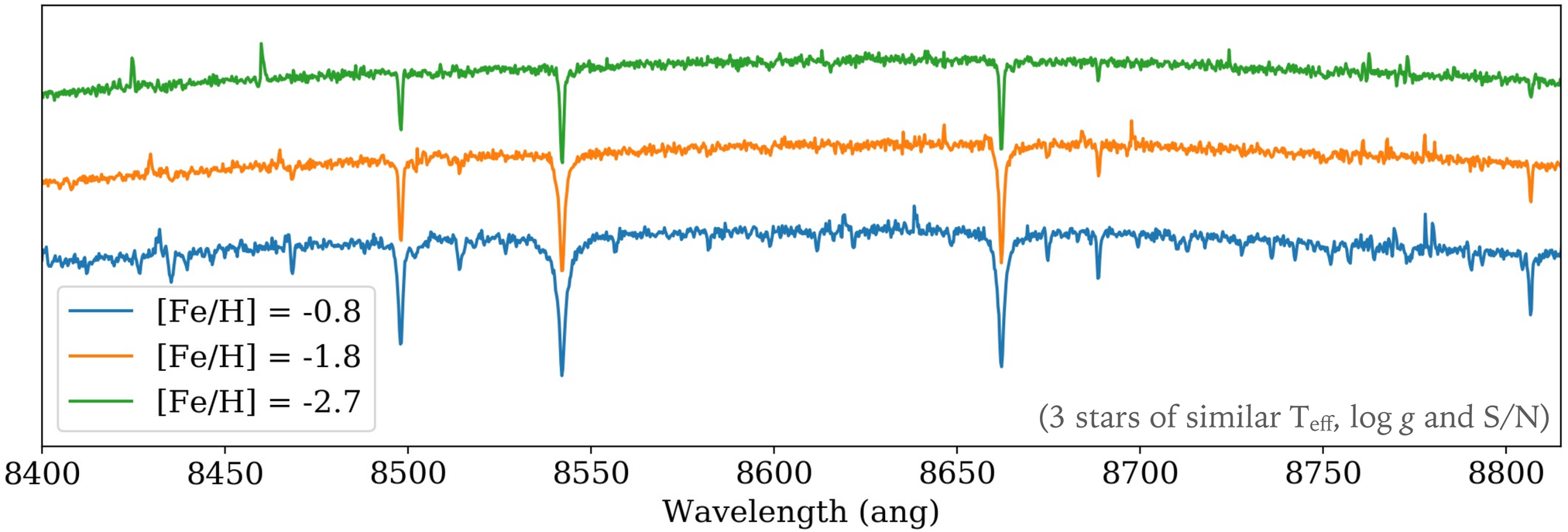
# Low-/intermediate resolution follow-up

## Teff, logg, [Fe/H] and [C/Fe]



# Low-/intermediate resolution follow-up

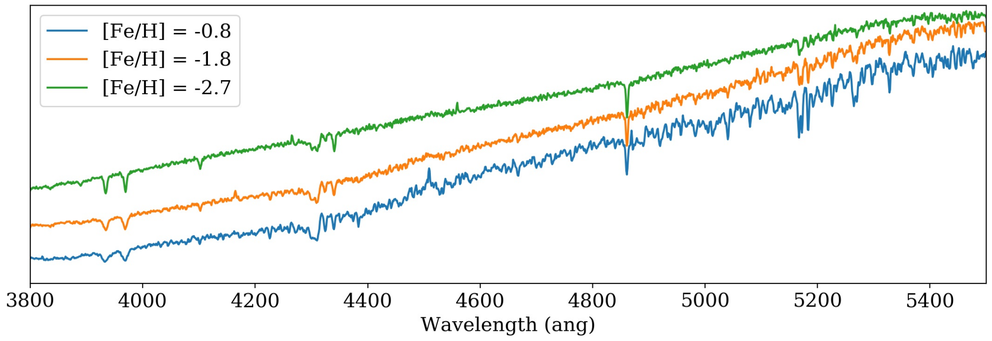
**Radial velocities, metallicities**
**(& some abundances?)**



# Low resolution follow-up

Full spectrum fitting of the blue spectra using
the empirical MILES library with the **ULySS** fitting code (Koleva+09)

> Teff, logg & [Fe/H] down to [Fe/H] = −2.8



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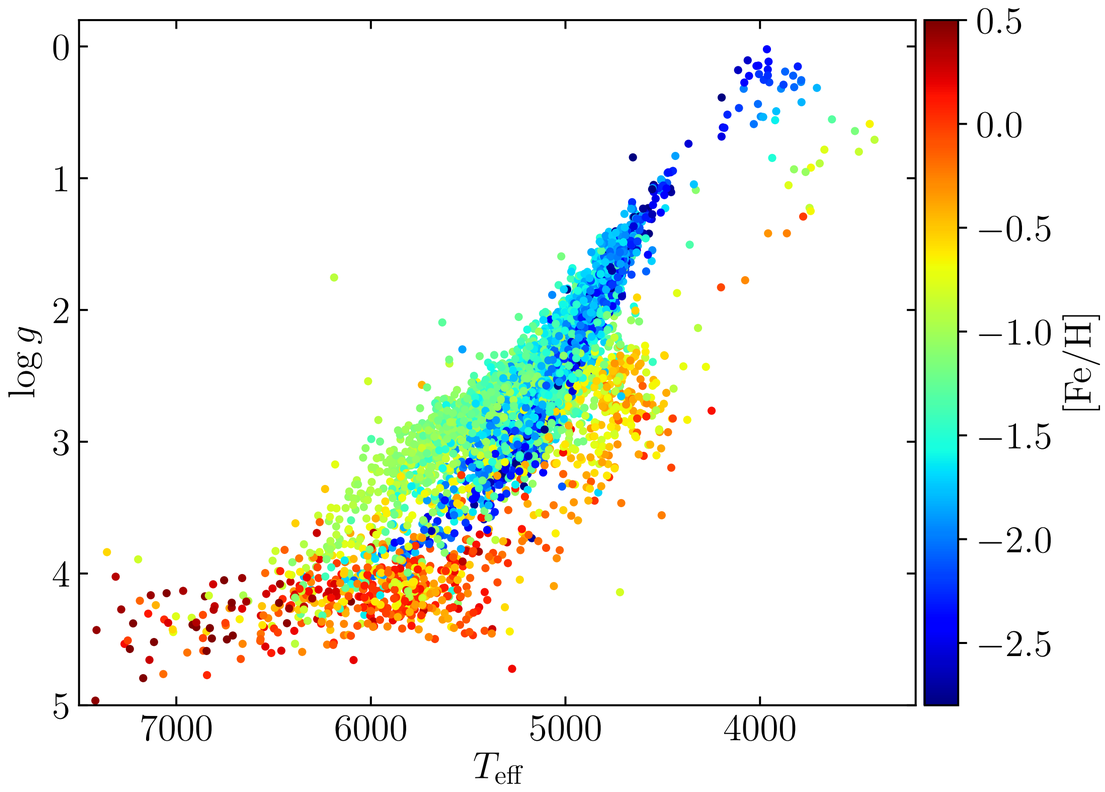
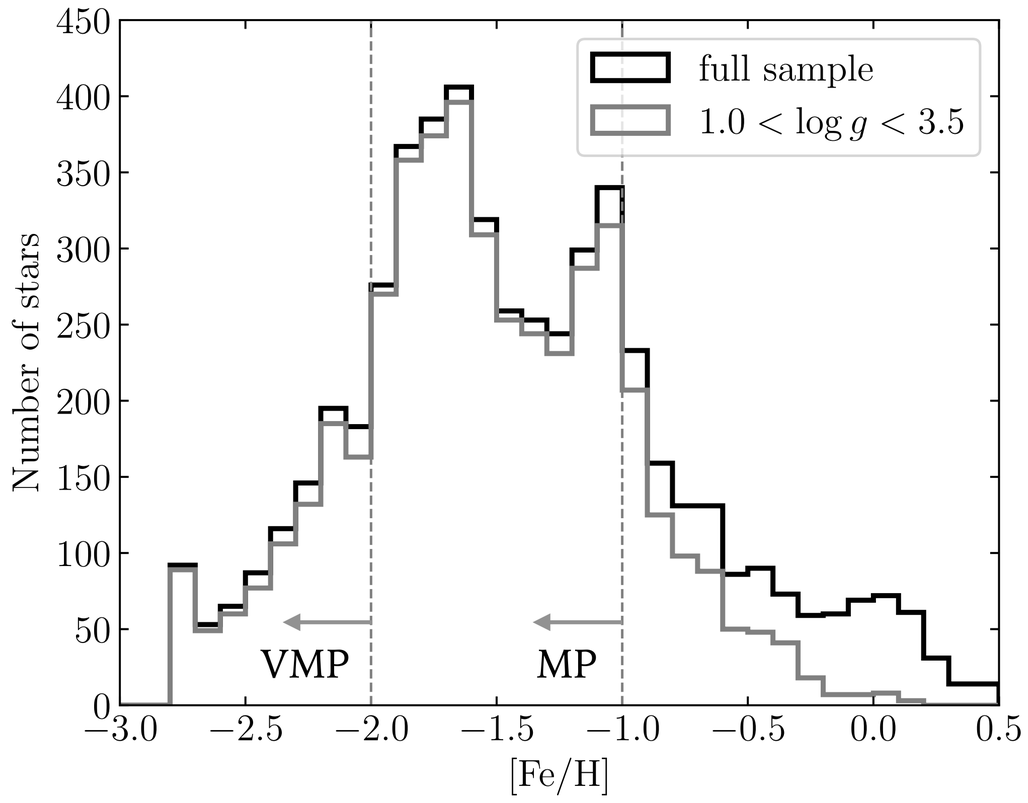
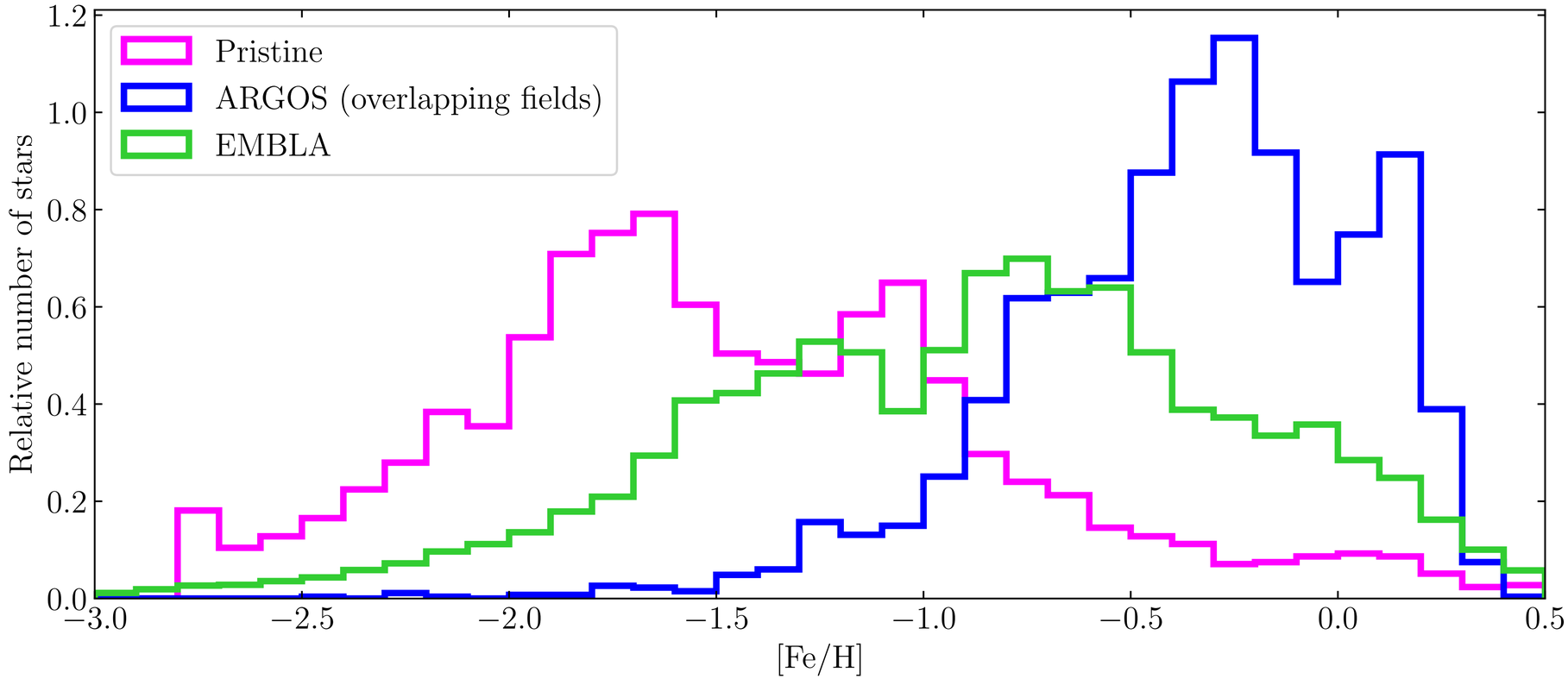


# Metallicity Distribution Function of our sample

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# Low resolution follow-up: metal-poor tail & [C/Fe]

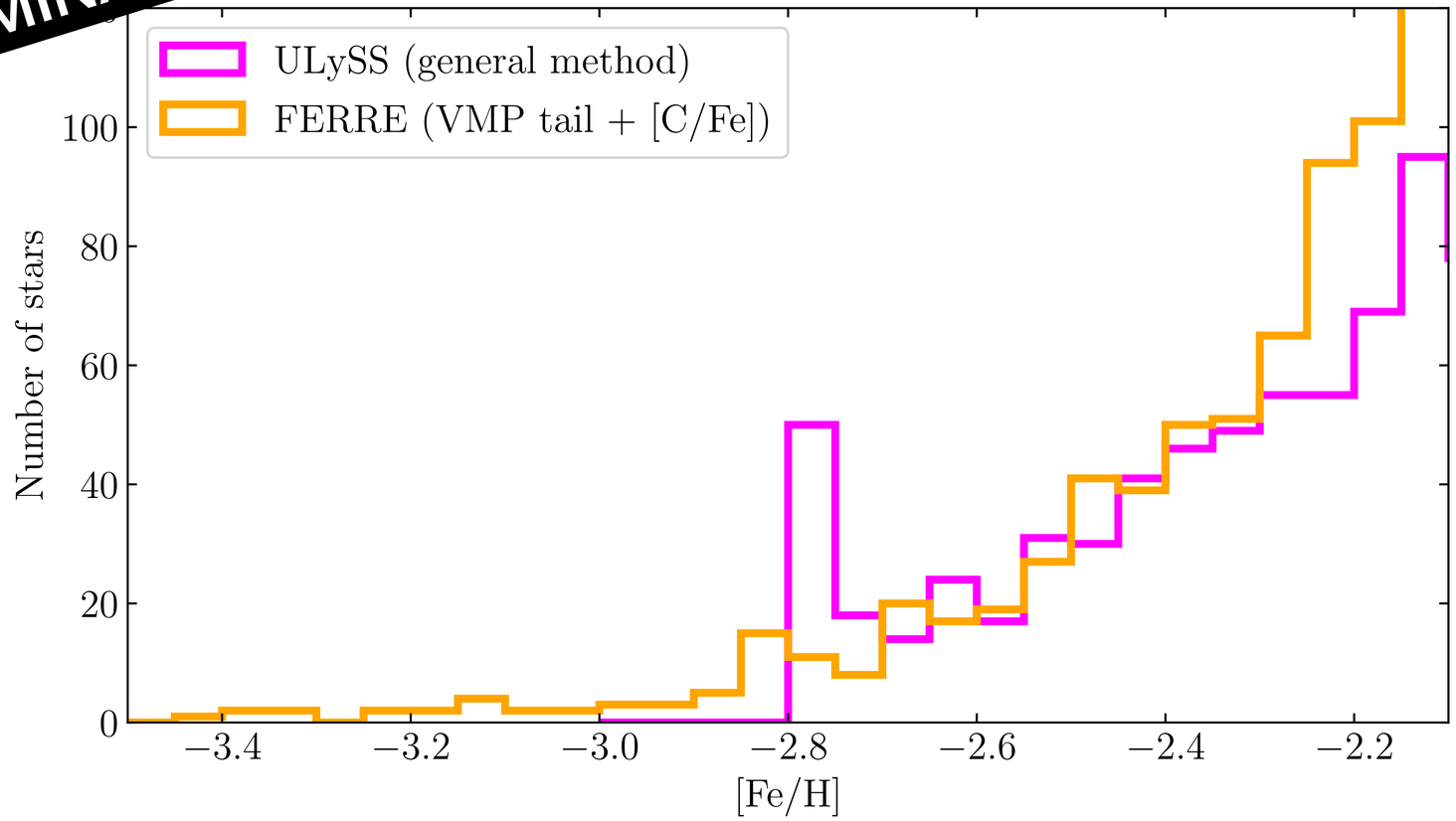
Low-[Fe/H] tail and [C/Fe] are still work in progress, using the synthetic CRUMP library with **FERRE** (Allende Prieto+06)

> below [Fe/H] = −2.0 (down to −6.0)

# Metallicity Distribution Function of our sample

Our two methods at low [Fe/H]

PRELIMINARY



# A closer look at the selection

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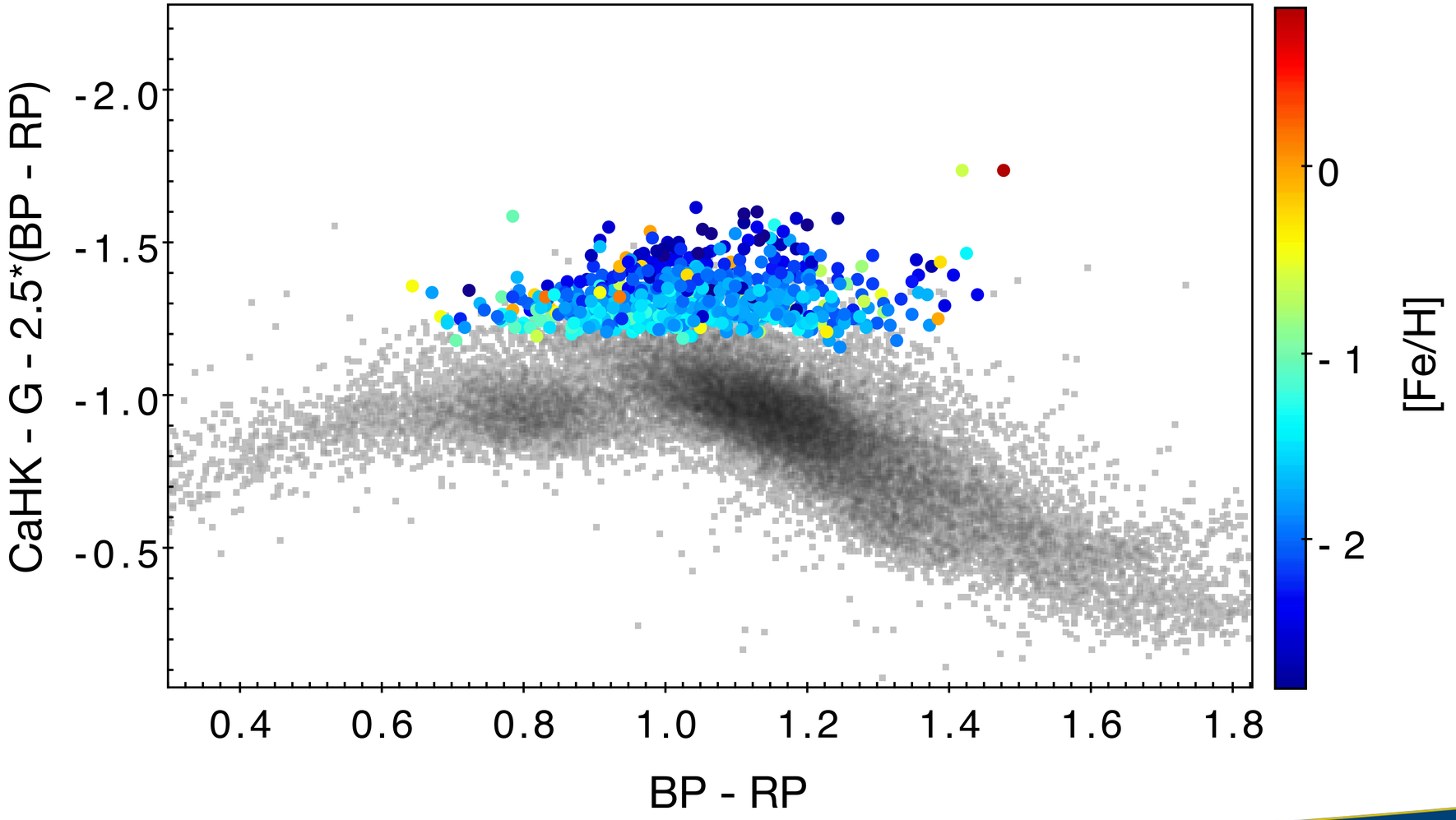
Low extinction region (EBV < 0.2)

(dereddened using PanSTARRS Bayestar extinction map)

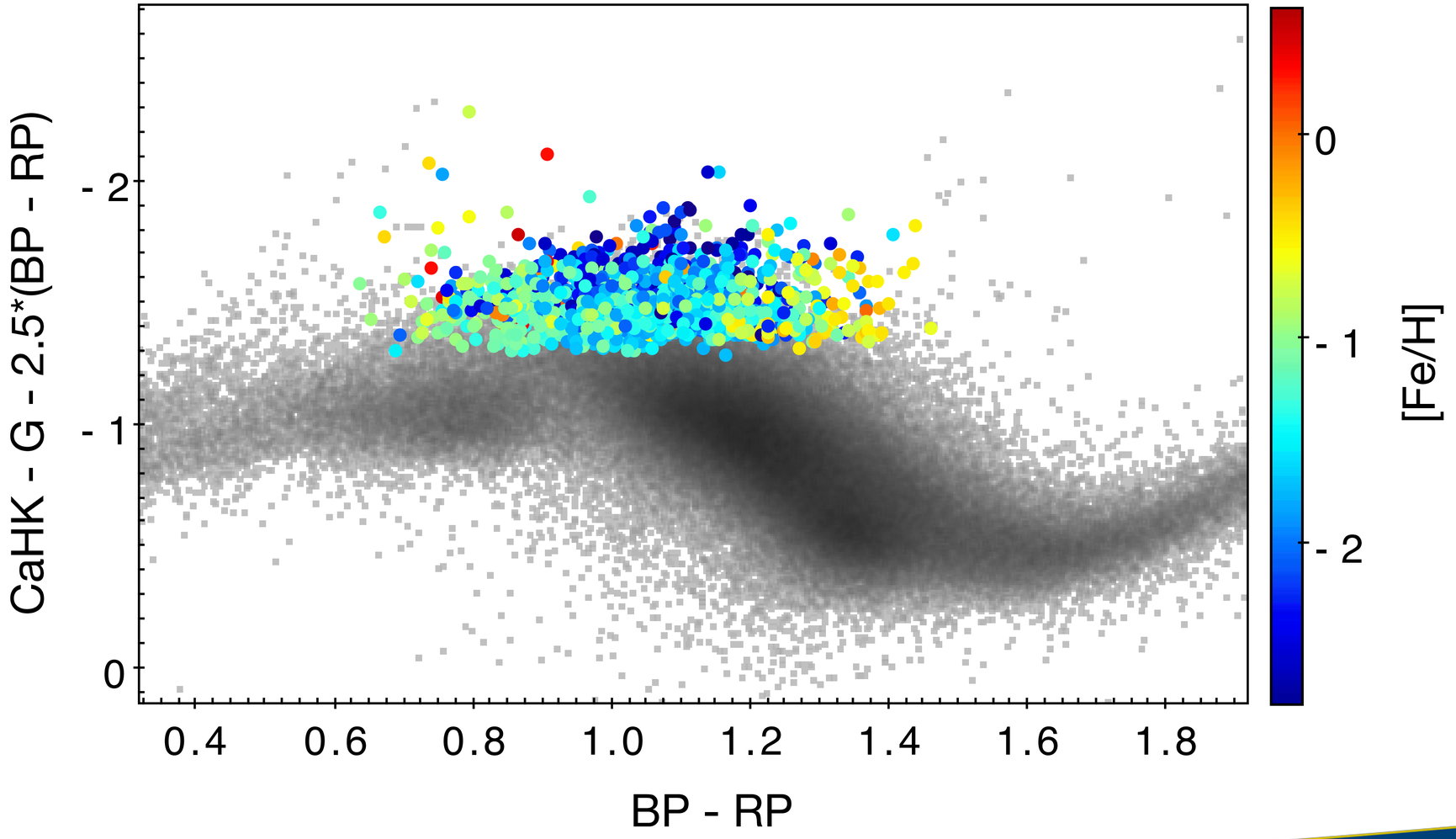


# A closer look at the selection

for regions with
|b| > 7

(EBV from 0.2 - 0.5)

(dereddened using PanSTARRS Bayestar extinction map)



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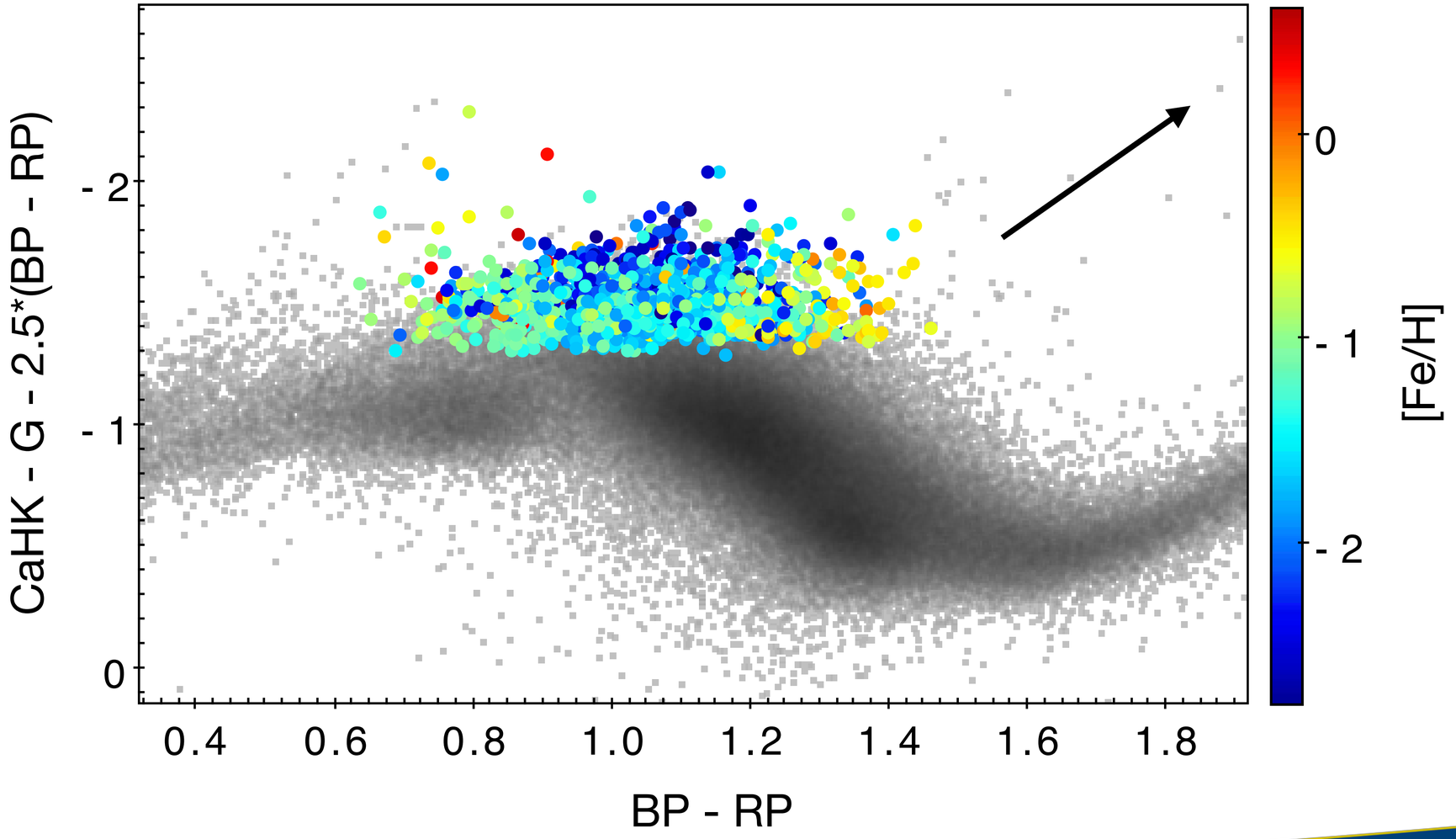
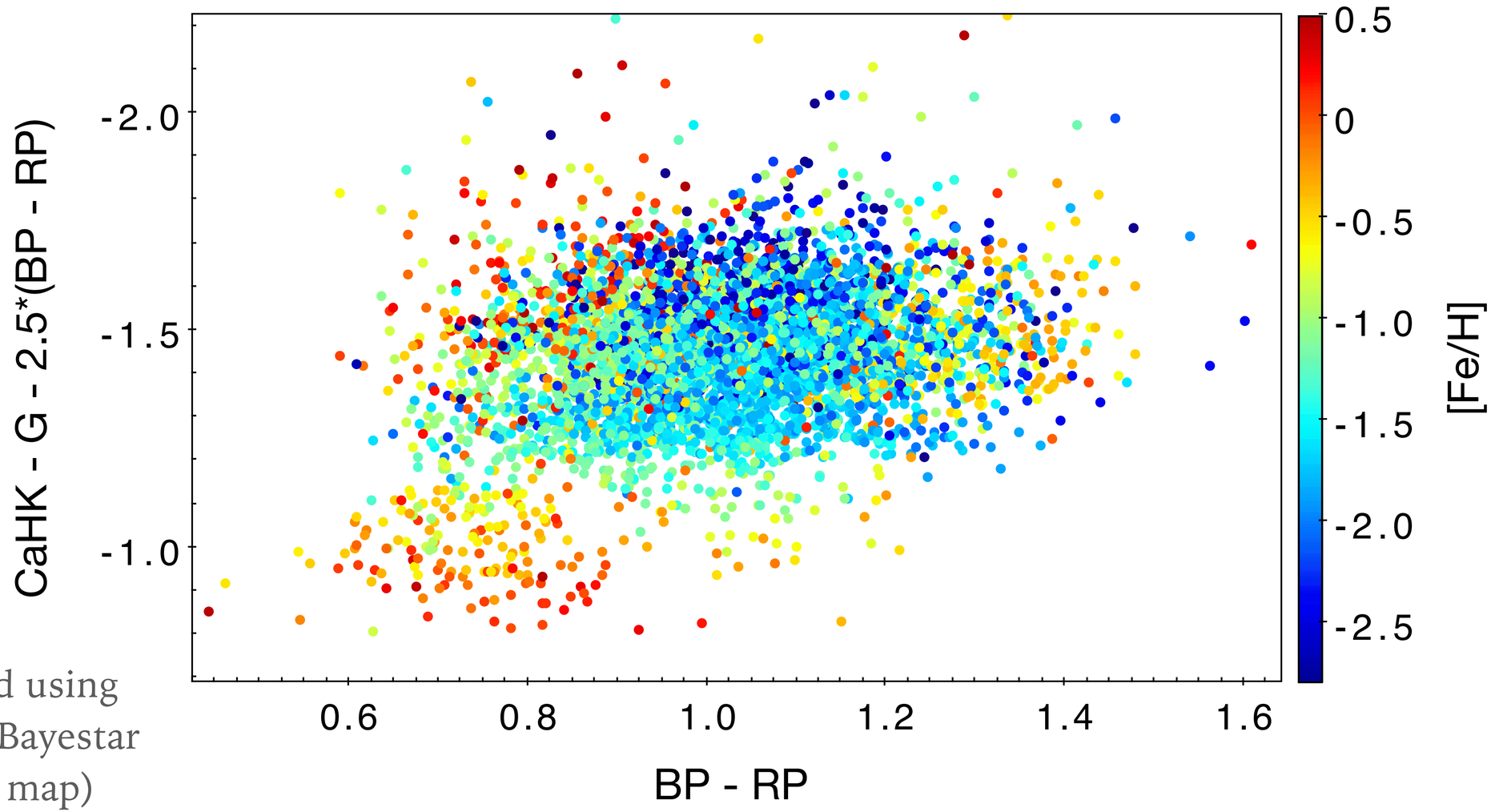
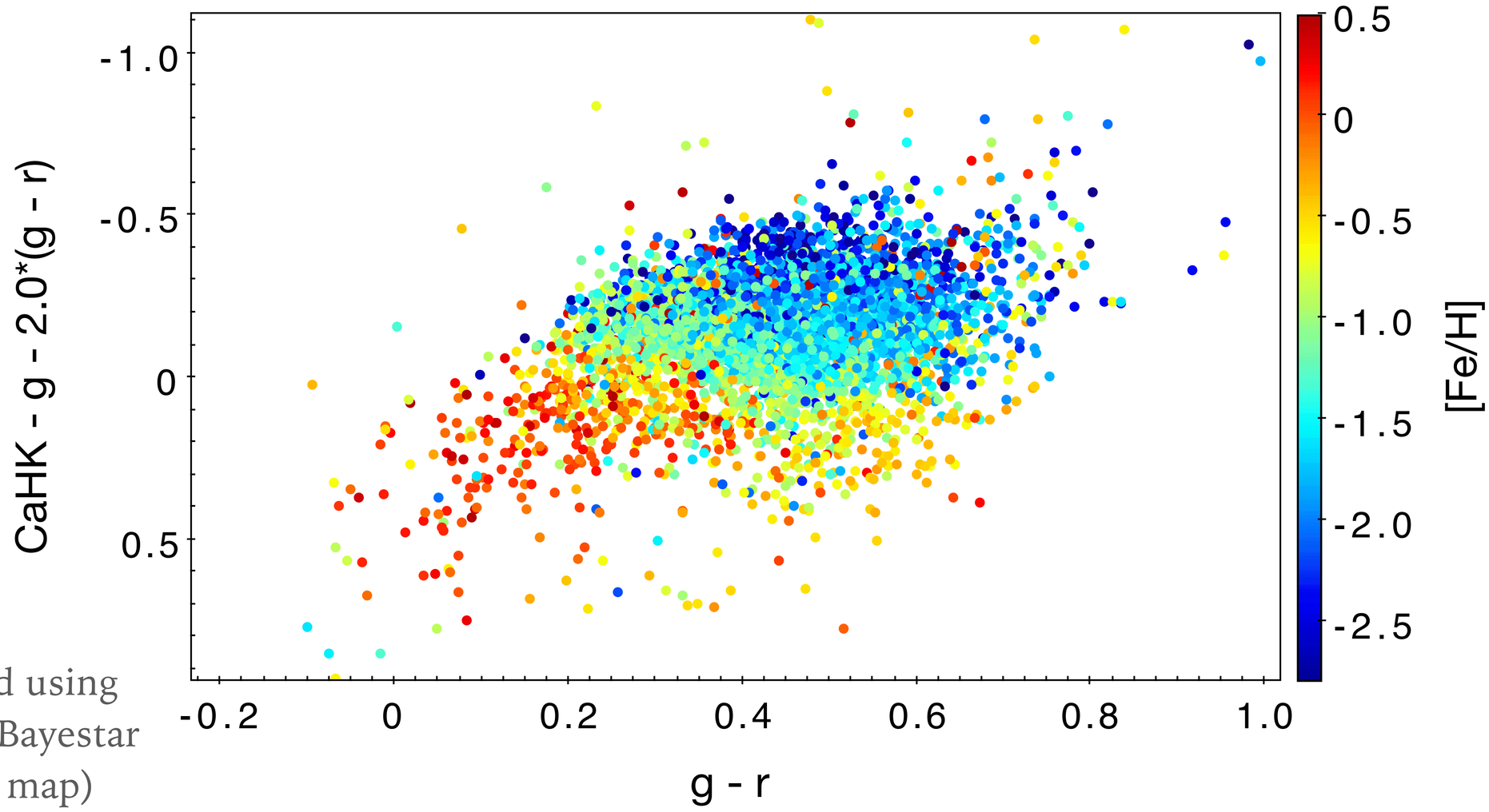


# All follow-up: Gaia DR2 photometry



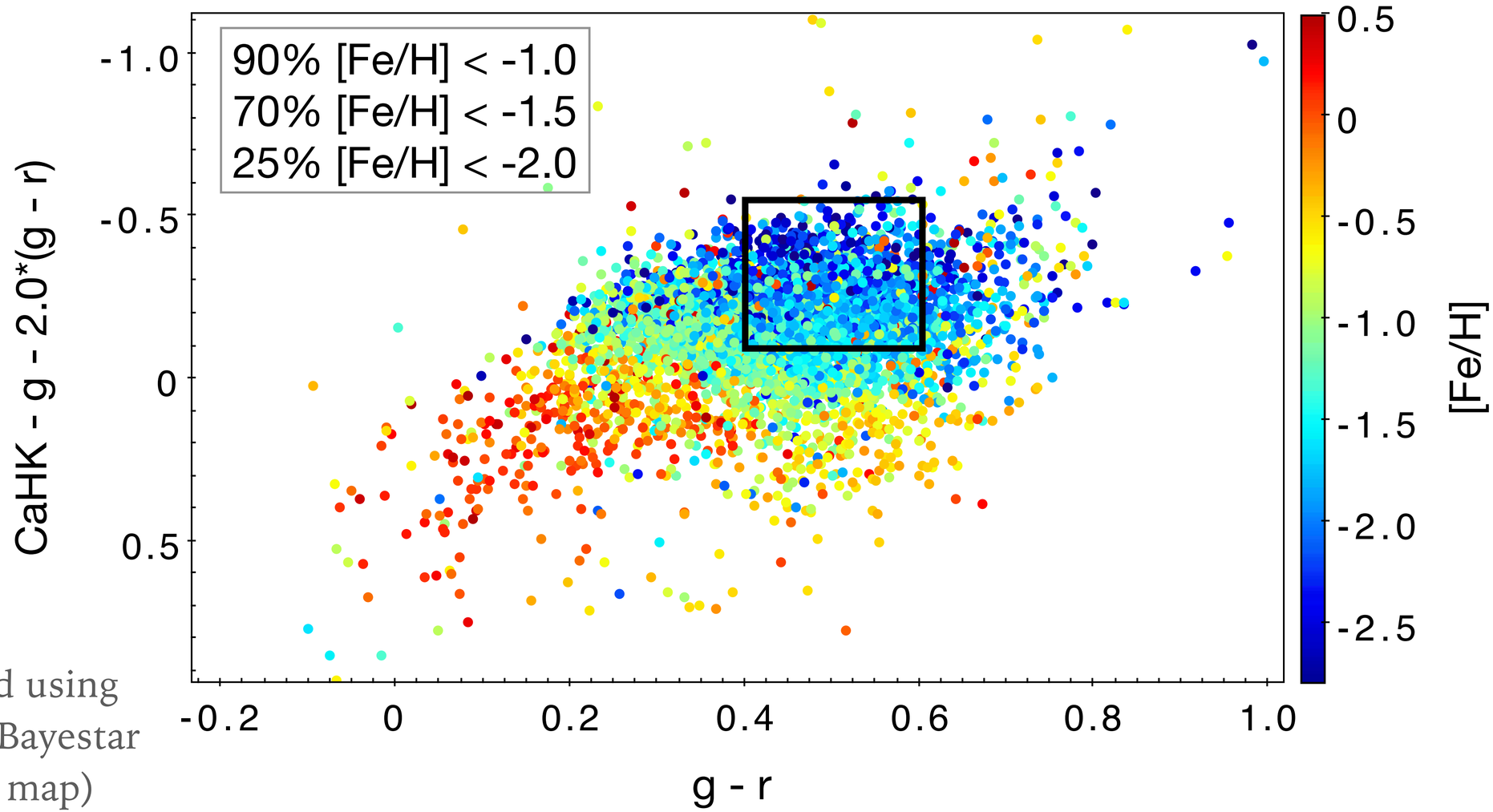

(dereddened using PanSTARRS Bayestar extinction map)

# All follow-up: PanSTARRS DR1 photometry




(dereddened using PanSTARRS Bayestar extinction map)

# PanSTARRS DR1 photometry: efficiency

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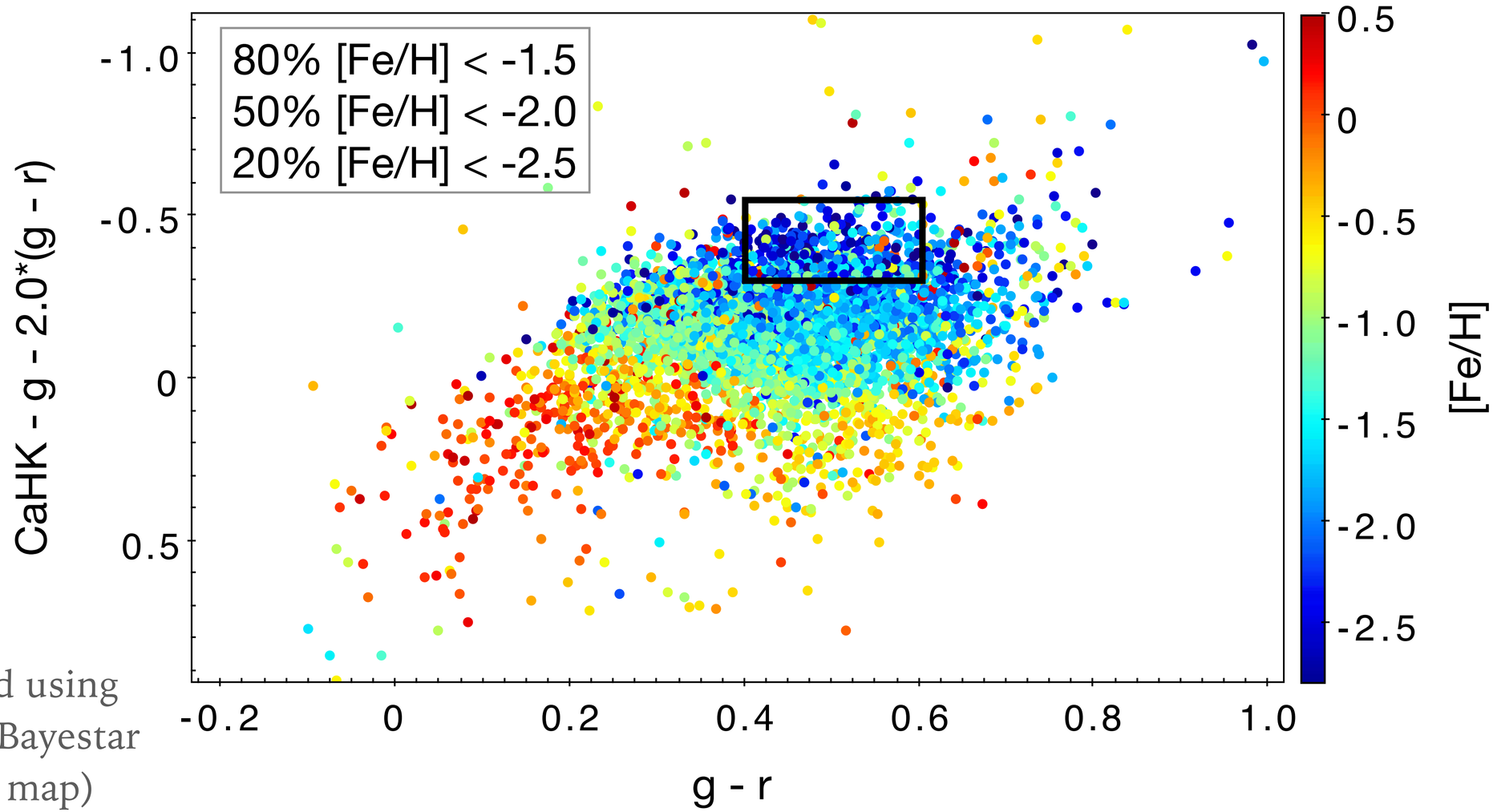


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# Kinematics of the Pristine stars

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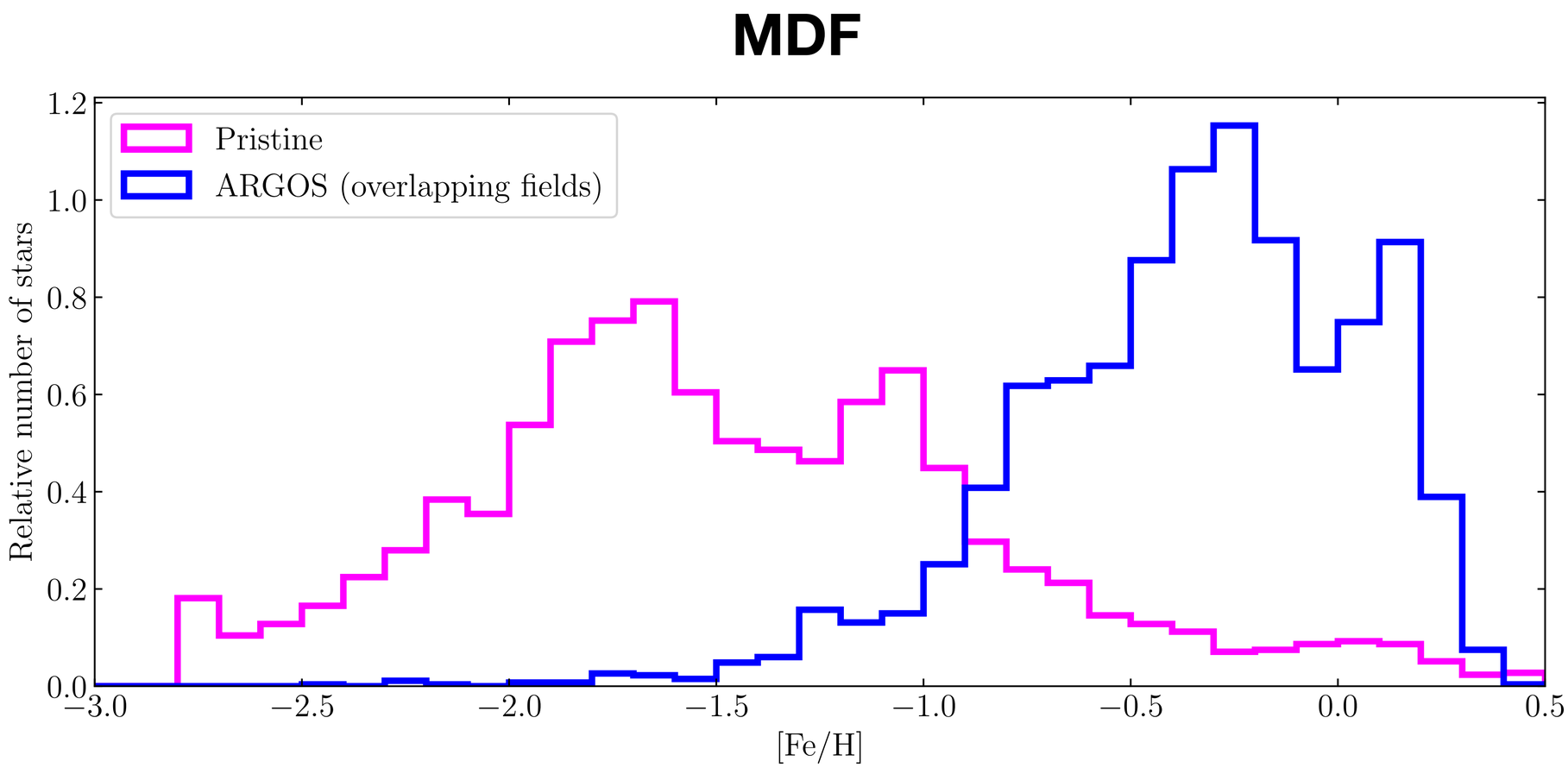


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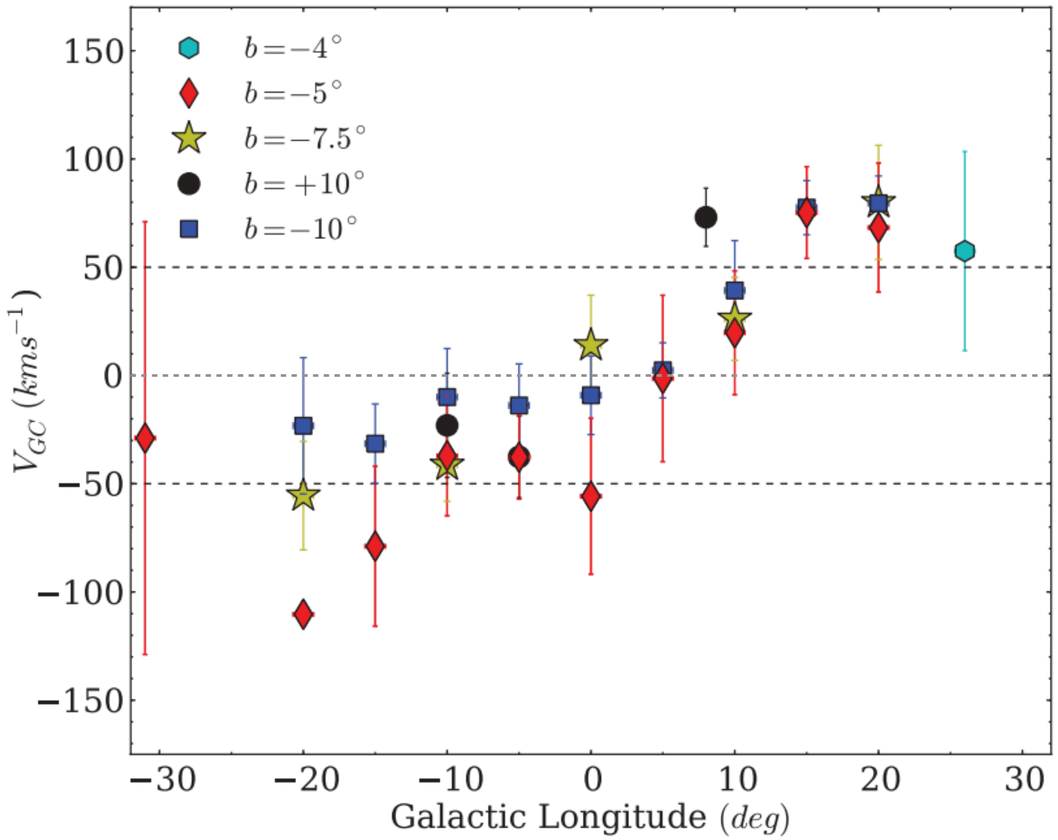
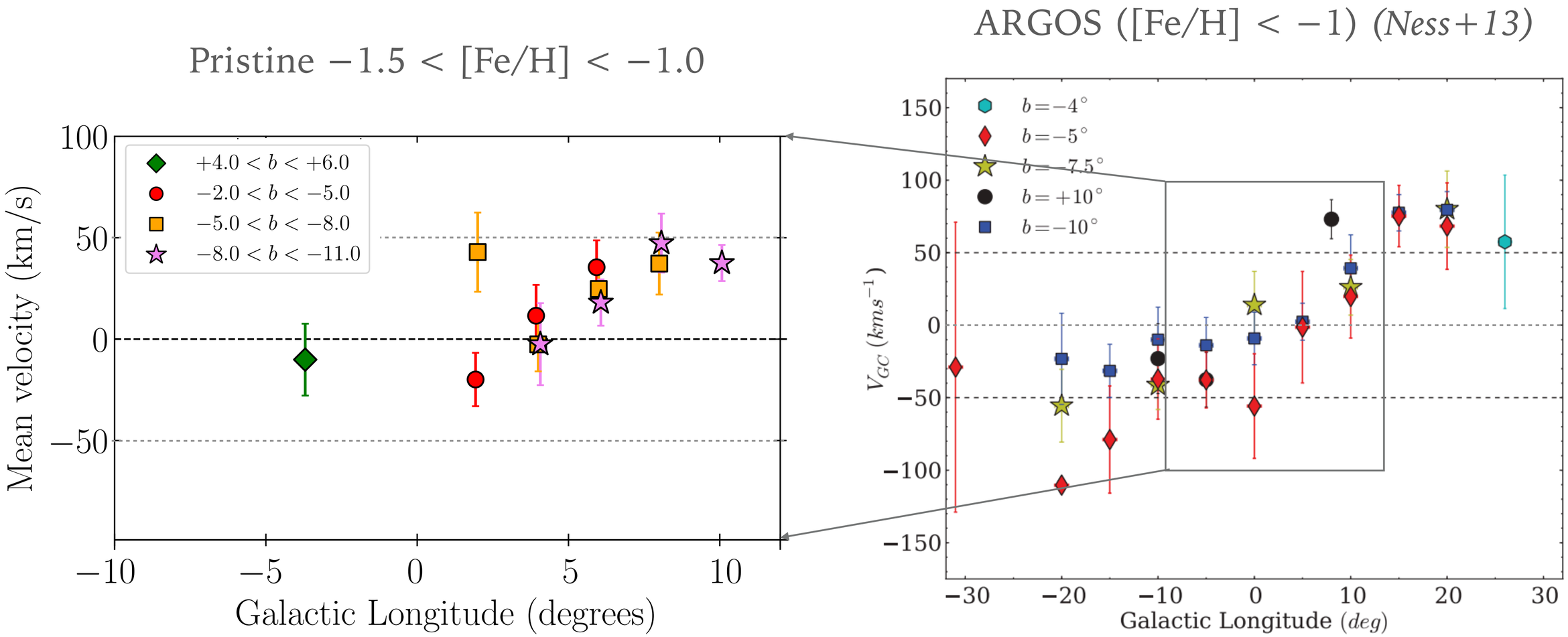
# Kinematics of the Pristine stars

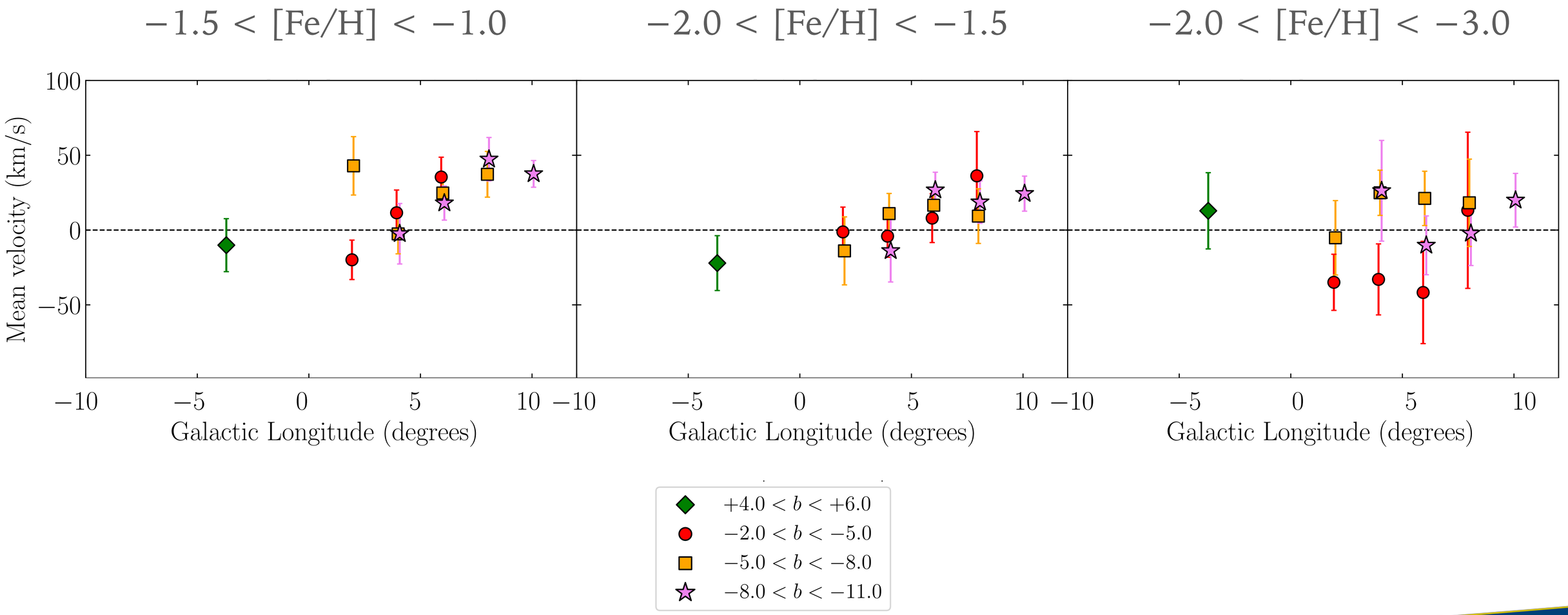
ARGOS ([Fe/H] $< -1$) *(Ness+13)*



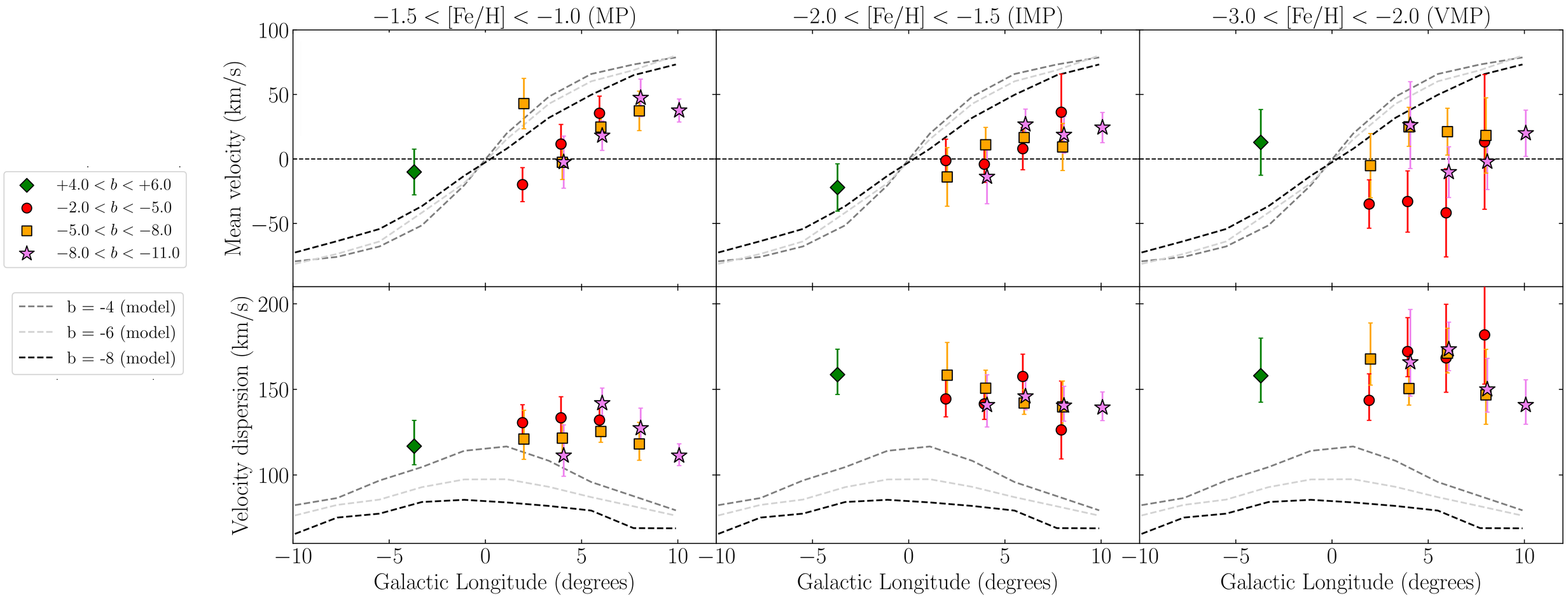
# Kinematics of the Pristine stars



# Kinematics of the Pristine stars



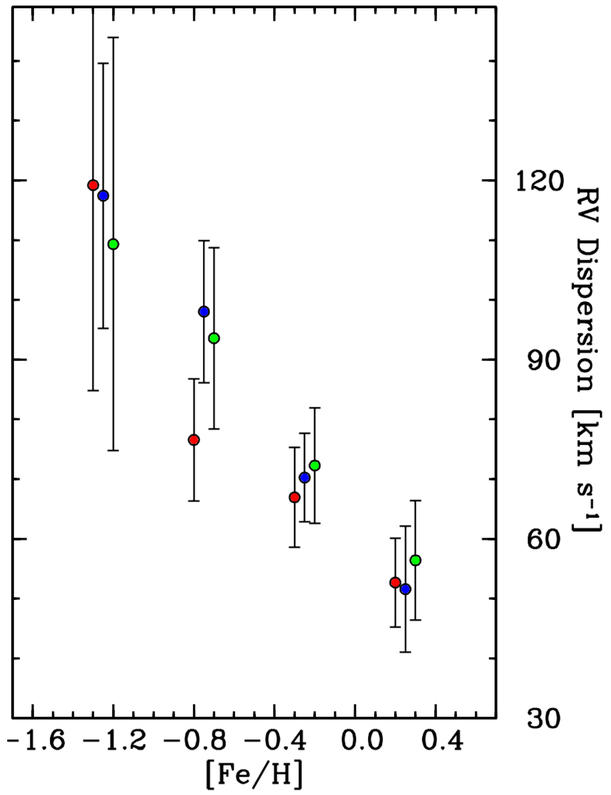
# Kinematics of the Pristine stars: rotation?



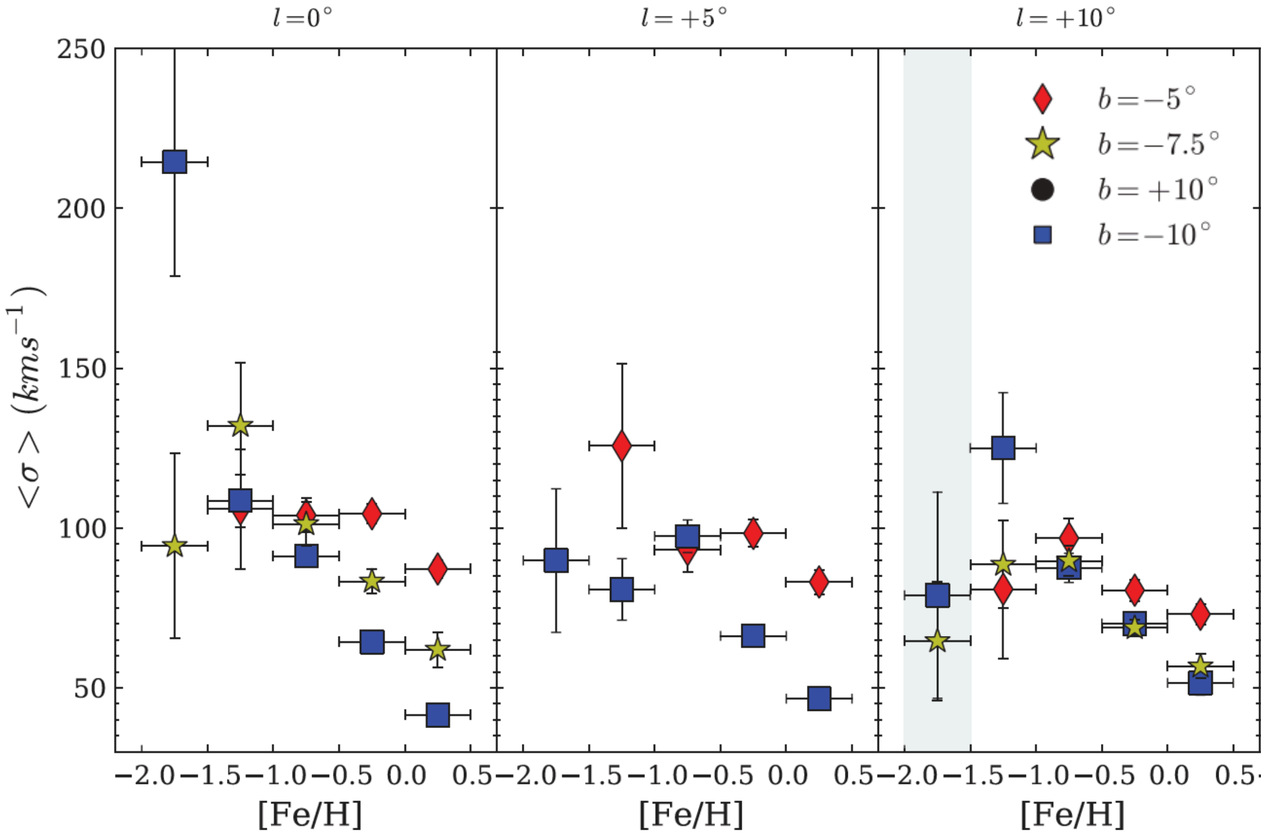

*(model: Shen+10 for [metal-rich] BRAVA giants)*

# Kinematics of the Pristine stars: rv dispersion

*Johnson+13* (3 outer bulge fields)

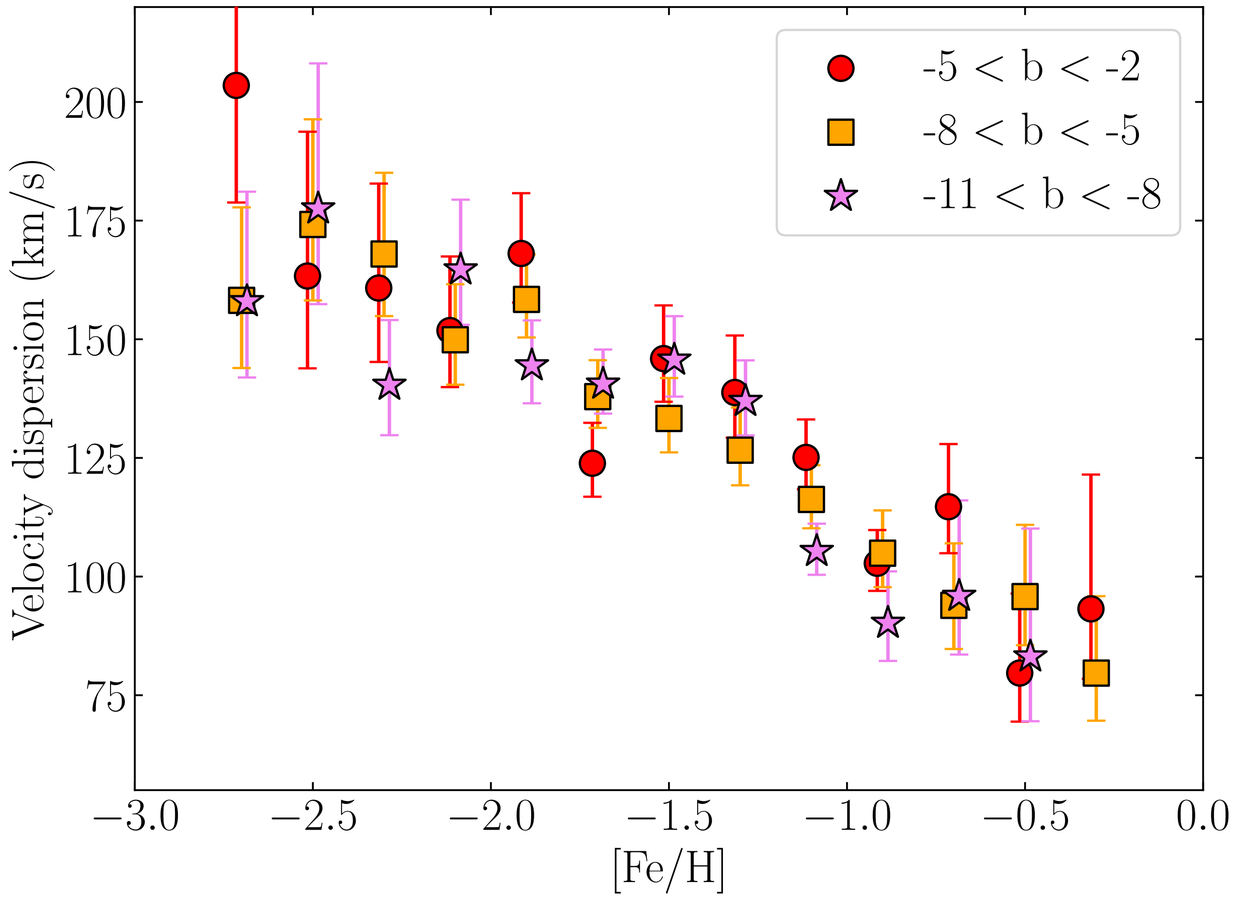



*Ness+13* (ARGOS fields)

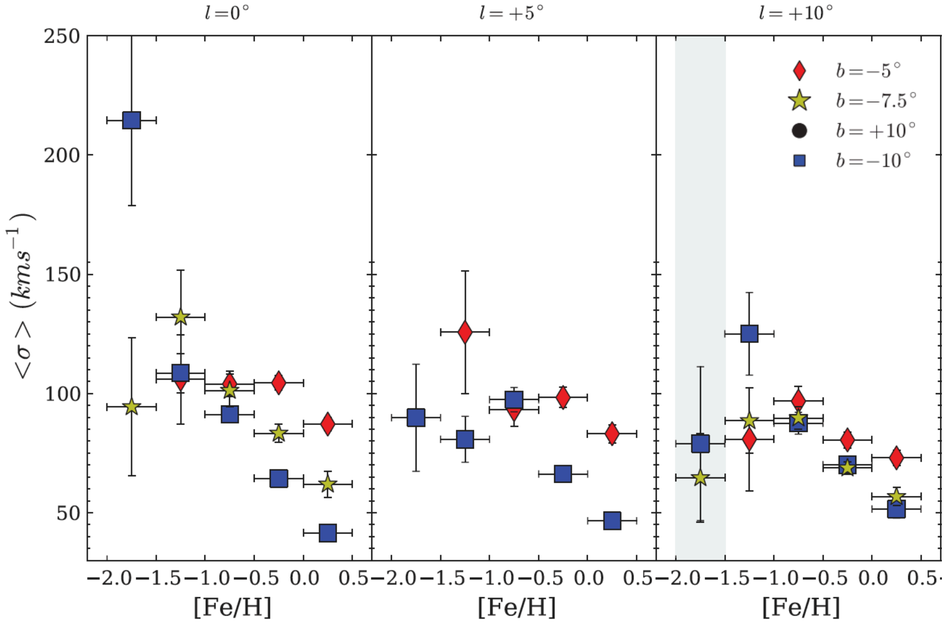


# Kinematics of the Pristine stars: rv dispersion

Pristine

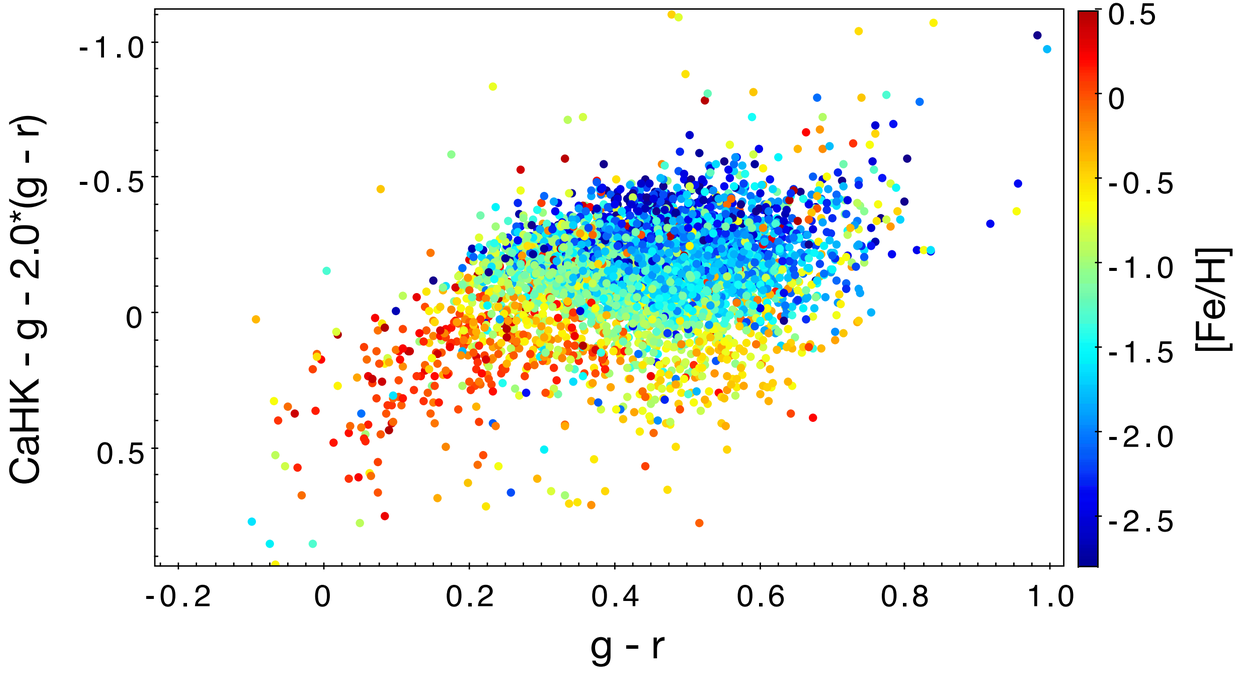


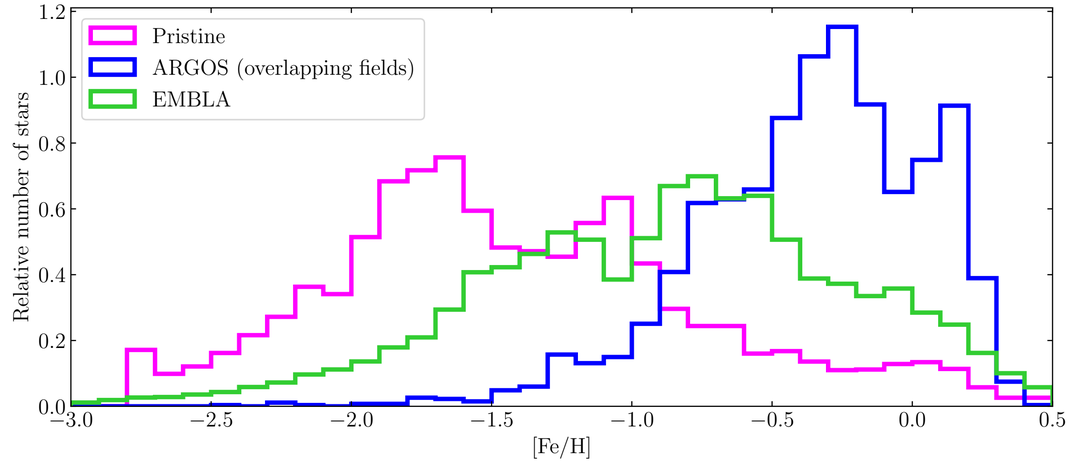

*Ness+13*
(ARGOS fields)



# Summary

- We can effectively select metal-poor stars in the Bulge with Pristine & Gaia/PanSTARRS
- Spectroscopic follow-up has been successful



# Summary

- We can effectively select metal-poor stars in the Bulge with Pristine & Gaia/PanSTARRS
- Spectroscopic follow-up has been successful

**Work in progress!**

- kinematics
- fraction of carbon-enhanced metal-poor stars
- study some (very) metal-poor stars in detail (select for high-res follow-up)