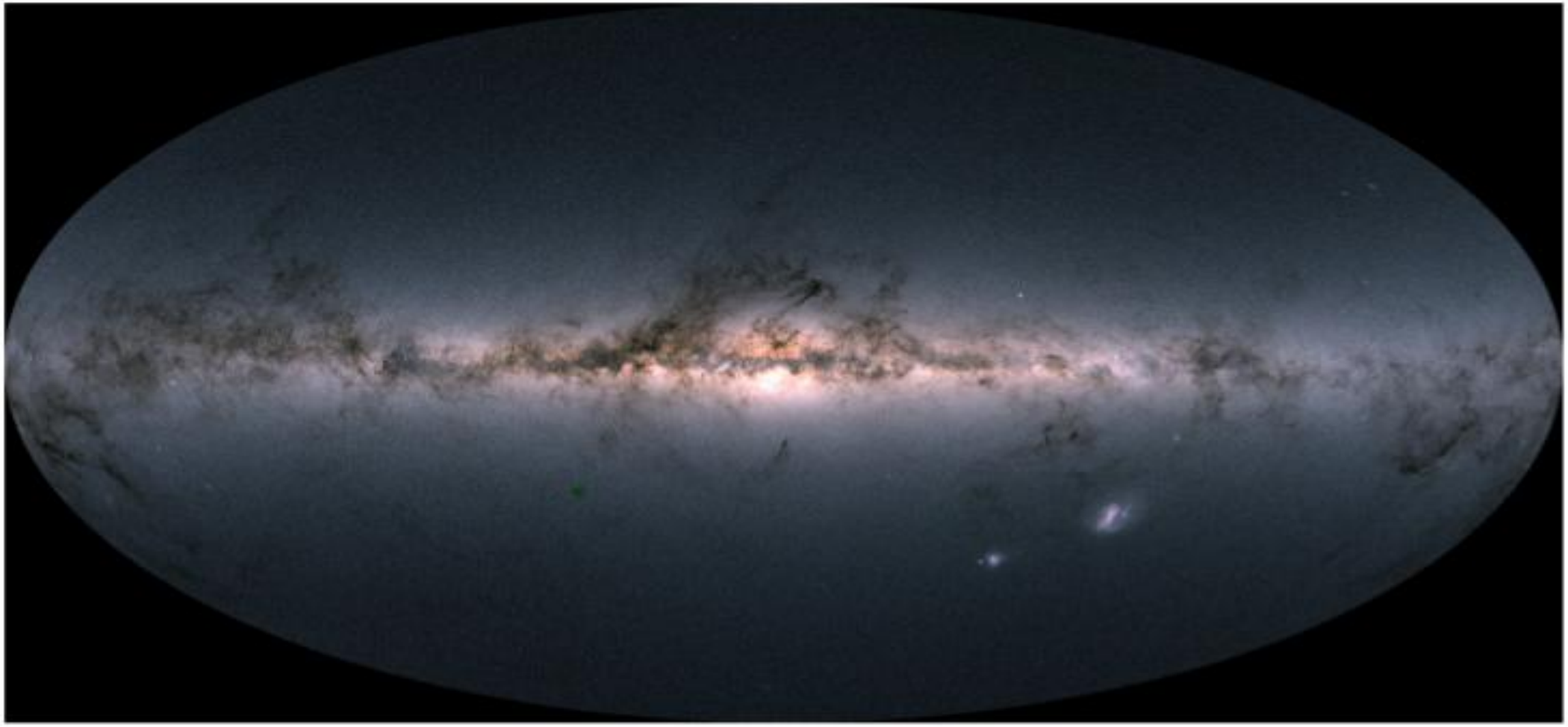
SHARP@ELT: deep into the dark side of the Milky Way & beyond

G. Bono, V. D'Orazi (TOV) + M. Monelli, V. F. Braga, M. Fabrizio, G. Fiorentino, R. da Silva (OAR), + A. Nunnari, V. Pipwala, K. B. Villagra + many others



Milano, October 1 2024

OUTLINE OF THE LECTURE

→ **Why variables stars?**

→ **Why the bulge?**

→ **(Why nearby galaxies?)**

→ **Conclusions**

Milano, October 1 2024

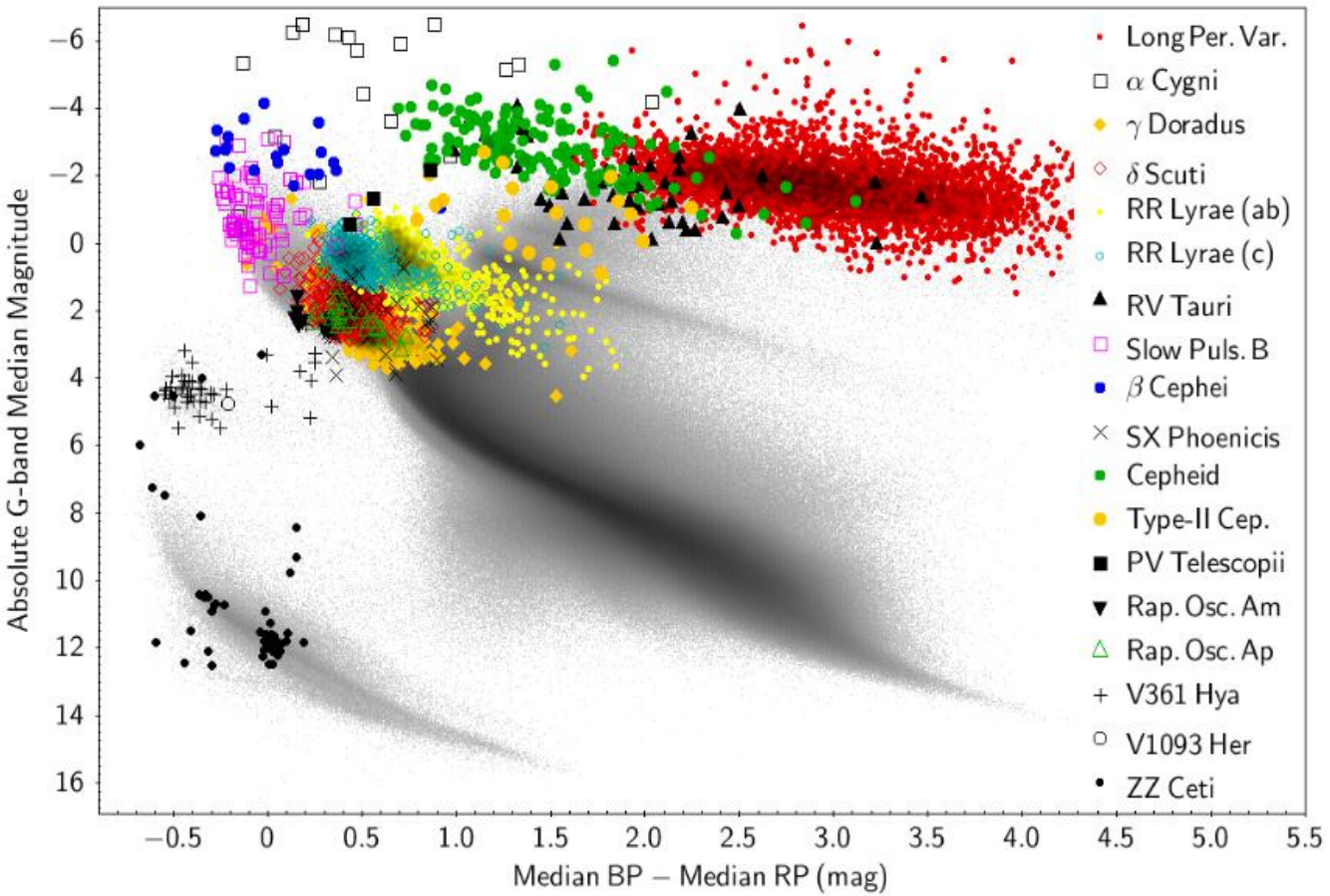


Fig. 2. Known pulsating variable stars retrieved from pubished catalogues are placed in the observational CaMD, with symbols and colours representing types as shown in the legend (see A.1 for the references from literature per type). All stars satisfy the selection criteria described in Appendix B. The background points in grey denote a reference subset of objects with a stricter constraint on parallax ($\varpi > 1$ mas), which limits the sample size, extinction, and reddening. The effects of interstellar matter and other phenomena (see text) are not corrected for. The condition on the relative precision of G_{BP} measurements introduces artificial cuts in the distributions of low-mass main sequence stars and red (super)giants.

Why Variables?

RR Lyrae,
Type II Cepheids,

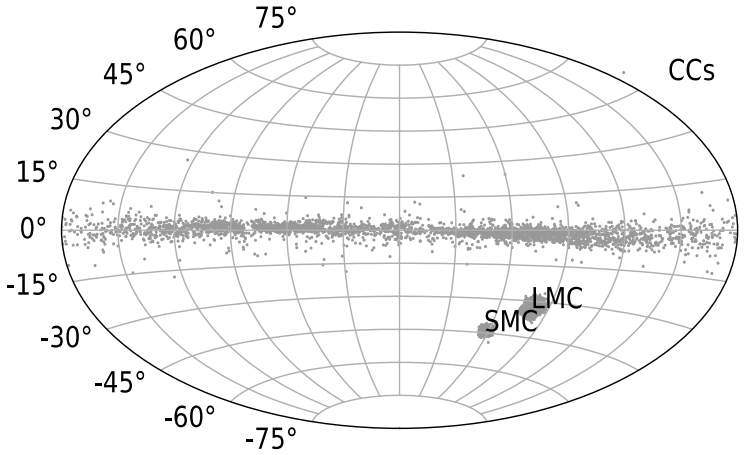
Anomalous Cepheids,
Miras,

Classical Cepheids,

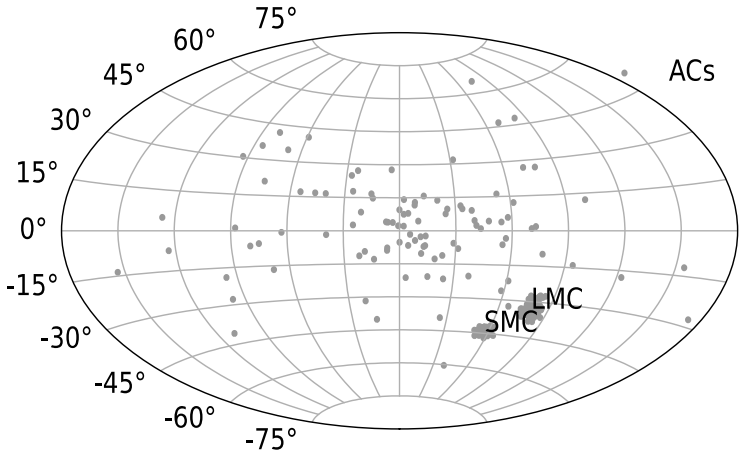
Accurate standard candles

Solid tracers of old (RRLs, TIICs), intermediate (ACs, Miras) and young (Classical Cepheids).

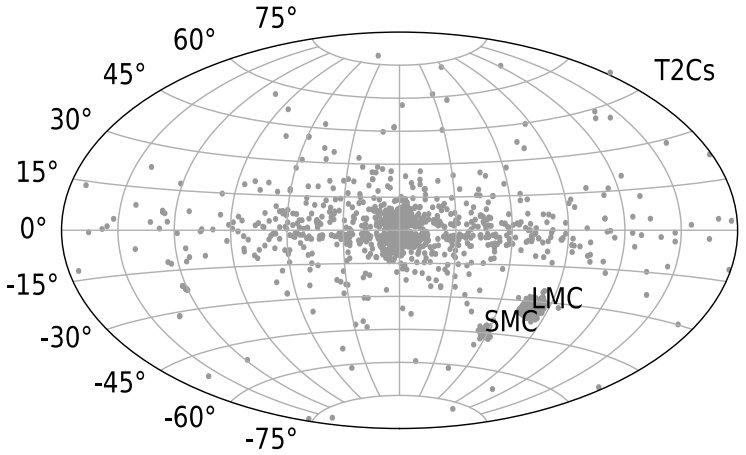
Distribution of variable stars across the MW



YOUNG

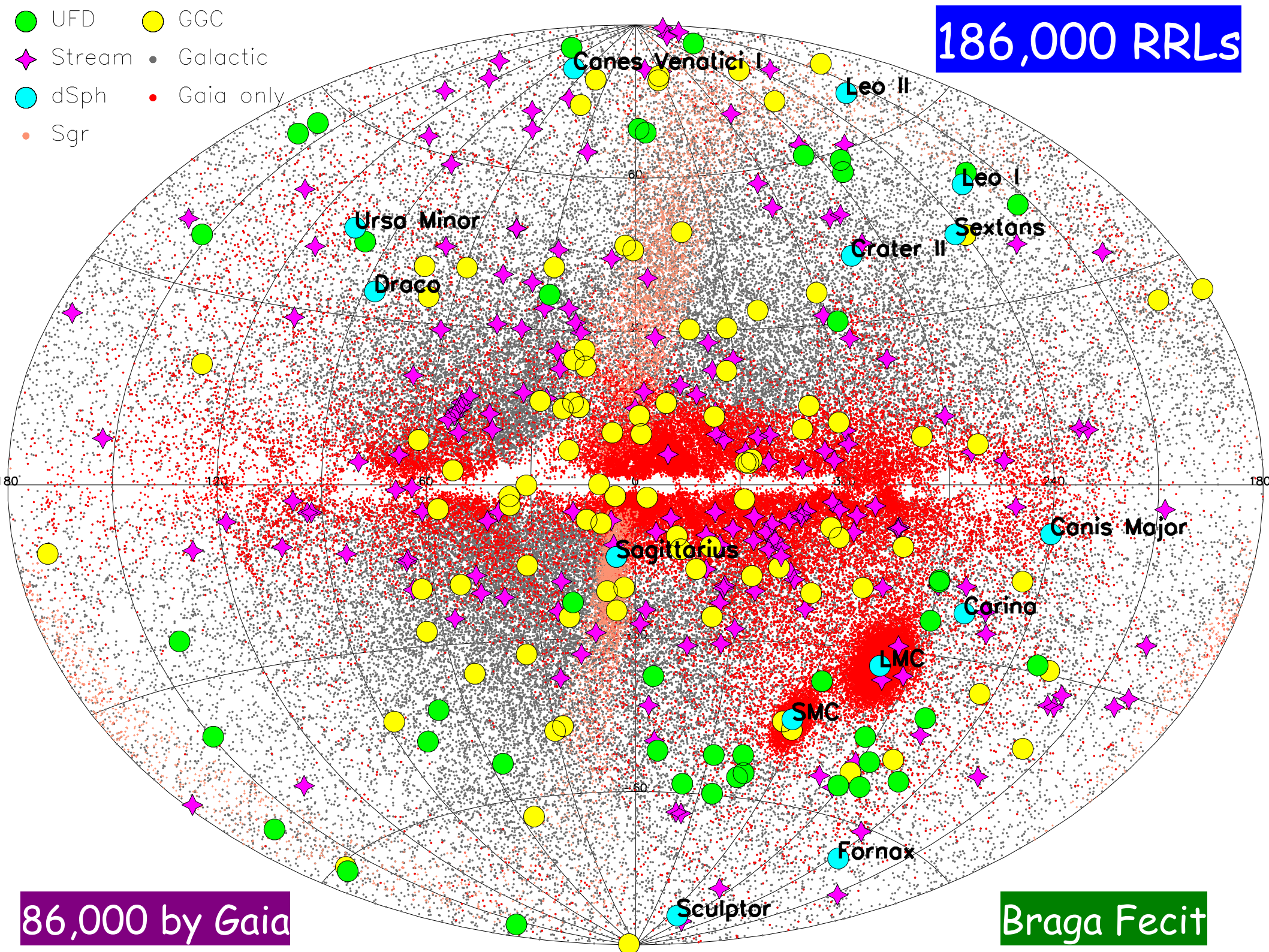


INTERMEDIATE



OLD

Bono+ TAAR, 2024


UFD
GGC
Stream
Galactic
dSph
Gaia only
Sgr
186,000 RRLs
Canes Venatici I
Leo II
Leo I
Sextans
Crater II
Ursa Minor
Draco
Sagittarius
Canis Major
Carina
LMC
SMC
Fornax
Sculptor
86,000 by Gaia
Braga Fecit

Homogeneous metallicities in HR and LR

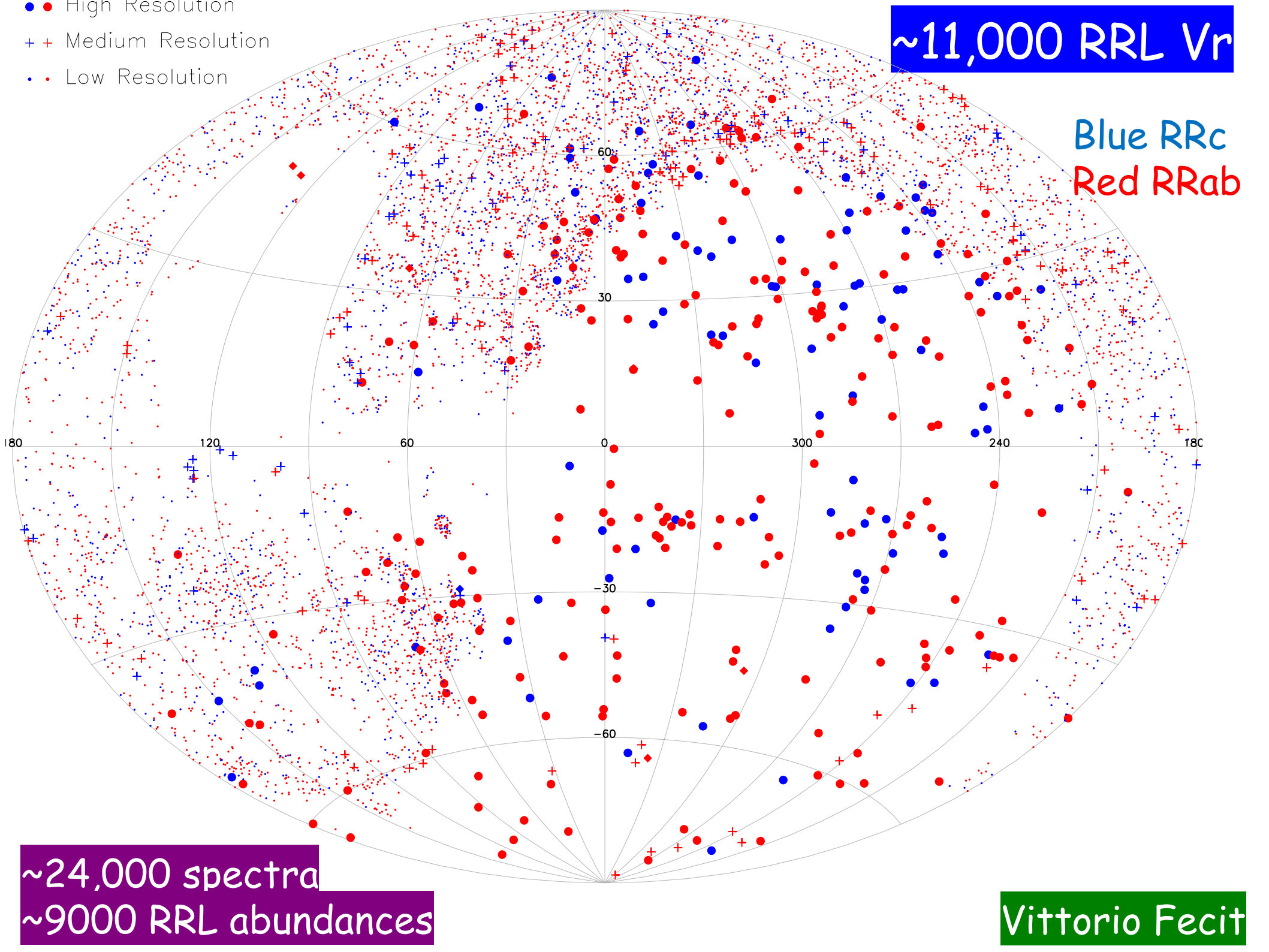
Full sample of RRLs: 247 in HR (full analysis), 7,768 in LR (metallicities)

- **TW-RRL:** 162 RRLs (138 RRab, 23 RRc, 1 RRd) for which the atmospheric parameters and chemical abundances based on HR spectra.

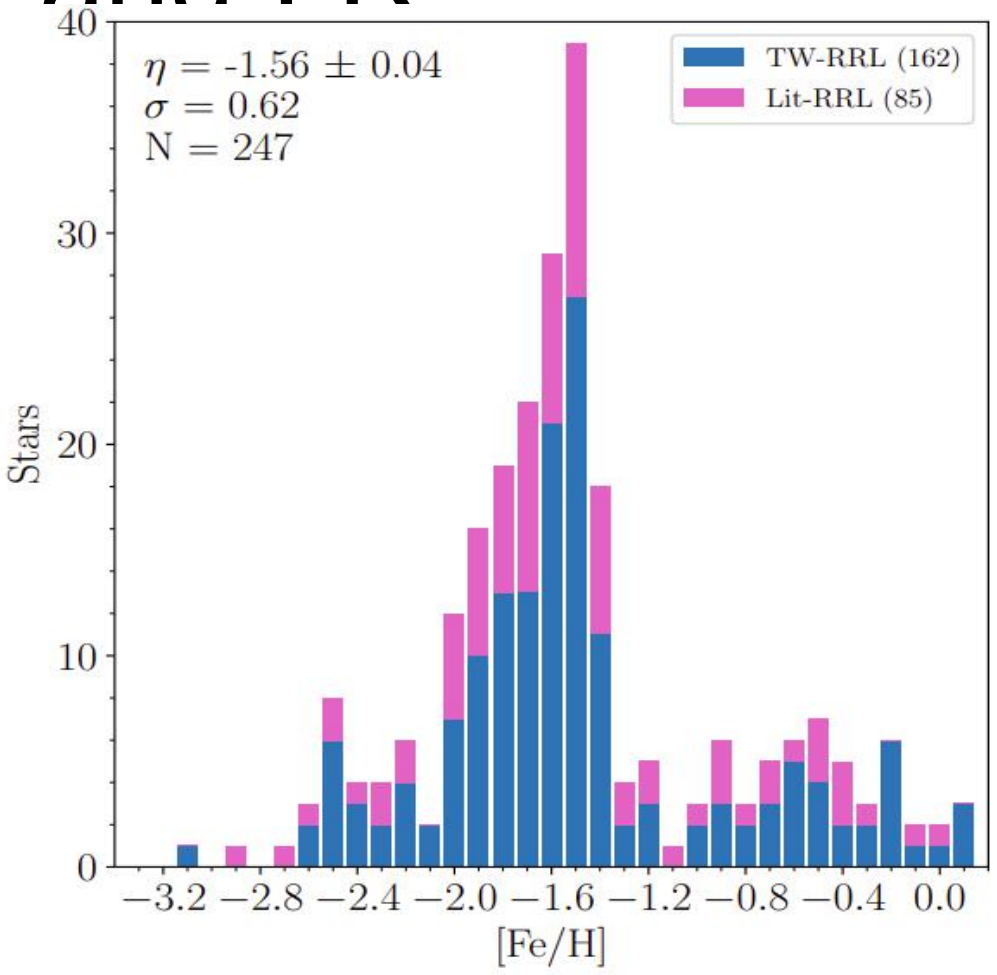
- **Lit-RRL:** 85 RRLs (65 RRab, 20 RRc) for which the HR chemical abundance values brought into our scale.

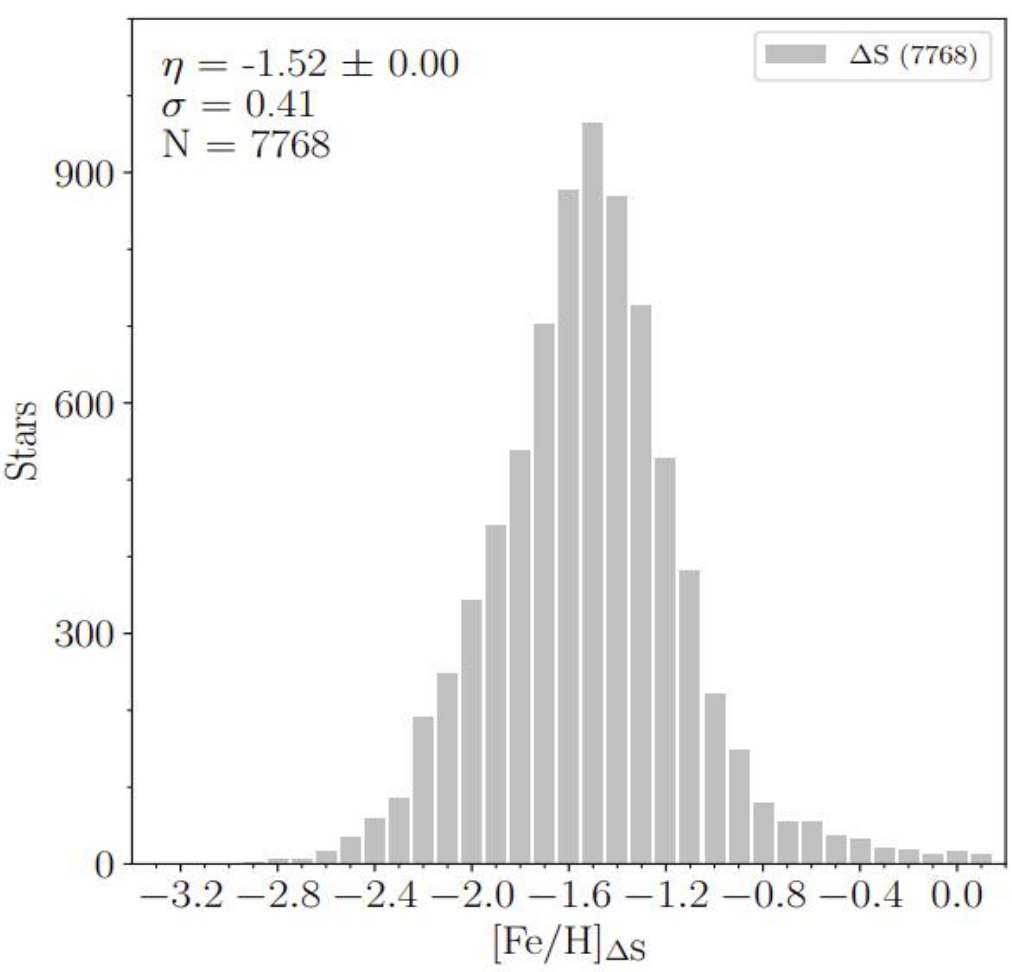
- **ΔS:** 7,768 RRL (5,196 RRab, 2,572 RRc) for which only ΔS metallicities (new calibration).

Crestani + 2021a


High Resolution
Medium Resolution
Low Resolution
~11,000 RRL Vr
Blue RRc
Red RRab
60
30
180
120
60
0
300
240
180
-30
-60
~24,000 spectra
~9000 RRL abundances
Vittorio Fecit

Homogeneous metallicities in HR and LR

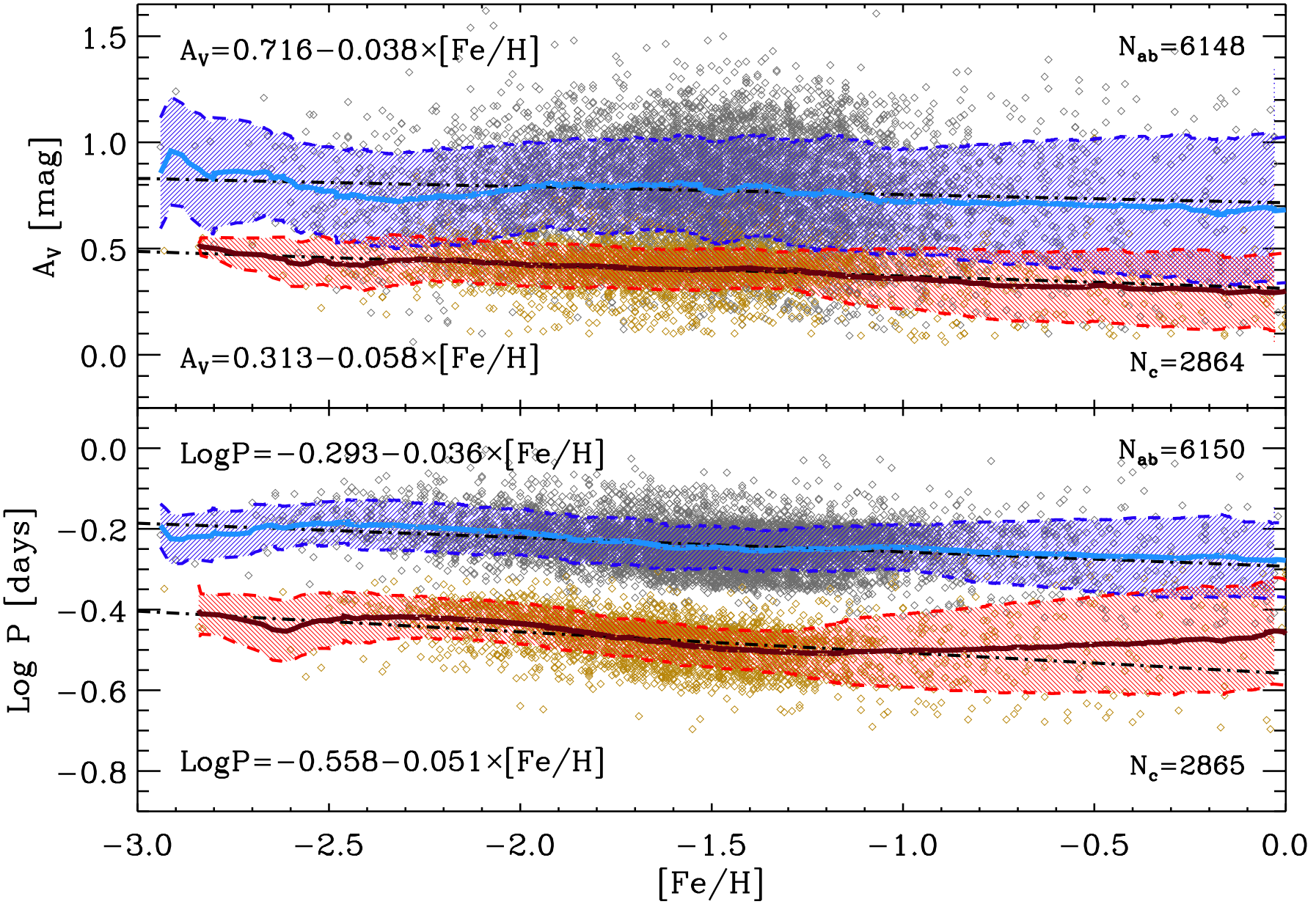




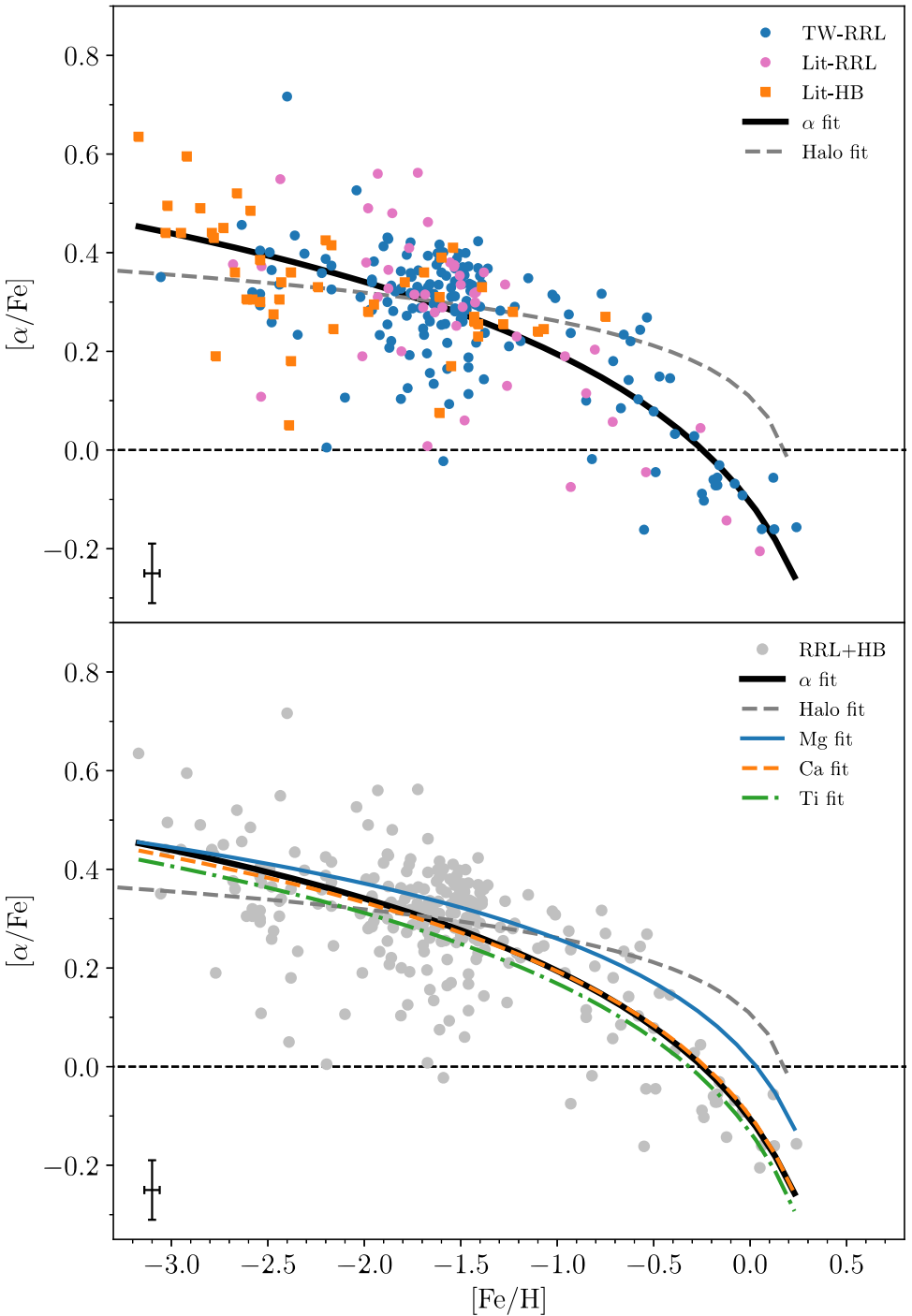
Solid evidence of RRLs at solar metallicity!!!

Preliminary evidence from For + 2011, Sneden + Crestani + 2021a

The transition from discrete to continuous distributions!!!



The more you get the more you want!!



Solid evidence of metal-rich alpha-poor RRLs

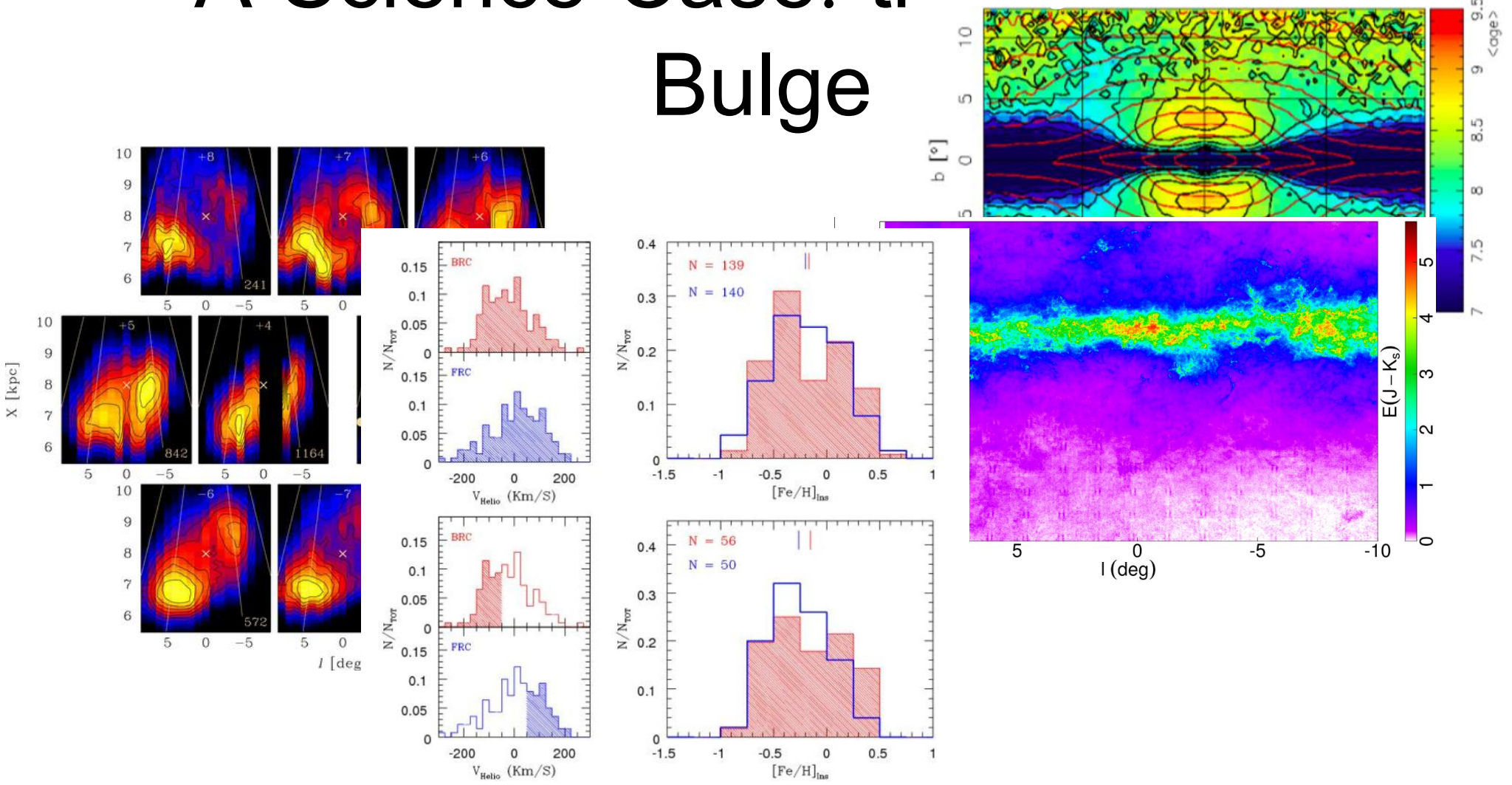
The trend is clear in Ca & Ti Milder in Mg

If supported by independent investigations → implications on the early SNIa enrichment

A new spin Spitoni + (19,20,21) delayed infall

Crestani + 2021b

A Science Case: the Galactic Bulge



Quantum Jump: Vera Rubin Observatotory/LSST complete census even beyond the Galactic center

unVEil the darknesS of The gAlactic buLgE (VESTALE)

G. Bono,[1,2] M. Dall'Ora,[3] M. Fabrizio,[2,4] J. Crestani,[1,2,5] V.F. Braga,[6,7] G. Fiorentino,[8] G. Altavilla,[2,4] M.T. Botticella,[3] A. Calamida,[9] M. Castellani,[2] M. Catelan,[10] B. Chaboyer,[11] C. Chiappini, [37] W. Clarkson,[12] R. Contreras Ramos,[6,10] O. Creevey,[13] R. da Silva,[2,4] V. Debattista,[14] S. Degl'Innocenti,[15,16] I. Ferraro,[2] C.K. Gilligan,[11] O. Gonzalez,[17] K. Hambleton,[40] G. Iannicola,[2] L. Inno,[18] A. Kunder,[19] B. Lemasle,[20] L. Magrini,[18] D. Magurno,[1,2] M. Marconi,[3] M. Marengo,[21] S. Marinoni,[2,4] P.M. Marrese,[2,4] C.E. Martínez-Vazquez,[22] N. Matsunaga,[23] M. Monelli,[24,25] P.G. Prada Moroni,[15,16] I. Musella,[3] M.G. Navarro,[26,7,6] J. Neeley,[27] M. Nonino,[28] A. Pietrinferni,[29] L. Pulone,[2] M.R. Rich,[38] V. Ripepi,[3] G. Sacco,[18] A. Saha,[22] M. Salaris,[30] C. Sneden,[31] P.B. Stetson,[32,33] R.A Street, [39] R. Szabo,[34] M. Tantalo,[1] E. Tognelli,[35,15,16] M. Torelli,[2] E. Valenti,[36] A.R. Walker,[22] and M. Zoccali[10,6],

with the support of the LSST Transient and Variable Stars Collaboration.

Metallicity distribution Bulge RRLs

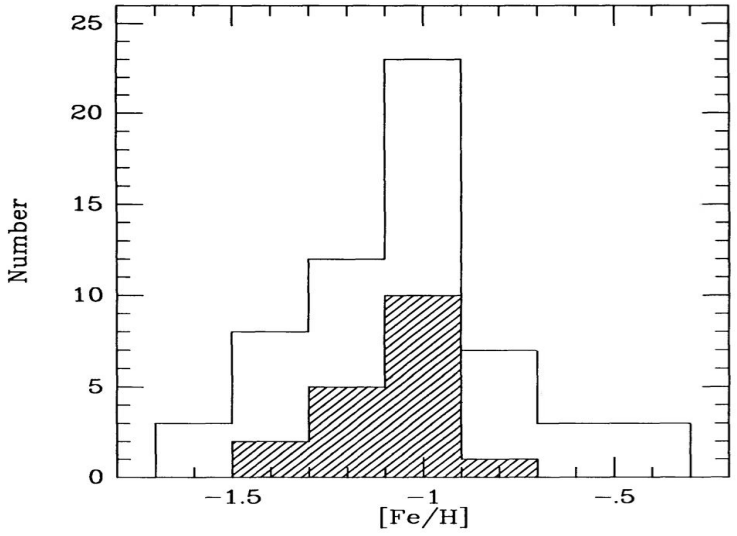


FIG. 7.—Histogram of the abundances determined for the BW RR Lyrae stars. The RRc stars are shaded.

Walker & Terndrup (1991)

Savino + 2020

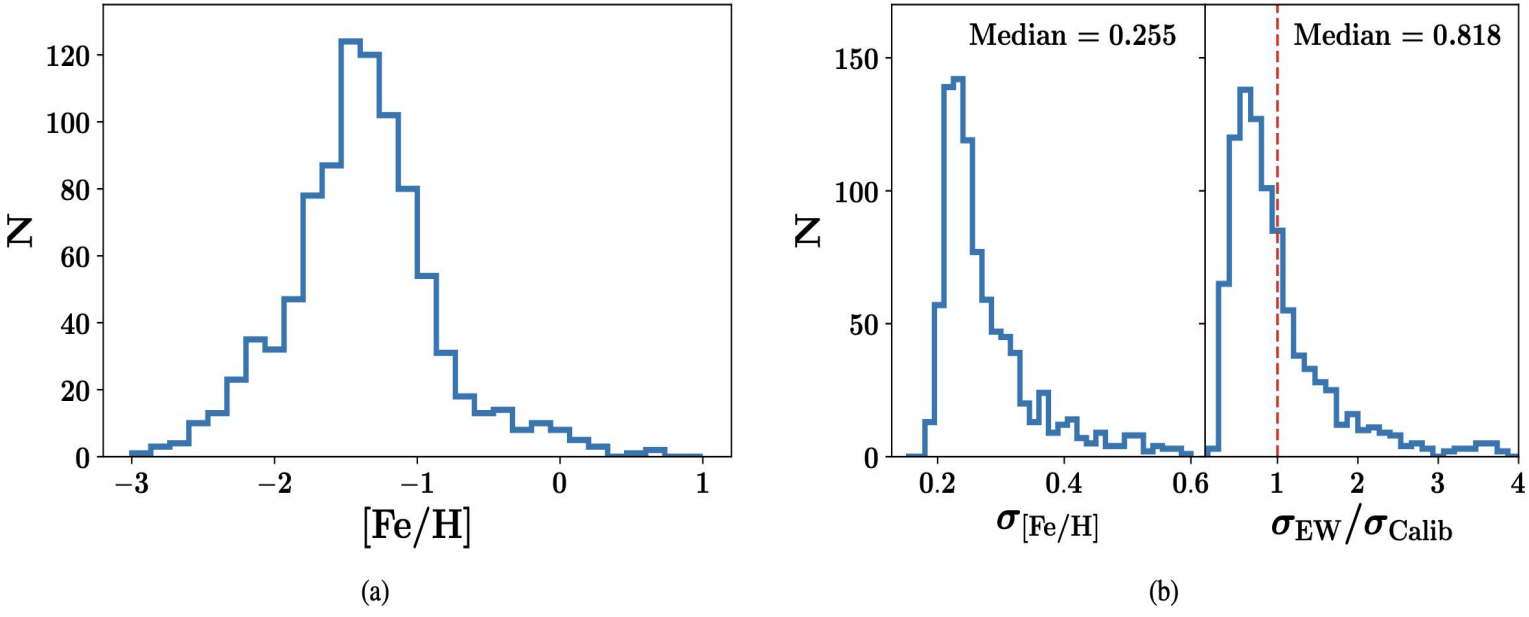
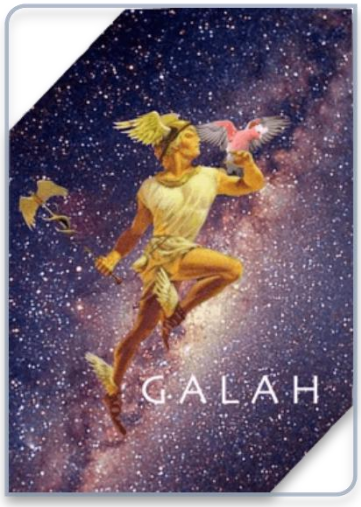
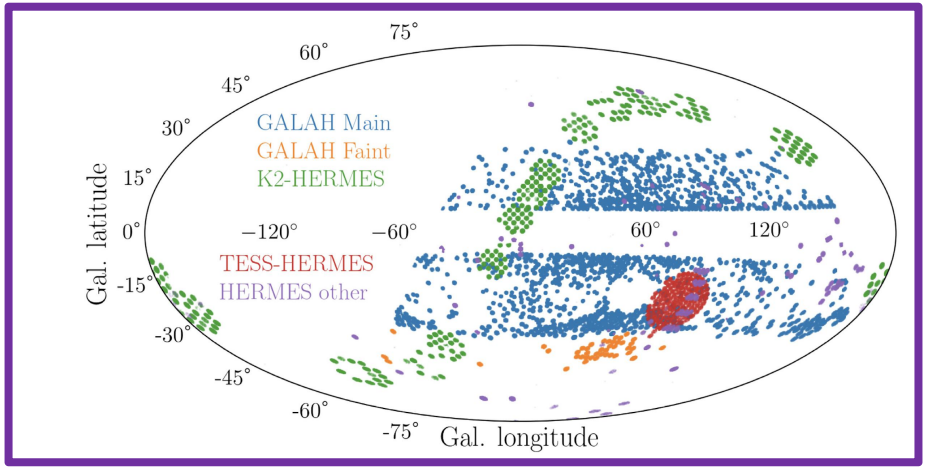


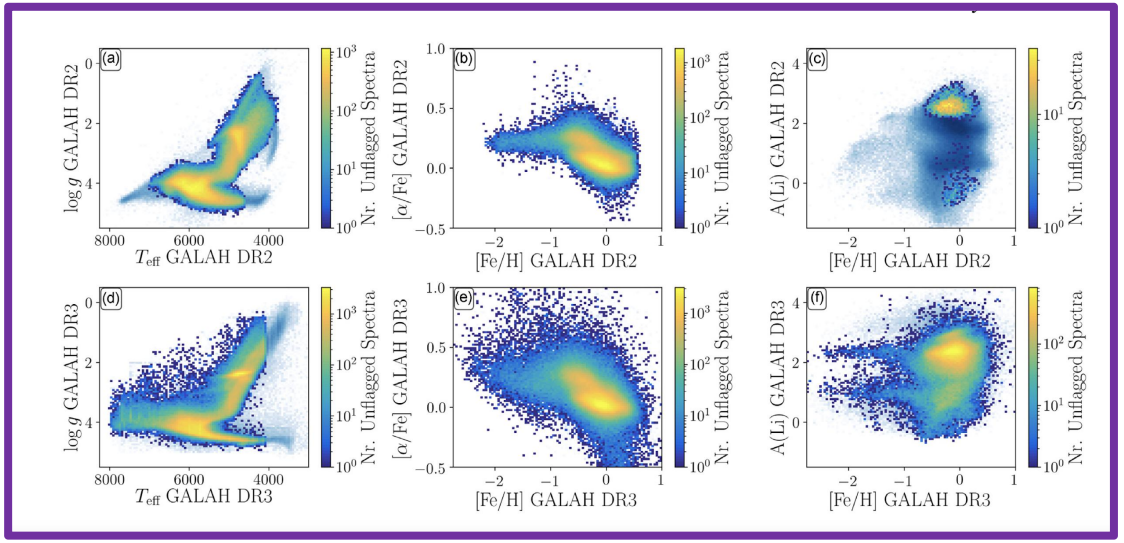
Fig. 3: a) Observed metallicity distribution function for our sample of RR Lyrae stars. b) Left panel: distribution of metallicity uncertainties. Right panel: distribution of $\sigma_{EW}/\sigma_{Calib}$, showing the dominant contribution to the metallicity uncertainties. The red dashed line marks unity.

The GALAH Survey



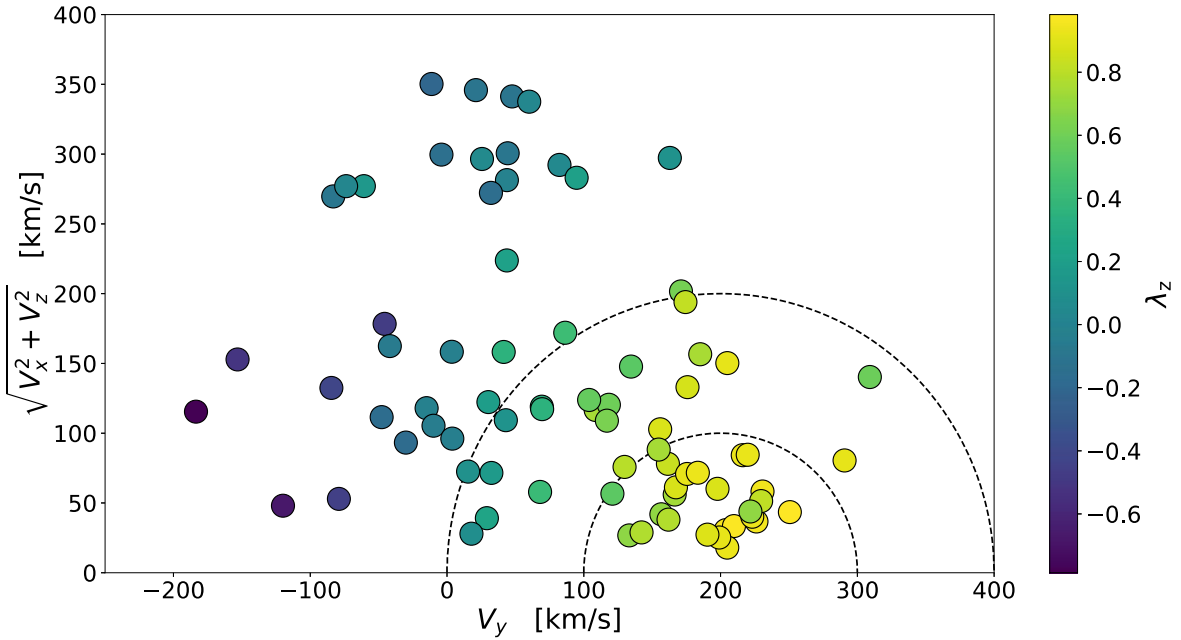
> 1 million stars
Spectral resolution: R = 28 000
Multi-plexing: 400 stars at a time
Lambda coverage: 470-790 nm (with gaps)
4-m class telescope (mag G up to ~14.5) HERMES @ AAT (AU)



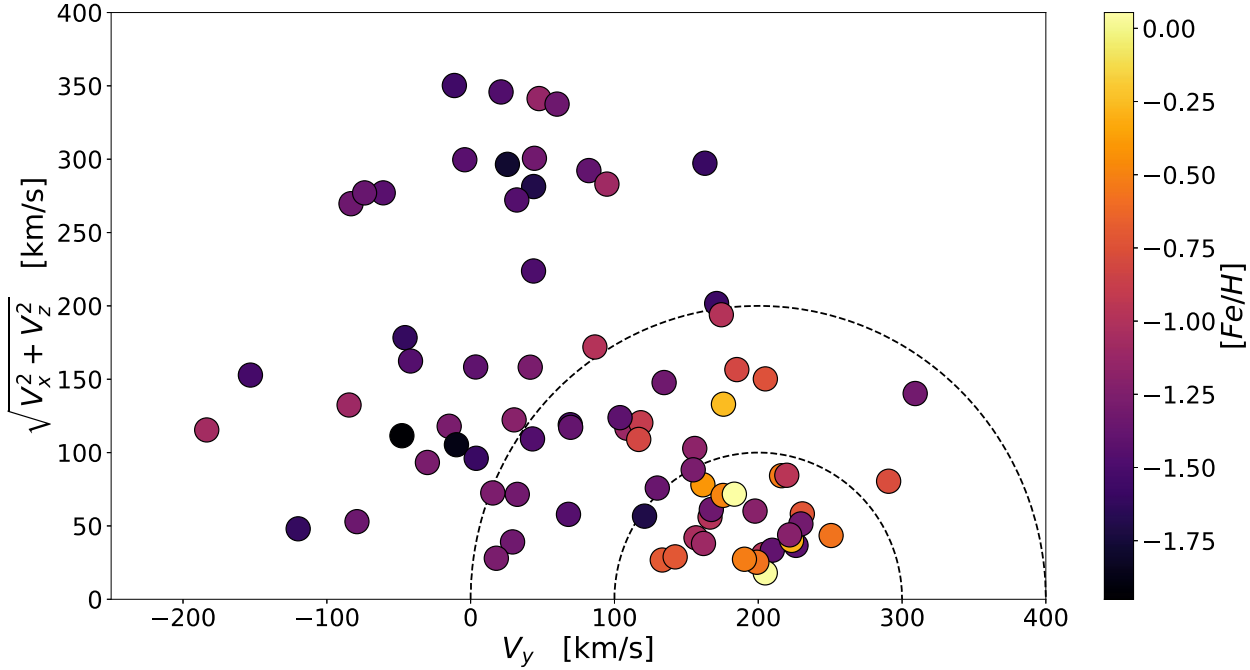


De Silva+ 2015
Buder+ 2018, 2021

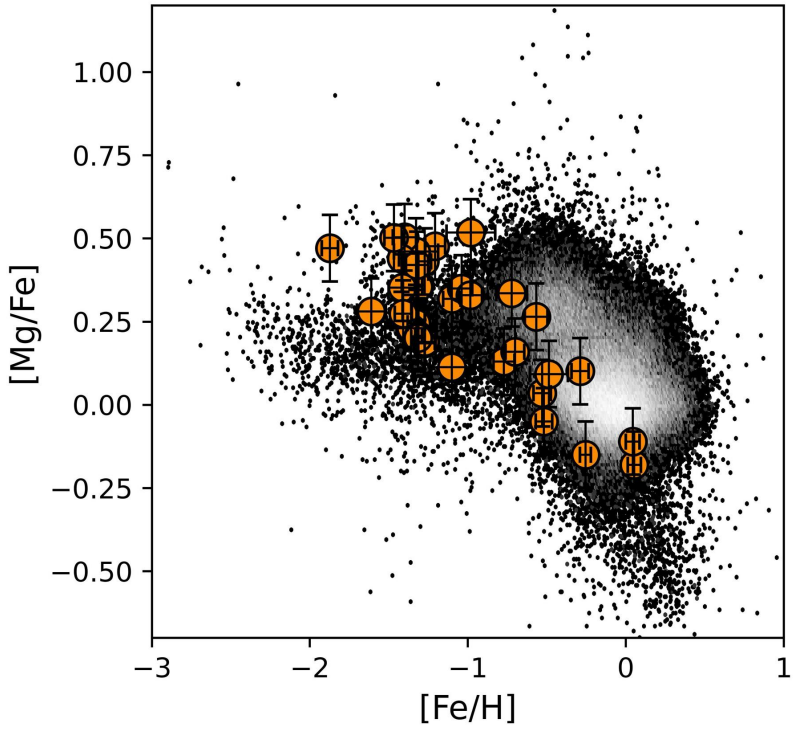
A new spin on field RR Lyrae: GALAH

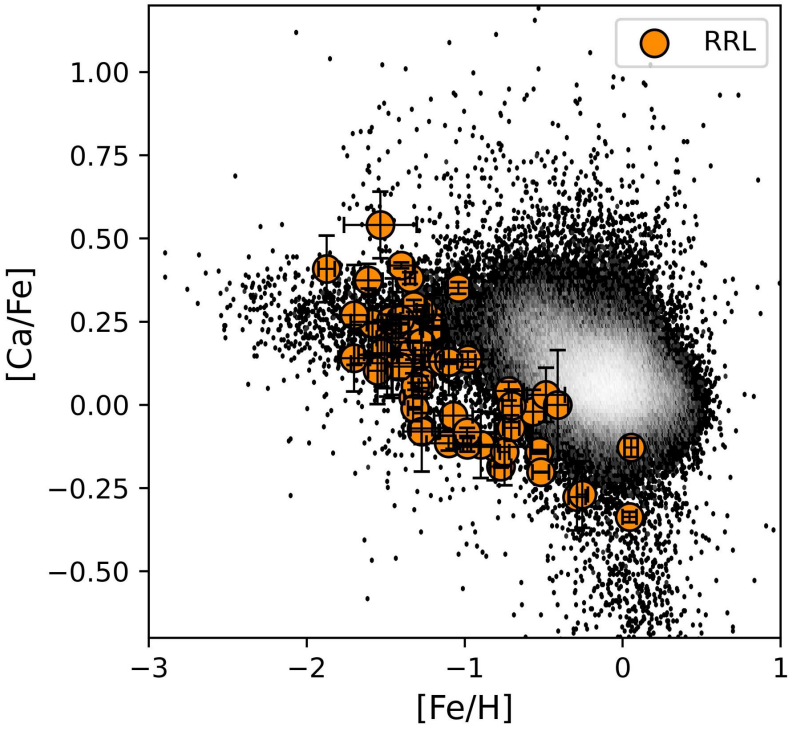


D'Orazi + 2024



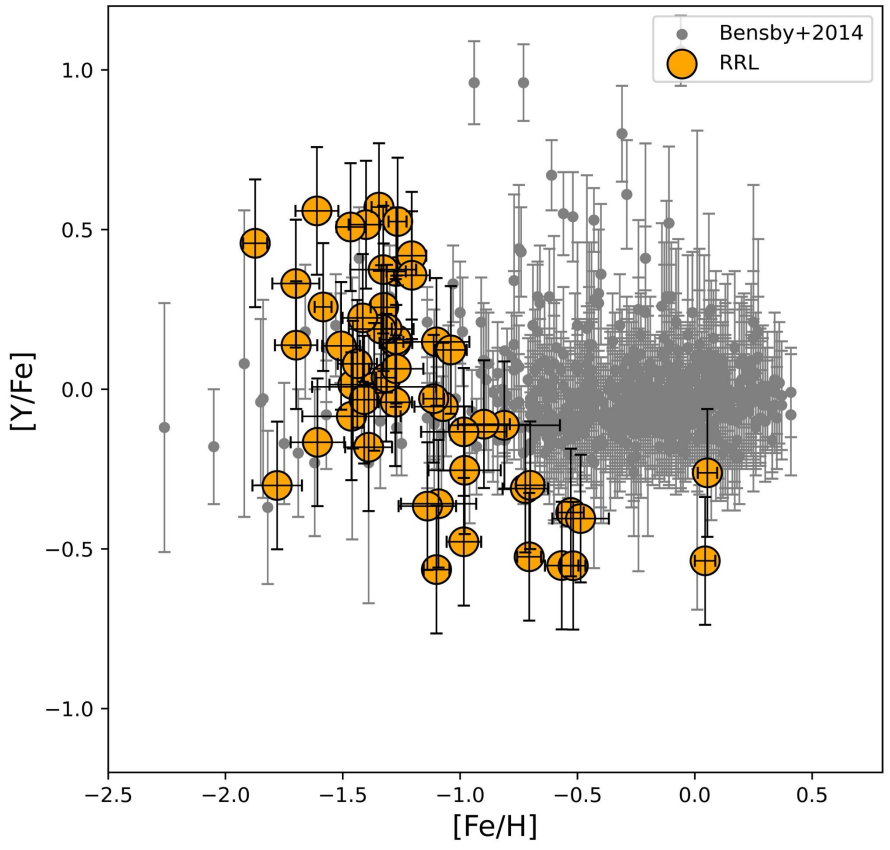
A new spin on field RR Lyrae: GALAH

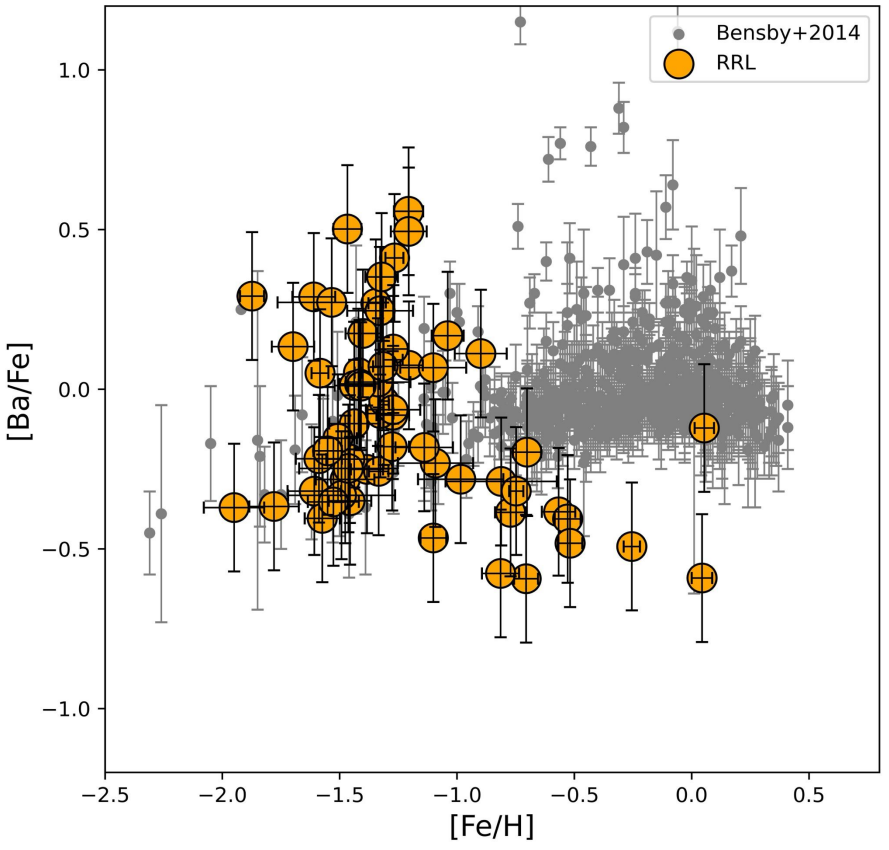




D'Orazi + 2024

A new spin on field RR Lyrae: GALAH





A lot of food for thought:

hierarchical formation →

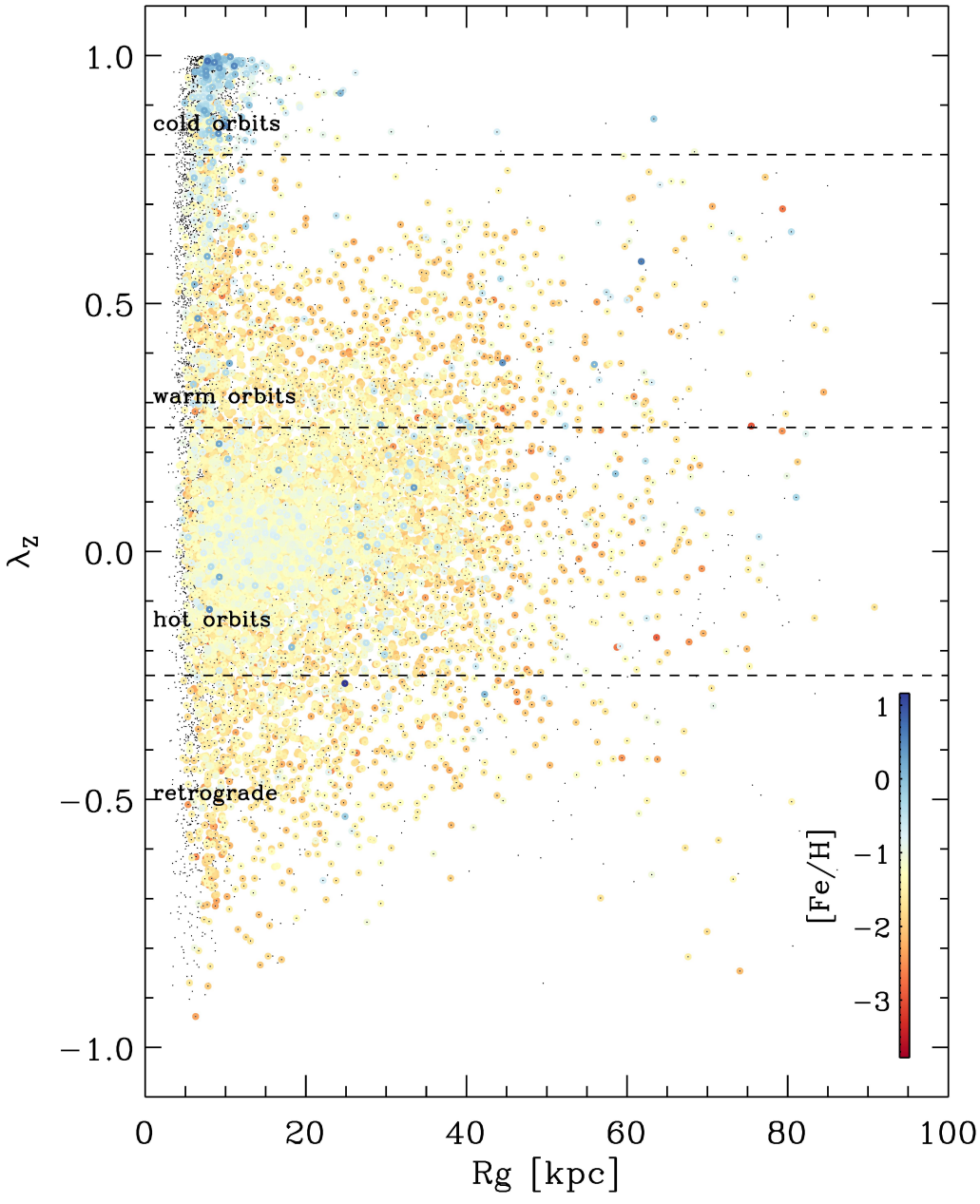
fraction of in situ and accreted components

D'Orazi + 2024

A new spin on field RR Lyrae: GALAH

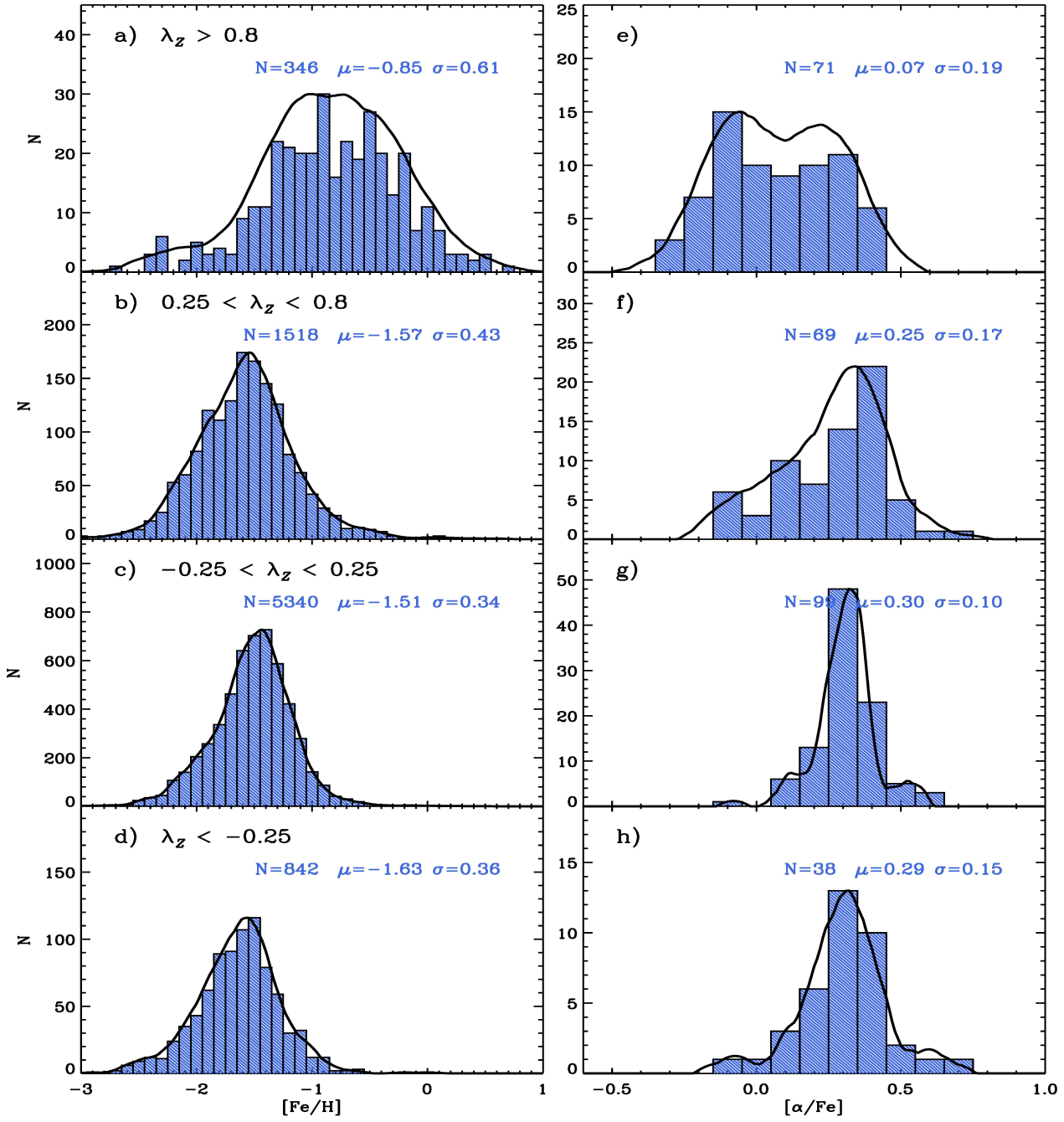
D'Orazi + 2024

One robin doesn't make a spring



Bono + 2024

One robin doesn't make a spring



Bulge/Bar & thin disk connection:

are they coeval?

who is dominated by in situ/ex situ stellar populations?

Is their chemical enrichment similar?

Bono + 2024

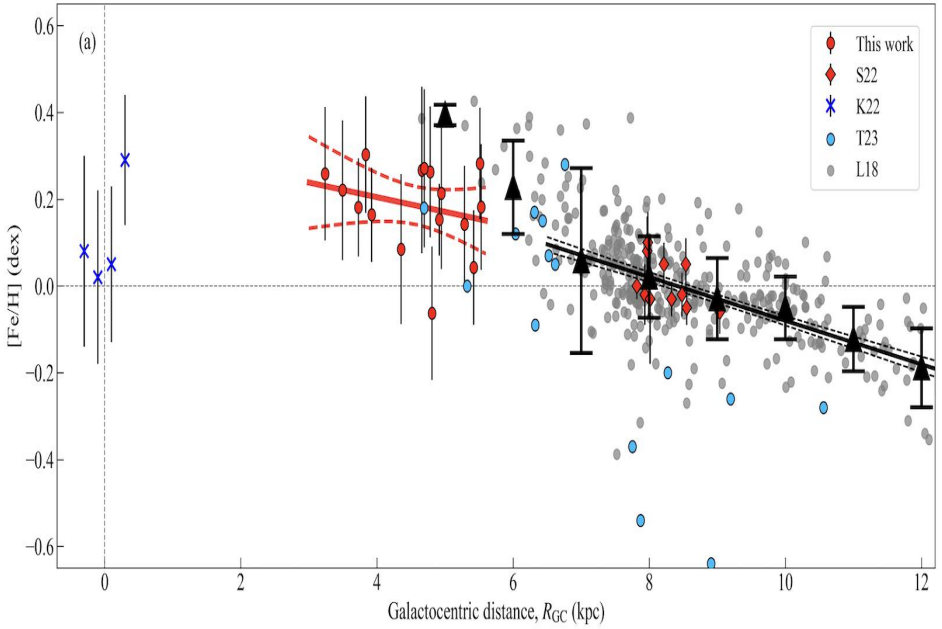
SHARP@ELT to unveil the elders

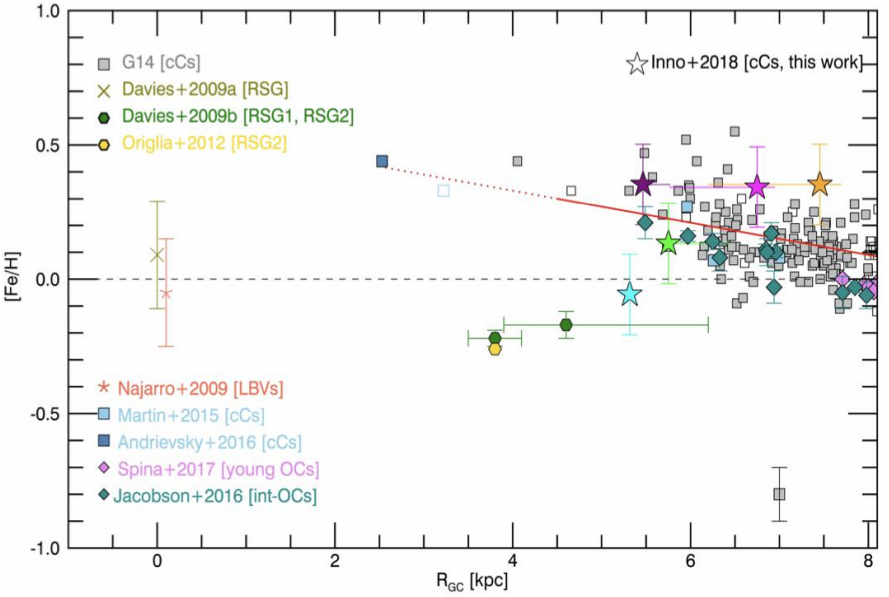
Zoccali+ (VVV) & VRO/LSST

4MOST/MOONS@VLT neither by HARMONI@ELT → fill the gaps

SHARP-NEXUS@ELT: multiplexity & FoV & slitlets + R~17,000 + Simult. NIR wav. range + MCAO are crucial (RGs/Miras

CCs in the inner disk & Galactic center + external galaxies





Evidence of a flattening (break) in the inner disk and in the Galactic center

High resolution NIR spectra collected with WINERED@Magellan

Matsunaga + 2023

CONCLUSIONS I

→ RRLs are unique beacons to investigate back in space and in time the early formation of the Galactic spheroid (age constraints) + chemical tagging

→ The next natural step are abundances (HR) of bulge/disk!!

→ The near future is even brighter for young/ intermediate (CCs, Miras, Blue/Red supergiants …)

CONCLUSIONS II

→ Golden age for stellar spectroscopy

→ Ground-based follow up spectroscopy:
Blue MUSE + MOONS + 4MOST
MAVIS → Halo outskirts
ERIS → Galactic Bulge

→ Ground-based multi-band photometry: LSST
from 20-21 to 25-26 mag →
JWST/WFIRST?

→ ELT: MICADO, HARMONI, ANDES …..

→ WST (!!!) ++++

Credits

To young, differently young & senior colleagues with whom I have the pleasure to share this wonderful adventure

THANKS!!!